A comparative analysis of water quality between public and private beach areas along the northwestern shoreline of Lake Erie.

Barry Alfred. Horrobin

University of Windsor

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A COMPARATIVE ANALYSIS OF WATER QUALITY BETWEEN PUBLIC AND PRIVATE BEACH AREAS ALONG THE NORTHWESTERN SHORELINE OF LAKE ERIE

by

(C) Barry Alfred Horrobin

A Thesis submitted to the Faculty of Graduate Studies through the Department of Geography in Partial Fulfillment of the Requirements for the Degree of Master of Arts at The University of Windsor

Windsor, Ontario, Canada
1989
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ABSTRACT

The purpose of this study is to compare and contrast differences in water quality that exist or are perceived to exist between private and public beach areas along the northwestern Lake Erie shoreline. This has been accomplished through regular water sampling and testing of the beaches and through the completion of a questionnaire survey by shoreline residents and public beach users. Sampling began on April 21, 1986 and concluded October 22, 1986. A total of 9 complete sets of samples were extracted for each of the six beaches sampled within the study region with each set taken from a different sampling period. In addition to the water samples, 120 questionnaires were completed; 60 by public beach users and 60 by private beach users.

The study has been designed to identify both spatial and temporal variations of water quality and the results could be used to assess similar shoreline areas. Results of the study indicate that a statistically significant difference in water quality exists between the public and private beach areas within the study region. Spatially, the study has determined that water quality improves as you move east within the region for the parameters sampled. The parameters of water quality also showed fluctuations from season to season.
ACKNOWLEDGEMENTS

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I dedicate this thesis to my mother and late father whose constant encouragement over the years has helped me succeed. To them, I am eternally grateful.
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INTRODUCTION

Beaches and their environmental surroundings are very valuable natural resources. In addition to their aesthetic value and to being a natural ecological habitat, beaches provide an important source of recreational utility (Ochs and Thorn, 1984). However, when such a beach is subjected to human activity, whether it be through recreational use or property development, the area can become polluted and a state of reduced water quality can occur. The end result will be a beach system moving closer to a point of environmental degradation (Fig. 1A). Beaches are a major component of the shoreline ecosystem and mark the interface between terrestrial and aquatic areas. Because of intense utilization through anthropogenic activity, shoreline areas must be carefully monitored and managed to ensure that environmental harmony and stability exists at all times within these delicate places (Templeton, 1986) (Fig. 1B).

The northwestern shoreline of Lake Erie in southwestern Ontario contains both public and private beach areas; in many instances adjacent to each other. It represents a small fraction of the total shoreline within the entire Great Lakes region; much of which is utilized through human activity for recreational use and property development. It is for this reason that the quality of water plays such a critical role in establishing the overall value and recreational potential of this particular area.
FIGURE 1A
THE ENVIRONMENTAL TRADE-OFF

HUMAN USAGE
- No Use
- Little Use
- Moderate Use
- Optimum Use
- Heavy Use
- Over Use

ENVIRONMENTAL STATE
- Pristine
- Near Natural
- Moderate Disturbance
- Chosen State
- Environmental Stress
- Environmental Destruction

Total Use


FIGURE 1B
GOVERNMENT CONTROL

FEDERAL
- Develop Policy

Policy Guidelines

Provincial
- Create Plan

Management Plan

Local
- Implement and Enforce

Implementation of Standards & Regulations

According to Young (1984), water quality is a primary factor in determining the recreational resource potential and property value of a particular area. When anthropogenic activity is taking place, the water that is in direct contact with the shore can become polluted, initiating environmental degradation. Common pollutants include suspended solids, pesticides, herbicides, nutrients from fertilized agricultural lands and residential septic tanks, pathogenic bacterial organisms and industrial pollutants such as toxins and heavy metals from nearby urban land uses.

Such pollutants are of both the point and nonpoint variety, most of which enter the system within the runoff, although some enter by air and water sources. Primarily, these contaminants enter shoreline areas via rivers and stream channels, culverts, groundwater flow, and overland flow from the surrounding land (Baalsrud, 1973). They combine to alter natural shoreline conditions and degrade overall water quality. In addition to specific pollutants, activities such as boating, the construction of erosion control structures, dredging and high bather loads can also contribute to reduced water quality and degraded natural shoreline conditions by altering bacteria, turbidity and suspended solid concentrations.

The issue of healthy, usable recreational water is continually of great concern, especially during the warmer months of the year when utilization is at its peak (Heidtke and Sonzogni, 1986). In many cases, the government monitors the
conditions at public beaches to ensure that they are safe for public use. If the quality of the water becomes too poor, a beach may have to be closed until it regains a state of suitable quality, as deemed by the officials who closed it. The result of this happening will be the severing of the beach as a usable recreational resource, placing further stress on the other beaches nearby. Unlike public beaches, regular monitoring of water quality at private beaches is not carried out. This is an important resource management practice whose absence makes overall environmental management of private beaches less complete. Degradation of water quality and shoreline conditions in private beach areas results in property devaluation and loss of aesthetic and recreational potential. According to Shannon (1988), a poll of Canadians concluded that environmental health concerns were repeatedly selected as a major issue to them, with water quality issues leading the way. Another conclusion of the poll was that Canadians believe they can have both managed development and high environmental quality. It is quite clear then, that the issue of water and shoreline quality is critical in maintaining the overall resource value of these delicate natural systems. According to Anderson and Baum (1988), there is no substitute for a sound, ecologically based resource inventory, as the foundation for decisions aimed at meshing the management of all major resources in the planned area.
REVIEW OF LITERATURE

Over the past two hundred years, the lower Great Lakes shoreline has been subject to an increasing range and intensity of land uses. Natural and human modification of the lower Great Lakes shoreline poses a problem of considerable magnitude in terms of damage and other costs (Kreutzwiser and Davidson-Arnott, 1984).

Much work has been done on the effects of different land uses, runoff regimes, loadings and human activity, on the water quality of shoreline areas. According to Novotny and Chesters (1981), contaminated runoff from urban sources is chiefly responsible for water quality problems on many lakes and rivers. Because aquatic ecosystems are so delicate and sensitive to any unnatural interferences, they must be carefully monitored and managed. Proper execution of this idea is accomplished through the development of a management strategy that monitors activities that might affect the conservation, development, utilization and overall enjoyment of water resources by present and future generations (Templeton, 1986).

The Detroit River is a major natural resource, historically important for fish and wildlife and for a variety of human uses. Land development and river use for human activities have impaired habitats and the river's suitability for other human uses (Kumler, 1987). The water quality of the river will never be
the same as it was before human settlement and the ensuing
development. However, many of the impacts can be remediated or
controlled to restore most impaired uses. Historically, the
river was bordered by extensive wetlands, but now much of its
shoreline has been filled and bulkheaded to accommodate
industrial, municipal and residential development (Great Lakes
Water Quality Board, 1987). The river is used extensively for
shipping, recreation, public and industrial water supply. It
also receives treated wastewater from numerous municipal and
industrial facilities, direct storm runoff and sewer overflows.
According to the Great Lakes Water Quality Board (1987), the
Detroit River is impaired for total body contact recreation and
aquatic life due to high levels of faecal coliform bacteria. The
Board also reports that Wheatley Harbour is in a similar state of
impaired water quality with dissolved oxygen depletion, elevated
bacterial levels, nutrient enrichment and organic contamination
of the harbour sediments. Subsequent studies have shown elevated
levels of PCBs in the harbour sediments as well. The source of
much of this contamination is primarily discharges from local
food processing operations.

Other than to protect agricultural crops, pesticides and
herbicides have no positive function. These chemical
constituents enter into the groundwater and runoff regimes which
eventually flow into shoreline areas. Haith (1985) stated that
an analysis of the effects of pesticides on the quality of
surface waters requires estimates of the runoff loads of the
chemicals. Two different loads are often used; mean annual loads and critical loads. Haith noted that pesticide loads to surface waters are essentially uncertain, but can be quantified in terms of probabilities through the Monte Carlo Simulation. This process determines pesticide loads in relation to weather, hydrologic and soil parameters.

One of the most widespread and critical water quality problems is the nutrient loading of water bodies. When high concentrations of nutrients enter watersheds, the eutrophication rate increases substantially, lowering dissolved oxygen levels and promoting algal overgrowth. The study of eutrophication rates is an important element in the determination of a lake's overall water quality conditions and trophic status (Baalsrud, 1973; Jones and Bachmann, 1976; Nowotny and Chesters, 1981; Wyer and Hill, 1984; Clebscher, 1986; and Hill, 1986). Supporting this idea was the study carried out by Jones and Bachmann (1976) on the prediction of phosphorus and chlorophyll levels in lakes. They found a very strong and direct correlation existed between summer levels of chlorophyll a and total phosphorus concentration for 143 lakes in the midwestern United States. Because such a strong relationship existed, the authors inferred that phosphorus is the main element controlling algal biomass in lakes, a key indicator of increased eutrophication rates. Gaynor (1979) obtained similar findings and concluded that housing and agricultural inputs were the main sources of phosphorus within the system. Clebscher et al. (1986) arrived at the same
conclusions in their study of phosphorus and nitrogen loading on Wisconsin lakes. They tested for dissolved orthophosphate, total phosphorus, total inorganic nitrogen and total nitrogen. The testing of these parameters showed nutrient levels varied according to specific land use. They also found that agricultural and municipal sewage waste produced the highest nutrient loadings to lakes. Neilson et al. (1980) concurred with these findings in their study of nonpoint nitrogen runoff from agricultural watersheds.

Acid precipitation also has a tremendous effect on the reduction of water quality, depending on geographical location with respect to source of acids, and the lake's underlying geology. The effect increases in areas where acidic precipitation fallout is heavier and where underlying lake geology is comprised of non-alkaline material (Novotny and Chesters, 1981). Bobee and Lachance (1984) in their study on lake acidification in Quebec, pinpoint acid precipitation as the cause of several ecological problems on lakes. This included an overall decrease in fish populations due to the inability of some species to tolerate and adapt to lower pH levels, decreased diversity of all buffering capability and water quality. Hendry and Brezonik (1984) are in agreement on the consequences of acid precipitation. By basing their study on softwater Florida lakes, the two revealed that acid precipitation is not a problem solely confined to the Canadian Shield, but in fact is spread out over North America. Their study showed that 31 percent of lakes
sampled were sensitive to acid precipitation, and in all cases, chlorophyll a concentrations were reduced.

Nonpoint pollution of shoreline areas from urban sources is a continual problem in many regions. Both Novotny et al. (1985) and Smullen et al. (1978) categorized the sources of urban pollution as wet and dry atmospheric deposition, street refuse (litter, dirt, organic residues), traffic emissions, urban erosion and road deicing. Urban runoff is strongly influenced by weather parameters such as rainfall, wind, etc. The study by Hudroch (1985) on the geochemistry of Detroit River sediments showed the effects heavy industrial land use have on the adjacent river. High concentrations of several heavy metals such as lead, cadmium and zinc were found in the sediments of the river, at the point where it enters Lake Erie.

Recreational activity also accounts for some reduction in water quality and degradation of shoreline ecosystems. Johnstone et al. (1985) studied how recreational boat traffic affected the dispersion of aquatic plants in New Zealand. They found that increased boat traffic actually helps spread weed growth through entanglement of plants with moving vessels. With this, plants are carried to places where the boats travel, intensifying weed concentrations. The problem is most intense in launching and docking areas of lakes and the end result is impaired use of the lake as a fully functionable recreational resource. Vasconcelos and Anthony (1985) and Sherry (1986) found that the concentration of fecal coliform bacteria greatly degraded the water quality of
recreational bathing beaches in the Pacific northwest and on Lake Ontario respectively. According to Sherry (1986), the occurrence of *Candida albicans* and *Pseudomonas aeruginosa* appear to be related to elevated faecal pollution indicator levels. Maximum numbers of all parameters were observed in July and August in association with peak bather loads at the beaches. The presence of faecal pollution in recreational water constitutes a potential health hazard. Bacterial indicators of faecal pollution such as faecal coliforms and *P. aeruginosa* are commonly used to monitor the water quality of freshwater recreational beaches. In particular, *P. aeruginosa* has been associated with eye, ear, upper respiratory tract and skin infections. Sherry concludes that because of the risk to bathers, a need exists to ensure that recreational waters are not contaminated with disease-causing agents.

Sewage discharge associated with septic tank usage is a major contributor to increased levels of bacterial water pollution, which in turn harms the health of users who come into contact with the polluted water (Ochs and Thorn, 1984; Vasconcelos and Anthony, 1985; Reddy et al., 1986; and Najarian et al., 1986). On a CBC Radio talk show in early June of 1989, Dr. Phil Fioret, the then Medical Officer of Health for the City of Windsor, stated that faecal coliform bacteria was a problem for beaches in and around Essex County. Dr. Fioret went on to say that direct contact in these waters could result in ear, eye, throat and stomach infection. He also stated that weather
conditions will compound the problems associated with faecal coliform pollution and that because of this, there is great fluctuation in the day to day quality of beach water. Both Ochs and Thorn (1984) and Young (1984) concluded that by improving the quality of recreational waters, the value of nearby seasonal homes will increase. The opposite is true if water quality conditions become degraded. The authors also conclude that the value of shoreline property is based on access or limitations to recreational activity and the overall aesthetic condition of the property and its surroundings. The benefits of owning shoreline property hinge on the quality of the nearby water (Ochs and Thorn, 1984).

The actual construction of buildings and roads near watersheds create a sudden increase in suspended sediment load and overall suspended solid load into the water. The findings of Taylor and Roff (1986) reveal that such an occurrence reduces ecological diversity by choking out the less tolerant benthic organisms. These communities are very sensitive to even the slightest changes in sunlight, dissolved oxygen levels and suspended sediment/solids. They also found that as one moved away from the construction site, both floral and faunal diversity were gradually re-established.

It is the overall conclusion of Baalsrud (1973; Tate 1984; Heidtke and Sonzogni 1986; and Templeton 1986) that proper resource management of aquatic resources is tri-faceted. It requires the concerned and dedicated input of government.
industry and, most importantly, the citizens who use the resources. If mankind continues to disregard and neglect these areas, further degradation will be the unfortunate consequence, which will limit the beneficial uses of these resources.

AREA OF STUDY

The Northwestern shoreline of Lake Erie lies within the vast confines of the Great Lakes Drainage Basin (Fig. 2). It represents a stretch of shoreland lined with both private and public beach areas. Surrounding these beaches are a variety of land uses, including parks, agricultural land, woods, marshes and some residential development in the form of both cottages and homes. Because there is a direct interaction between the shoreline ecosystem and human activity, this section of the Lake Erie shoreline is ideal for the undertaking of a research study on water quality and shoreline management. Much recreational development and activity also takes place in this area which emphasizes its importance as a natural resource. This fact is demonstrated through a wide variety of uses such as a drinking water supply, fish and wildlife habitat, swimming, boating, fishing and relaxation. The study region extends from Holiday Beach Conservation Area in southwestern Essex County, east along the Lake Erie shoreline up to and including Wheatley Provincial Park in southwestern Kent County. This covers virtually all of the southern shoreline of Essex County, plus a small fraction of
LOCATION OF STUDY AREA WITHIN THE GREAT LAKES DRAINAGE BASIN

Kent County's southern shoreline. Water quality in this region is of major significance because the area is one of Canada's most coveted in terms of climate, property value and recreational value. These factors combine to form one of the greatest aquatic recreation areas in the entire country.

The public beaches within the study include a conservation area, a provincial park and a national park. Because all the public sites selected are park-like in nature, land use is uniform for all three sites. The private beach areas exhibit varied land use including residential, wooded and a mixture of other natural and artificial landscape features. The maintenance of suitable water quality conditions for these beach areas is critical, as it reflects the extent to which human activity influences the local environment. This issue is of special significance to this part of the Great Lakes system because of its tremendous recreational and overall resource value. Lack of confidence in local government and devalued shoreline properties are the consequences of inadequately maintained and degraded shoreline water quality conditions at both public and private beaches (Young, 1984). The study region itself is composed of three public and three private beach areas along the northwestern Lake Erie shoreline. These beaches are at the following locations (Fig.3):

<table>
<thead>
<tr>
<th>Public Beach Sites</th>
<th>Private Beach Sites</th>
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<tbody>
<tr>
<td>1) Holiday Beach Conservation Area</td>
<td>2) Colchester Beach Property</td>
</tr>
<tr>
<td>3) West Beach - Point Pelee</td>
<td>4) Cedar Beach Property</td>
</tr>
<tr>
<td>5) Wheatley Provincial Park</td>
<td>6) Town of Seacliffe</td>
</tr>
</tbody>
</table>
Since the two types of beaches blend with one another throughout the study region, a water quality study could be used to distinguish temporal and spatial patterns of water quality and the influence of different land uses/activities acting on it. This could be used as a resource management tool to help ensure that the area continues to function optimally as a recreational region.

Holiday Beach Conservation Area marks the western edge of the study region. It is a public beach/park area located close to the mouth of the Detroit River in southwestern Essex County and adjacent to the mouth of Big Creek. In terms of its topography and bathymetry, Holiday Beach has a high back dune-crested beach with a distinct berm that slopes down gradually out into the lake (Fig.4). This is a popular beach which is used extensively for swimming and picnicking.

Colchester lies to the east of Holiday Beach and is an area of private shoreline property. A distinctive feature of this area is the high cliffs extending back from the beach. Its bathymetry is steeper than at Holiday Beach but it has a similar topographic profile (Fig.5). Rock breakwalls and sheet piling along the edge of the beach acts as a form of erosion protection. This beach had fewer users in comparison with Holiday Beach.

Cedar Beach is a private beach area that is situated between the Colchester and Seacliffe areas of southern Essex County. The beach here is divided between breakwall-protected sections and
sections of open, sandy beach. The profile of this area is rather flat and the nearshore zone is marked by a large sand platform (Fig.6). Like Colchester, it had relatively few users and its primary uses are boating, fishing and swimming.

The Seacliffe Area is located just west of the town of Leamington and is also a private beach area. It is a low volume beach having a topographic profile exhibiting a gently sloped beach with vegetated background dunes. The bathymetry is very similar to Cedar Beach with a rather large shallow platform extending out from the edge of the water (Fig.7). Houses and cottages are located behind this beach with swimming and water-skiing being the primary recreational activities.

The West Beach at Point Pelee National Park is another popular public beach located just east of Leamington on a cuspatate foreland in southeastern Essex County. The profile of the beach features a prominent berm near the water's edge with somewhat steep topography. From the edge of the water, the beach drops off very quickly (Fig.8). The West Beach is backed by vegetated dunes and underbrush, emphasizing its park setting. Most recreational activity here involves swimming and nature study.

Wheatley Provincial Park marks the eastern edge of the study region, located adjacent to the mouth of Muddy Creek in southwestern Kent County. Like Holiday Beach and the West Beach at Point Pelee, it is a public beach/park area. In terms of its topography, the beach has a prominent berm at the water's edge and slopes back gradually to the base of a straight cut bluff.
FIGURE 4
HOLIDAY BEACH CONSERVATION AREA
-TOPOGRAPHIC & BATHYMETRIC-

FIGURE 5

COLCHESTER
-TOPOGRAPHIC & BATHYMETRIC-

ELEVATION (metres)

DISTANCE (metres)

Lake Erie = 173.92 m

Figure 7
SEACLIFFE
-TOPOGRAPHIC & BATHYMETRIC-

ELEVATION (metres)

Lake Erie = 173.92m

FIGURE 8
POINT PELEE NATIONAL PARK - WEST BEACH
-TOPOGRAPHIC & BATHYMETRIC-

ELEVATION (metres)

176
175
174
173

DISTANCE (metres)

0 10 20 30 40 50

Back of Beach

Lake Erie = 173.92 m

FIGURE 9
WHEATLEY PROVINCIAL PARK
-TOPOGRAPHIC & BATHYMETRIC-

ELEVATION (metres)

DISTANCE (metres)

Bathymetrically, the beach drops off moderately and evenly (Fig. 9). Swimming, canoeing and picnicking comprise the bulk of the recreational activity at this beach.

In terms of general surrounding land use for the six sites within the overall region of study, there is a distinct difference between the private and public beaches. All three public sites are located in parks with the surrounding land use consisting of woodlot and open green space. Land use surrounding the private beach areas is primarily residential development in the form of houses and cottages. This different land use setting contributes to the possibility of water quality variances between the public and private beach areas.

OBJECTIVES OF THE STUDY

The objectives of this research are:

1) The assessment of general water quality conditions at the six beaches selected in order to obtain a general assessment of water quality for the entire study region.

2) To distinguish any possible temporal and spatial patterns of water quality between the public and private beaches of the same type.

3) To determine which beaches have the highest and lowest values of the selected water quality parameters during the study period.

4) To obtain a user perception of water quality at both beach types through the use of a questionnaire survey. This will be used as a means of assessing water quality from a subjective perspective to supplement objective water quality data.

5) To establish a general inference regarding which
beaches have the overall best and worst water quality conditions within the study region, based on both objective and subjective data.

6) To attempt to explain why the water quality conditions that are found to exist are the way they are, based on such criteria as weather conditions, the presence of artificial landscape components, user loads, land use, wind speed and direction and geographical location.

A PRIORI MODEL

Determination of the water quality at the six beaches in the northwestern Lake Erie shoreline study area will be accomplished through the development of a process-response model (Fig. 10). The beaches can be treated as a process-response system, as the water quality at each site reflects a response to the surrounding land use and recreational processes acting upon them (anthropogenic activity). For the public beaches, the surrounding land use is uniform with parkland forming the predominant land use at each site. With the three private beaches, however, the surrounding land use is not of the same type. These areas have primarily urban, residential land uses behind them in the form of houses and cottages. For both beach types, swimming, picnicking, birdwatching and relaxation comprise the majority of the recreational activities, with fishing and boating more common at private areas. The study region as a whole is an open system, freely allowing for the input and output of matter and energy through it. The water quality conditions at
each beach will serve as an indicator of anthropogenic influence on the functioning and environmental status of the shoreline system.

The a priori model (Fig. 10) shows that, in any given recreational season, the antecedent water quality conditions at both the public and private beach areas are strongly influenced by the runoff load, acid rain, and anthropogenic activity. The magnitude of this activity is quantified in terms of boating activities and discharge, bather load, suspended solids, beach debris, man-made shoreline protection, and dredging. Resultant water quality is the response to these activities. This is determined through testing of the parameters temperature, pH, total suspended solids, turbidity, faecal coliform concentration and P. aeruginosa concentration. From the resultant water quality conditions, negative feedback mechanisms are introduced such as government control and regulation of utilization, and regular testing and monitoring of the water, which attempt to stabilize and harmonize water quality conditions. These are necessary components to ensure that proper environmental management of the resource is accomplished.

HYPOTHESES

There are three hypothesis for this research study. The first is that there is a significant difference in water quality between public and private beaches. This is based on differences
FIGURE 10
PROCESS RESPONSE MODEL FOR THE SHORELINE WATER QUALITY STUDY, 1988 - NORTHWESTERN LAKE ERIE

Type of Land Use

Effects of Septic Tanks

Boating Activities

Debris

Acid Rain

Anthropogenic Activity

Antecedent Water Quality of Private Beaches

Antecedent Water Quality of Public Beaches

Bather Load

Runoff Load

Man Made Shoreline Protection

Dredging

Resultant Water Quality of Private Beaches

Resultant Water Quality of Public Beaches

Stricter Regulation

Negative Feedback Mechanisms

Parameters Used To Test Water Quality Conditions

Regular Monitoring

according to land use as discussed by Uttermark et al. (1974). It is hypothesized that this difference will be seen in both a spatial and temporal context. This hypothesis will be tested by employing a Fisher's Analysis of Variance Test on the sample data to assess the difference in water quality between the two types of beaches. Temporal variation of the data will be addressed by comparing data collected in each of the Spring, Summer and Fall sampling periods.

According to officials at the Windsor and Essex County Health Unit, climatological parameters such as air temperature, wind speed and wind direction strongly influence local water quality conditions in beach areas. With this in mind, the second hypothesis states that there will be significant correlation between sampled parameters and climatological parameters. This hypothesis will be examined through the use of Pearson Product Moment Correlation Analysis which will detect any such relationship within the data.

The author has identified two general types of beach users: the public beach user and the private beach user. Because the two groups utilize beach areas in different ways (i.e., different activities according to land use, etc.), their perception of water quality conditions is likely to be different as well (i.e., private beach owner/users see the beach area on a continual basis for the entire recreational season, while public users only do so with each visit). This generates the hypothesis that significantly different trends in water quality perception exist.
between the two user groups. This third hypothesis will be explained by running a number of Two-Sample Chi Square Tests on comparable data collected for both beach user groups via the questionnaire survey.

The testing of these hypothesis and the inferences they generate will form a framework for the development of a water quality assessment of the northwestern Lake Erie area.

**METHODOLOGY**

An evaluation of the spatial and temporal variation of water quality at the six beaches and the variation between beach types was carried out, employing the concepts and procedures outlined in the process-response model. This will be used to determine the influence of anthropogenic activity within the northwestern Lake Erie study region.

The six beach sites within the study area were selected in such a way as to have them nested within one another, so as to avoid spatial segregation between the two types of beaches. This will help ensure that any patterns in water quality produced will be unbiased. At each of the six beaches, three randomly selected water samples were taken, making the entire sampling design randomly clustered in nature. Two of the samples were taken in the shallow wading zone, approximately 2-3 metres from the shore, while the third was taken approximately 25-30 metres from the shore to delineate the furthest extent to which the majority of
shoreline water users will go. This set up a triangular grid pattern of samples at each beach (Fig. 11). It might be noted that only one shallow water sample instead of two was used when assessing bacteria concentrations and that this sample was taken between the other two shallow water samples. This made for a total of 24 samples per sampling period. It is the mutual belief of the investigator and the research supervisor that this sampling design would provide an adequate representation of water quality for this study region.

For each of the water samples taken, testing for the six aforementioned parameters was conducted to indicate existing water quality conditions. Temperature and pH were tested in the field while the other four parameters were analyzed in the laboratory. Sampling was carried out on April 21, May 18, June 15, July 5, July 20, August 8, August 28, September 17, and October 22. This made for a total of nine sampling periods covering three seasons (Spring, Summer, Autumn), with stronger representation in July and August when the beaches are utilized the most. This particular data gathering scheme allows for temporal as well as spatial variations of water quality to be examined. Actual water sampling was done using a small inflatable boat and a pair of chest waders.

After the water samples were collected, they were taken to the Windsor Public Health Laboratory to be tested for bacteria concentration. This was accomplished using the Membrane Filter Technique for the detection of bacteria in water samples. From
WATER SAMPLE LOCATIONS AT EACH BEACH

here the samples were taken to a lab in the Department of Civil Engineering, where they were tested for turbidity using a Nessler's Turbidity Meter. Finally, testing for total suspended solids was conducted in the Department of Geography lab by straining each sample through filter paper, drying, and then weighing it. This procedure of water testing was done for all nine sampling periods.

Wind speed, wind direction, and local weather conditions supplemented the water data for each sampling period. This data, along with the raw data collected from each of the beaches over the study period is contained in Appendix A. A topographic and bathymetric profile, using an automatic level and stadia rod was also determined for each beach. It might be noted that the resultant profiles extrapolated from this survey portray some temporary features such as bars and platforms. Observations regarding the beaches' aesthetic conditions and a beach user count were also documented at each of the six beaches for all nine sampling periods. In all cases, sampling was carried out between 1030 hours and 1400 hours, alternating the starting position within the study region each time. This was to help ensure that purely random samples would be produced. In addition to the interval scale variables of water quality, nominal and ordinal scale data were collected on beach user perception of water quality. This was accomplished using a questionnaire survey (see Appendix B). The main idea of this aspect of the study is to incorporate a subjective perspective of water quality
from the viewpoint of the beach users; both private and public. It is the opinion of the author that the combination of this subjective data with the objective water data he made the study fairly comprehensive. This bi-faceted approach to studying shoreline water quality conditions provides a good assessment of the environmental status of northwestern Lake Erie. 60 private and 60 public beach users were personally interviewed in the field by the investigator to develop this overall perception of water quality from the point of view of both parties. Interviewing took place during the summer months when recreational utilization of shoreline resources was greatest. Interviewing covered virtually the length of the study region with a number of questionnaires completed at each of the six sites.

The fieldwork for this study was a fundamental step in the formulation of a water quality scheme for the northwestern Lake Erie shoreline. Raw data collected as well as observations made in the field provide the base from which to draw inferences regarding water quality conditions. From this, a sound research study will be produced which will become a tool for good environmental management in this area.

OBSERVATIONS

Throughout the nine sampling periods extending from April 21 to October 22, observations of each beach were made with respect,
to physical appearance, evidence of human use and modification, number of beach users, and climatological conditions.

Holiday Beach had the greatest intensity of beach users with a total of 207. The majority of this total was in June and early July. For many of the sampling periods, the beach was littered with organic debris such as twigs, aquatic weeds, and shells, and the water was quite often clouded with weeds and sediment. This tended to reduce the aesthetic quality of the beach. There was some man-made litter and a few of the picnic tables were in contact with the shore. This beach is seen in Figure 1.

A striking feature of Colchester beach was the presence of a runoff ditch extending from the adjacent urban development directly into the lake (Fig. II). This ditch was covered in algae and had garbage scattered within it. It also gave off a sewage smell. Colchester experienced the fewest number of beach users (14) and the shoreline was heavily protected with both a rock and a sheet pile breakwall. Like Holiday Beach, the water here was often cloudy and both beaches experienced warmer water temperatures.

Sections of Cedar Beach also had shoreline protection in the form of rock and sheet piled breakwalls. However, its water seemed cleaner and the presence of a large sand bar made for an extensive shallow water zone. Cedar Beach had only 32 beach users over the study period with many of them fishing from boats offshore. The beach itself had a large sandy area which provided a scenic view (Fig. III). One concern regarding this beach was
that residents discovered several small plastic tubes with residue of a food preservative gel washed up on shore over the course of the summer. Nobody is sure from where they originated, but it is possible they were discharged from either a shipping vessel or a nearby manufacturing plant.

The Seacliffe area was the most secluded and least developed of the private beaches. It was characterized by lightly vegetated dunes and an extensive sand bar, much like the one that existed at Cedar Beach (Fig. IV). Also like Cedar Beach, Seacliffe had only a total of 32 beach users. Over the study period, the beach was used primarily for swimming and water skiing.

The West Beach at Point Pelee National Park was characterized by a steep drop from the edge of the water and a generally swift longshore current. It is a moderate volume beach, attracting 121 users over the study period. An attractive feature of this beach was its abundance of sand and a scenic backdrop of vegetated dunes and underbrush. Its topography and steep bathymetry made the West Beach more popular for sunbathing and nature study than swimming (Fig. V). One negative aspect of this beach was the abundance of biting flies during the summer months.

The beach at Wheatley Provincial Park featured a uniformly smooth sandy topography extending towards the water from a high, steep bluff (Fig. VI). Over the course of water sampling, 75 beach users were seen here with the majority of them swimming or
picnicking. A striking feature of Wheatley's bathymetry was the presence of several large rocks and other debris which made swimming somewhat dangerous. The bluff in the background made this beach aesthetically attractive and it was well maintained with virtually no man-made litter.

Overall, the public beaches had far more beach users than the private areas, reflecting the restricted access to private beaches. Even with this, numbers were likely lower than average since most of the water sampling was conducted on weekdays. Of the 481 total beach users, only 78 were counted at private beaches during the times water samples were drawn from each site. Of the nine sampling periods, the summer samples revealed the highest beach user counts. July 5 had the highest with 118 total users, while April 21 had the lowest at zero (Fig. 12).

There was a distinct pattern of wind speed experienced throughout the course of the study. The Spring and Fall had moderate to high wind speeds with very low wind speeds recorded during the summer months. There was a high of 35 km/hour (June 15) and a low of 7 km/hour (July 5, July 20) creating an overall mean wind speed of 21.0 km/hour (Fig. 13). Wind direction varied over the course of the study with the lighter winds generally blowing out of the east and west, and the stronger winds blowing out of the southwest and northwest. The mean wind direction was southwest.

In terms of air temperature and general weather conditions, very warm temperatures prevailed throughout 80 percent of the
FIGURE I

HOLIDAY BEACH CONSERVATION AREA - Photographs
FIGURE II

COLCHESTER - Photographs
FIGURE III

CEDAR BEACH - Photographs
Figure IV

SEALIFFE - Photographs
WEST BEACH, POINT PELEE - Photographs
FIGURE 12

NUMBER OF BEACH USERS

PER BEACH

TOTAL = 481

Mean # of Users

Holiday Beach: 230
Colchester: 1.56
Cedar Beach: 3.56
Seacliff: 3.56
Point Pelee: 13.44
Wheatley: 8.33

PER MONTH

October 22nd: 8
February 17th: 51
August 28th: 55
August 8th: 73
July 20th: 72
July 5th: 118
June 15th: 94
May 18th: 10

FIGURE 13
CLIMATOLOGICAL FACTORS
MEAN WIND SPEED AND DIRECTION

Mean = SW 21 km/hr

LAKE

ERIE

Mean = 22.56 °C

study period and primarily associated with this were sunny, hazy, and humid conditions. There was a high temperature of 33°C on August 8 and a low temperature of 6°C on April 21 (Fig. 13). In general, the summer of 1988 was hotter and drier than average, making Lake Erie beaches in this area a good place to relax and refresh.

ANALYTICAL FINDINGS

Upon examination and analysis of the data obtained through regular water sampling and personal interviewing during the course of the study, many trends and inferences can be drawn. The parameters for indicating water quality as outlined in the a priori model were applied to each beach.

Results From Water Sampling

Beginning at the western boundary of the study region and moving in an easterly direction, the results of the water sampling at each beach have been tabulated. Holiday Beach Conservation Area had the poorest water quality of the three public beaches and was one of the poorest beaches overall in terms of the parameters sampled. Most notably, this beach had the highest mean P. aeruginosa concentration (1479/100 ml), second highest mean turbidity (35 NTUs), highest mean temperature (19.9°C), highest mean pH (7.07), third highest mean fecal coliform concentration (133/100 ml), and the fourth highest mean
total solids (319 mg/L). Except for pH, all readings were higher in the shallow water samples compared to those taken in deep water. There wasn't much correlation with wind speed and direction except that winds out of the north and northwest generally were associated with reduced bacteria concentrations. Another trend was that higher values for total solids were in the Spring.

In terms of the tested parameters for water quality, Colchester had the poorest conditions of any beach in the study area. It had a very high mean fecal coliform concentration of 1244/100 ml which was by far the highest and the third highest mean P. aeruginosa concentration at 1019/100 ml. The highest readings were consistently obtained in the shallow water samples, particularly from one that was located near a runoff ditch entering the beach from the nearby residential development. In addition to these, Colchester had the fourth warmest mean water temperature (19.4 °C), the highest mean total solids (354 mg/L), but the lowest mean pH (6.91) and the second lowest mean turbidity (115 NTUs). Generally, higher values were associated with shallow water samples which is perhaps due to the lack of flushing and water turnover as compared to deeper water samples.

Two slight trends that existed were that northerly winds were associated with lower fecal coliform concentrations and the Spring samples showed higher values for total solids. Under northerly wind conditions, the wind is blowing from the beach out towards the Lake which circulates the water better. The higher
total solids in the Spring indicate the influence of the higher Spring runoff.

Compared to the other five beaches, Cedar Beach was average in terms of its water quality, having good values for some parameters and poor values for others. Specifically, this beach had the second highest mean *P. aeruginosa* concentration (140/100 ml), third highest in mean total solids (320 mg/L), mean temperature (19.8 °C), mean pH (7.01), and mean turbidity (22 NTUs), and it had the fourth highest mean fecal coliform concentration (77/100 ml). The only noticeable patterns detected were higher turbidity values under southwest and northwest wind conditions and higher total solids in the Spring.

Seacliff was similar to Cedar Beach in that it had high values for some parameters and low values for other parameters. Specifically, it had the warmest mean temperature overall with Holiday Beach (19.9 °C), the second highest mean total solids (322 mg/L), the second highest mean pH (7.03), the third highest mean fecal coliform concentration (114/100 ml), and it was fourth highest in both mean *P. aeruginosa* concentration (1120/100 ml) and mean turbidity (16 NTUs). There were no distinct patterns present in the data except that pH values were highest in mid-summer.

The West Beach at Point Pelee was by far the beach with the best overall water quality conditions. It consistently recorded the lowest bacteria, turbidity, and total solids readings throughout the duration of the study period. Specifically, it
had the lowest mean fecal coliform concentration (40/100 ml), mean turbidity (12 NTUs), mean \textit{P. aeruginosa} concentration (289/100 ml), and mean total solids (143mg/L), the second lowest mean temperature (18.5°C), and the third lowest mean pH (6.96). Although no truly clear trends in water quality existed here, higher turbidity values were generally associated with southwest and northwest wind conditions. This is likely due to the fact that this beach faces west, and larger waves are produced under these conditions, creating more turbidity. Also, the highest total solids measurements occurred in the Spring when seasonal runoff is greatest.

The beach at Wheatley Provincial Park was certainly above average in terms of its water quality when compared to the other beaches studied and was the next cleanest beach following Point Pelee. Specifically, Wheatley had the second lowest mean fecal coliform concentration (75/100 ml), mean \textit{P. aeruginosa} concentration (975/100 ml), mean pH (6.94), and mean total solids (289mg/L), the lowest mean temperature (17.6°C), but the highest mean turbidity (41 NTUs). There were no detectable patterns in the water quality at Wheatley.

When comparing and contrasting the three public beaches against the three private beaches, many differences are evident along with some rather obvious similarities. Except for pH, which did not fluctuate very much, both the private and public beaches experienced higher values of turbidity, bacteria, total solids, and temperature in the shallow water samples. Also
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</table>

**Sources:** Korotkin, P. 1988.

**Table 2:** Mean Values - Private
FIGURE 14
MEAN WATER TEMPERATURE

Overall Mean = 19.20 °C

FIGURE 15
MEAN TURBIDITY

Overall Mean = 22.82 NTU's

FIGURE 16
MEAN FAECAL COLIFORM CONCENTRATION

Number / 100ml

Holiday Beach: 133.09
Colchester: 1244.45
Cedar Beach: 76.67
Sealiffe: 141.11
Point Pelee: 40.00
Wheatley: 75.56

Overall Mean = 284.97 / 100ml

FIGURE 17
MEAN TOTAL SOLIDS

Holiday Beach: 319 mg/L
Colchester: 354 mg/L
Cedar Beach: 320 mg/L
Seacliffe: 322 mg/L
Point Pelee: 143 mg/L
Wheatley: 288 mg/L

Overall Mean = 291.25 mg/L

straight across the study region, water temperatures fluctuated in exactly the same manner as the air temperatures, and beach user numbers were higher during the warmer months. In terms of differences, public beach areas had far more beach users and higher turbidity, but lower fecal coliform and _P. aeruginosa_ concentrations, water temperatures, and total solids. The pH for both types of beaches was the same overall. Higher fecal coliform concentrations at the public beaches were generally associated with lighter wind conditions while the opposite held true for the private beaches. There did not appear to be any explanation for this pattern. Over the course of the study period, the pattern in fluctuations in all six measured parameters of water quality except for pH, differed between the two beach types. The mean values for both beach types is shown in Tables 1 and 2 and the data values for each beach are shown in Appendix A.

The incidence of these regular differences prompted a one-tailed, directional Student's t-test to be conducted in order to determine whether there was a significant difference in water quality between the two beach types. This was the first hypothesis. Four parameters were tested for: turbidity, fecal coliform concentration, _P. aeruginosa_ concentration, and total solids. When the two types of beaches were compared in terms of fecal coliform numbers, a statistically significant difference was found to exist at the 0.05 level of significance. The observed value of 2.25 exceeded the critical value of 1.75,
indicating that a significant difference existed between the two beach types. Since the values for fecal coliforms were higher at the private beaches, the inference can be made that the concentration of fecal coliforms is significantly higher at the private beaches, indicating reduced water quality conditions. A similar t-test was also run between the two beach types for turbidity. A significant difference was again detected at the 0.05 level of significance since the observed value of 1.84 exceeded the critical value of 1.73. In this case, values of turbidity were higher at the public beaches which advances the inference that turbidity is significantly higher at the public beaches. There was no significant difference between the two beaches for either P. aeruginosa or total solids. In both of these cases, the critical value exceeded the observed value.

Even though the differences between the two beach types for these two parameters were not found to be statistically significant, values recorded were higher at the private beaches for both parameters. The results of these t-Tests are shown in Table 3.

From this, one can infer that there is a statistically significant difference in water quality between the two beach types based on the parameters used and that water quality is poorer at the private beaches based on the data collected. A series of t-tests for the same four parameters were also run between the best public beach (Point Pelee) and the worst private beach (Colchester). As the results in Table 4 indicate, Colchester had a significantly higher fecal coliform
concentration and higher total solids. For fecal coliforms, the difference was found to be significant at the 0.05 level of significance since the observed value of 2.47 exceeded the critical value of 1.75. For total solids, the difference was found to be significant at the 0.01 level of significance since the observed value of 5.60 exceeded the critical value of 2.58. No statistically significant difference was detected between the two beaches for *P. aeruginosa* or turbidity but values for both parameters were higher at Colchester. These results indicate that water quality is much better at Point Pelee than at Colchester. A similar battery of t-tests were run between the worst public beach (Holiday Beach) and the best private beach (Seacliffe). Only the test comparing turbidity revealed a statistically significant difference between the two beaches with Holiday Beach having the higher values. Holiday Beach also had a higher *P. aeruginosa* concentration but Seacliffe had higher values for total solids and fecal coliform concentration. All these tests combined, indicate that there is in fact an overall difference in water quality between the two beach types with the private beaches being poorer than the public beaches.

To assess the hypothesis that there will be significant correlation between sampled parameters and climatological conditions, a Pearson Product Moment Correlation Analysis was run. For all beaches combined, a strong, direct, significant (0.01) relationship existed between wind speed and turbidity. This same relationship existed at the public beaches but only a
not significant

\[
\begin{array}{|c|c|}
\hline
\text{Total Solids} & \text{Tobs} = 0.91 & \text{Crit} = 1.75 \\
\hline
\text{P. Aeruginosa} & \text{Tobs} = 0.53 & \text{Crit} = 1.75 \\
\hline
\end{array}
\]

df = 16

significant at 0.05 significance level

\[
\begin{array}{|c|c|}
\hline
\text{Turbidity} & \text{Tobs} = 2.25 & \text{Crit} = 1.75 \\
\hline
\text{Public vs. Private Beaches} & \text{Tobs} = 1.84 & \text{Crit} = 1.75 \\
\hline
\end{array}
\]

SUMMARY OF T-TESTS

TABLE 3
Summary of t-Tests

**Point Pattle vs. Colchester**

| 
| Total Solids | 
| Top = 1.56 | CRITICAL = 1.75 |
| Not Significant at 0.01 Significance Level |

| 
| TURBIDITY | 
| Top = 0.53 | CRITICAL = 1.75 |
| Not Significant at 0.05 Significance Level |

| 
| 
| 
moderate strength relationship existed at the private beaches. In all cases, very strong, direct, significant relationships occurred between bather load and water temperature and bather load and air temperature. Significant relationships were detected between *P. aeruginosa* and water temperature and *P. aeruginosa* and fecal coliforms at the public beaches, but no such relationships were present at the private beaches. For both beaches, there was significant correlation between air temperature and water temperature, but only the private beaches saw a moderate, inverse significant relationship between turbidity and water temperature. At the public beaches, a direct, moderately strong significant relationship was present between water temperature and both bacterial readings. This was not the case at the private beaches. The private beaches did, however, experience strong, inverse relationships for total solids with pH and fecal coliforms. A similar relationship existed at the public beaches except that the second correlation was with *P. aeruginosa* and not fecal coliforms. Finally, there was a strong, direct, significant relationship between the two bacterial parameters at the public beaches but not at the private beaches. Looking closely at the correlation data, there are a number of differences when analyzing the two beach types separately. A summary of the relationships at the public beaches indicates that an increase in water temperature was associated with increased concentrations of fecal coliforms and *P. aeruginosa*, higher bather loads, and warmer air temperatures.
<table>
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<th>Variable</th>
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<td>Water Temp</td>
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<td>Turbidity</td>
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</tr>
<tr>
<td>Flume</td>
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</tr>
<tr>
<td>Collisions + area</td>
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</tr>
<tr>
<td>Suspended</td>
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</tr>
<tr>
<td>Collisions</td>
<td>0.59</td>
</tr>
<tr>
<td>Air Temp</td>
<td>0.23</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>0.10</td>
</tr>
<tr>
<td>Bath Load</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Significance at 0.01 level of significance: ***
Significance at 0.05 level of significance: **
Significance at 0.1 level of significance: *

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<td>1.0</td>
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<td>Fecal Coliforms</td>
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<td>Air Temp.</td>
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<td>Gravel Load</td>
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<td>Source: Horrobin, 1996.</td>
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</table>
In addition, fecal coliforms increased with increased *P. aeruginosa* concentrations. Turbidity increased as wind speed increased, bather loads increased as air temperatures increased, and total solids decreased with increased pH levels and increased *P. aeruginosa* concentrations. A summary of the relationships at the private beaches indicates that air temperature and bather load increased with increased water temperature but turbidity decreased. In addition, total solids decreased with increased pH and fecal coliform readings, and increases in bather loads were associated with increased air temperatures and *P. aeruginosa* concentrations. A major difference between the two beach types is the lack of correlation between the two bacteria parameters and water temperature at the private beaches, while moderate yet significant relationships exist at the public beaches for these parameters.

In terms of temporal variation between the two types of beaches, distinct differences were found to exist from season to season. With respect to *P. aeruginosa*, both beaches had low values in the Spring, peak values during the Summer, and lower values again in the Fall. The same pattern was true for water temperature and the number of beach users at both types of beaches. Fecal coliforms fluctuated in a similar manner except that at the private beaches, values continued to be high into the Fall. For turbidity, both beach types had high values in the Spring, a reduction in the Summer, followed by a rise again in the Fall. Readings at both beaches for total solids indicated
peak values in the spring with a gradual decrease into the fall. The values for pH followed a similar pattern to that of water temperature but with a sharp rise in October. Overall, there was a clear seasonal variation in the sampled parameters for both the private and public beaches.

As a means of ranking the six beaches in order to determine the best and the worst, the author graded each site with respect to conditions of turbidity, fecal coliforms, *P. aeruginosa*, and total solids. Since there were six sites, the beach with lowest value for each individual parameter received a score of 6 and the beach with the highest value received a score of 1. Therefore, the best score possible would be 24 and the lowest would be 4. The results of this test showed the west beach at Point Pelee with a perfect score of 24 points, Wheatley Provincial Park with 16 points, Seacliffe and Cedar Beach each with 12 points, and Colchester and Holiday Beach Conservation Area both having 10 points. As mentioned earlier, the tested parameters indicate that the beach at Point Pelee had the best water quality. If one examines these results in a spatial context, water quality seems to degrade as you move west across the study region. A possible explanation for this might be the factor of proximity to the mouth of the highly polluted Detroit River. In any case, the public beaches seem to have better overall water quality when examining these four parameters. This differs from the findings of Sherry (1986) that an increased number of bathers were associated with increased concentrations of fecal coliforms and
FIGURE 18
SEASONAL VARIATION - BACTERIA
P. AERUGINOSA

FAECAL COLIFORMS

FIGURE 19

BEACH BREAKDOWN OF OVERALL CONDITIONS OF WATER QUALITY

Rating Scheme

6 POINTS [best]
5
4
3
2
1 POINT [worst]

Based On: Suspended Solids, Turbidity, Faecal Califorms, P Aeruginosa

P. aeruginosa on Lake Ontario. The public beaches in this study had significantly higher bather loads yet significantly lower concentrations of fecal coliforms and P. aeruginosa. This fact further emphasizes the probability that septic tank runoff and other runoff associated with residential land use is the reason behind the higher bacterial values at the private beaches. This was a point made by Gaynor (1979).

Results From The Questionnaire Survey

As mentioned earlier, the questionnaire survey involved the personal interviewing of 60 private and 60 public beach users throughout the region of study. This was done to obtain a subjective perception of water quality from the perspective of the beach users.

With respect to recreational activities, response from both groups was relatively equal to swimming, nature study, picnicking, and relaxation, but fishing and boating were more popular with private users. Both groups felt the beaches in this area were polluted in some way with 98 percent of public users and 86 percent of private users indicating as such. The public users were far more critical in their ranking assessment of the water quality, yielding a mean score of only 3.98 out of 10 compared to the 5.73 reading from the private user group. Both values are quite low, reflecting a perception of degraded water quality. The causes most frequently cited for this were runoff from surrounding land uses, debris, lack of government control,
and boating activities/discharges. Two differences between the two groups were that the public users pointed out acid rain and inadequate sewage disposal as major problems while this was not the response with the private users. Both groups concurred that the government is not doing its part but the public users thought the water presented more of a health hazard than did the private users. When asked where they thought water quality was better, private users responded heavily to private beach areas while the majority of public beach users said they did not know. In terms of the private beach areas, 93 percent were on septic tanks, 50 percent had drainage ditches on or near their property, and the majority of the property owners received their drinking water from the nearest municipality. Of those interviewed, about 60 percent had houses as compared to cottages, and 80 percent of the property values were in the $35,000 - $60,000 and over $60,000 ranges. The mean number of times public users visited beaches in the area per year was 14, as was the mean number of years they had been going to the beaches in the area. 75 percent of those asked said they thought public beaches were used extensively. Those interviewed in both groups had an equal split of male and female respondents with a reasonable representation from all age categories. In addition to this, many of the respondents had university or college education.

In order to assess the hypothesis that there is a significant difference in the perception of water quality between the two groups, a series of 2-Sample Chi Square Tests were run.
There were significant differences (0.01 level) between the users' perception of where the water quality was higher, and also for responses as to specific recreational activities (0.05 level), and whether or not the water posed a health threat (0.05 level). There was no significant difference between the two groups' views on causes of pollution, educational background, or whether the government was doing an adequate job. The results of the Chi Square Analysis indicate that public beach users feel more strongly that there is a problem with water quality in this area than the private users. Private users seem protective of their waterfront property by indicating that they feel water quality is better at private beaches, as opposed to public beaches, and that the water doesn't present a health hazard. The public users on the other hand felt the water did pose a health threat but did not know where water quality was better. The two groups also differed significantly in terms of recreational activities. The main differences were that private users did more fishing and boating related activities while the public users enjoyed picnicking more often. The results of the questionnaire survey between the two types of beach users reflected an overall difference of opinion of the water quality of the study area.
### TABLE 8

**SUMMARY OF CHI SQUARE TESTS**

<table>
<thead>
<tr>
<th>Recreational Activities</th>
<th>Private</th>
<th>Public</th>
<th>TOTAL</th>
<th>(O-E)^2/E</th>
</tr>
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<tr>
<td></td>
<td>obs exp</td>
<td>obs exp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swimming</td>
<td>47 50.7</td>
<td>50 46.3</td>
<td>97</td>
<td>0.57</td>
</tr>
<tr>
<td>Fishing</td>
<td>33 24.0</td>
<td>13 22.0</td>
<td>46</td>
<td>7.06</td>
</tr>
<tr>
<td>Boating Activ.</td>
<td>28 24.6</td>
<td>19 22.4</td>
<td>47</td>
<td>0.99</td>
</tr>
<tr>
<td>Picnic</td>
<td>25 33.4</td>
<td>39 30.6</td>
<td>64</td>
<td>4.42</td>
</tr>
<tr>
<td>Bird Watch/Nature</td>
<td>29 27.2</td>
<td>23 24.8</td>
<td>52</td>
<td>0.25</td>
</tr>
<tr>
<td>Relaxation</td>
<td>58 60.1</td>
<td>57 54.9</td>
<td>115</td>
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<tr>
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<td>201</td>
<td>421</td>
<td>13.44</td>
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</table>

\[ X^2_{OBS} \]

\[ X^2_{CRIT} = 11.07 \ (0.05) \]

\[ X^2_{OBS} > X^2_{CRIT} \]

Therefore a significant difference exists.

<table>
<thead>
<tr>
<th>Causes of Pollution</th>
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<th>Public</th>
<th>TOTAL</th>
<th>(O-E)^2/E</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>obs exp</td>
<td>obs exp</td>
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<td></td>
</tr>
<tr>
<td>Acid Rain</td>
<td>15 19.4</td>
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<td>45</td>
<td>1.79</td>
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<td>Inadeq. Sew. Disp.</td>
<td>27 30.7</td>
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<td>0.81</td>
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<tr>
<td>Boating Activ.</td>
<td>25 21.3</td>
<td>24 27.7</td>
<td>49</td>
<td>1.14</td>
</tr>
<tr>
<td>Bather Load</td>
<td>2 5.3</td>
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<td>12</td>
<td>3.56</td>
</tr>
<tr>
<td>Debris</td>
<td>36 31.2</td>
<td>36 40.8</td>
<td>72</td>
<td>1.27</td>
</tr>
<tr>
<td>Lack of Controls</td>
<td>29 27.8</td>
<td>35 36.2</td>
<td>64</td>
<td>0.09</td>
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<tr>
<td>Runoff</td>
<td>31 28.6</td>
<td>35 37.4</td>
<td>66</td>
<td>0.36</td>
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<tr>
<td>Dredging</td>
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<td>17 16.4</td>
<td>29</td>
<td>0.05</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td>177</td>
<td>233</td>
<td>410</td>
<td>9.07</td>
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</table>

\[ X^2_{OBS} \]

\[ X^2_{CRIT} = 14.07 \ (0.05) \]

\[ X^2_{OBS} < X^2_{CRIT} \]

Therefore no significant difference exists.

**SOURCE:** Horrobin, 1989.
### Summary of Chi Square Tests

#### Level of Education

<table>
<thead>
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</thead>
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<td>exp</td>
<td>obs</td>
<td>exp</td>
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<td>Secondary</td>
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<td>17</td>
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<td>Technical School</td>
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<td>4.5</td>
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<td>College</td>
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<td>11</td>
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<td>29</td>
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<td><strong>TOTALS</strong></td>
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<td>60</td>
<td>60</td>
<td>60</td>
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</tbody>
</table>

\[X^2_{OBS} = 5.16\]

\[X^2_{CRIT} = 9.49\] (0.05)

\[X^2_{OBS} \lesssim X^2_{CRIT}\] Therefore no significant difference exists.

#### Where is Water Quality Better

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<th>((0-E)^2 / E)</th>
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\[X^2_{OBS} = 19.80\]

\[X^2_{CRIT} = 13.28\] (0.01)

\[X^2_{OBS} \gtrsim X^2_{CRIT}\] Therefore a significant difference exists.

#### Is Water a Health Hazard

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\[X^2_{OBS} = 7.76\]

\[X^2_{CRIT} = 5.99\] (0.05)

\[X^2_{OBS} \gtrsim X^2_{CRIT}\] Therefore a significant difference exists.
FIGURE 20

POLLUTION OF BEACH AREAS

FREQUENCY [%]

YES

98
86

NO

2
14

Public Response
Private Response

FIGURE 21
RESPONSE TO POLLUTION CAUSE

PUBLIC

- Bather Load: 17%
- Dredging: 28%
- Boating Activities: 40%
- Inadequate Sewage Disposal: 73%
- Debris: 60%
- Surface Runoff: 58%
- Lack of Control: 58%
- Acid Rain: 50%

PRIVATE

- Bather Load: 3%
- Dredging: 20%
- Acid Rain: 25%
- Boating Activities: 42%
- Inadequate Sewage Disposal: 45%
- Debris: 60%
- Surface Runoff: 52%
- Lack of Control: 48%

FIGURE 22
WHERE IS WATER QUALITY BETTER?

PUBLIC RESPONSE
PRIVATE RESPONSE

FREQUENCY [%]

YES
18
55

NO
13
2

DON'T KNOW
68
43

FIGURE 23

BEACH WATER AS A HEALTH HAZARD

PUBLIC RESPONSE

PRIVATE RESPONSE

DON'T KNOW

NO

YES

FREQUENCY [%]

PRIVATE BEACH PROPERTY VALUES

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PROPERTY VALUE

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<td>Over $80,000</td>
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FIGURE 26
EDUCATION OF RESPONDENTS

PUBLIC
- University 49%
- Secondary 28%
- Technical School 8%
- College 15%

PRIVATE
- University 33%
- Secondary 28%
- College 22%
- Technical School 9%
- Elementary 8%

A COMPARISON BETWEEN 5 ONTARIO WATERSHEDS

The issue of recreational water quality is drawing increasing attention from different levels of government, the media, various environmental organizations, and particularly the thousands of people who utilize these resources (Tate, 1984). Of particular concern are the many health implications which are associated with water quality, but aesthetic reasons and overall recreational potential are also important considerations (Sherry, 1986) and (Ochs and Thorn, 1984).

Water quality is an important issue in virtually all areas in Ontario where there are nearby water resources. For this reason, a comparison of water quality is being made between 5 Southwestern Ontario watersheds to determine whether there is geographical variability within the region. Southwestern Ontario, because of its long summer season, abundance of water resources, and large population base, is a key target area in terms of recreational water quality.

The 5 watersheds include the Detroit River at Windsor, Lake St. Clair at Stoney Point, Lake Erie at Wheatley Provincial Park, Grand Bend Beach on Lake Huron, and the Upper Thames River Conservation Authority watershed near Stratford, Ontario (Fig. A). The 5 areas differ in terms of surrounding land use. Windsor has medium to heavy urban development, Stoney Point and Grand Bend are associated with light urban development. Wheatley Provincial Park is surrounded by parkland and woodlot, and the
Upper Thames River study area is on predominantly agricultural land. All these different land uses could help account for any differences in the readings of the water quality parameters examined.

According to Hayman and Merkley (1985), agricultural activities were significant contributors to beach closings and water quality problems in the Upper Thames River watershed. Primarily, these sources were from overland runoff of sediment and associated nutrients, contaminated sub-surface drainage, uncontained manure and feedlot runoff, and livestock access to open water. These problems have prompted regular monitoring by the local Conservation Authority and the Ministry of the Environment. Although not as much as in the Upper Thames area, Grand Bend Beach on Lake Huron is also affected by contaminated agricultural runoff along with other fecal bacteria contributions (M.O.E., 1985). Bacterial contamination of the water at Grand Bend is that area's primary concern since beach closures over the years have proven economically as well as environmentally damaging. Windsor, Stoney Point, and Wheatley share a similar concern for high bacterial numbers since such instances greatly inhibit safe human contact with the water. However, a major factor in these areas is pollution from industrial sources which further complicates the situation.

Data were obtained for the 5 study sites within the region depicted in Figure A. This data ranged from 1985 to 1988 and the author only addressed data in June, July, and August. This was
because the summer months are when these watersheds are used most intensively. The mean values for total suspended solids, pH, fecal coliforms, _P. aeruginosa_, turbidity, and temperature were tabulated for each of the 5 watersheds to obtain a general idea of water quality (Table A).

After examination of the data, Windsor was found to have the highest mean total solids (277mg/L), mean temperature (21.75°C), and mean turbidity (61.05 NTUs). The Upper Thames River watershed area had the highest mean fecal coliform concentration (240/100ml) and mean pH (8.06), and Wheatley had the highest _P. aeruginosa_ concentration (1181/100ml). In terms of overall water quality assessment, there does not seem to be any clear cut geographical area that is cleaner or more degraded than another. Perhaps the faster moving Detroit River could account for the relatively turbid conditions at the Windsor sampling site. Similarly, the highly concentrated nutrient feces runoff in the Upper Thames River area may explain why it showed the highest pH and fecal coliform values. Windsor, being the most southerly of the 5 sample areas has the warmest water temperature. There is a noticeable trend in the distribution of fecal coliforms over the study region. Values seem to be highest in the upper portion of the study region and decrease steadily as you move southwest to the lower end of the region. Virtually the opposite situation seems to hold true for turbidity, with highest values located in the southern section and a decrease as you move towards the northern section of the region. A similar but not so well
defined pattern holds for total solids. Water temperatures distinctly rise the further you move south within the region.

The resultant patterns seem to indicate a variability in the level of water quality across the region. Certain parameters are higher at one end of the region while others are higher at the other end. This tends to indicate that point source pollution is a primary component of local water quality conditions, particularly based on runoff from surrounding land uses. Agricultural runoff appears to be a major contributor to degraded water quality conditions in the form of high bacteria loads.
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<th>Grand Bend</th>
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<td>Total Solids (mg/L)</td>
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<td>192.75</td>
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<td>Fecal Coliforms (#/100ml)</td>
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<td>82.0</td>
<td>1.33</td>
<td>240.43</td>
<td>194.71</td>
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<td>P. aeruginosa (#/100ml)</td>
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<td>1181.0</td>
<td>NA</td>
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<td>20.72</td>
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</table>

SOURCE: Author
FIGURE B
COMPARISON OF FECAL COLIFORMS

OVERALL MEAN = 112.63/100ml

SOURCE: Author
COMPARISON OF MEAN TURBIDITY

OVERALL MEAN = 27.77 NTU's

SOURCE: Author
FIGURE D
COMPARISON OF TOTAL SOLIDS

TOTAL SOLIDS (mg/L)

Windsor: 277
Stoney Point: 193
Wheatley: 228
Grand Bend: N.A.
Upper Thames: 19

OVERALL MEAN = 179 mg/L

SOURCE: Author
CONCLUDING COMMENTS

Many different conclusions can be drawn from the data collected throughout this study. In terms of overall difference between public beaches and private beaches, there appears to in fact be a considerable difference. As described earlier, statistically significant differences in turbidity and fecal coliform concentrations were found to exist between the two beach types. Turbidity was higher at the public beaches while fecal coliforms were higher at the private beaches. Although no such significant differences were found with regard to the other parameters tested, the private beaches had the higher readings for all of the remaining parameters. This supports the inference that water quality was poorer at the private beaches over the course of the study. Further supporting this conclusion is that when the worst public beach (Holiday Beach) was compared with the best private beach (Seacliffes), Seacliffes still had higher readings for fecal coliforms and total suspended solids. Similarly, when the worst private beach (Colchester) was compared with the best public beach (Point Pelee), Colchester had higher readings for all of the tested parameters except pH.

An unusual finding of the Pearson Correlation Analysis for both beaches was that there was no relationship between wind speed and total suspended solids, yet a significant relationship was found between wind speed and turbidity. There appears to be no tangible reason behind this except for the fact that possibly
there was a greater proportion of fine-grained solids (lighter in weight) to large-grained solids within the region. Another conflicting discovery was that total solids were correlated with fecal coliforms at private beaches but not at public beaches. The opposite pattern existed for \textit{P. aeruginosa}. This finding disagrees partially with the well known understanding that high bacterial counts are associated with water that is clouded with suspended sediment. Similarly, no relationships were found to exist between turbidity and either of the two bacterial pathogens tested, for either the public or private beaches. There is simply no explanation for why this is so.

The results of the questionnaire survey revealed that the two user groups differ in their opinion of the area's water quality. Despite the results of the water sampling, 55 percent of the private beach users interviewed said they thought water quality was better at private beaches. This differed significantly from the public users polled; the majority of which not knowing where water quality was better. Along the same notion, private users concluded in general that the water in the area posed no health threat, while public users felt it did. Interestingly, both groups concluded that the government is not doing an adequate job of maintaining water quality standards. The main finding which contradicts the results of the water sampling was the question regarding cause of pollution. Private users cited only 2.95 causes/person while public users pinpointed 3.88 causes/person. Of the causes listed, 73 percent of the
public users stated that inadequate sewage disposal was a cause of water pollution in the area while only 45 percent of private users said so. This indicates that perhaps public users think septic tank runoff is a problem but the private users (who use the septic tanks) don't think so. It might be noted here that Colchester had the highest fecal coliform concentrations of any of the beaches and the investigator identified a drainage/runoff ditch entering this beach from the surrounding residential development. This would lead to the inference that inadequate sewage disposal is a significant contributor to the reduced water quality conditions in this area.

The overall results of this extensive, bi-faceted, comparative water quality study of the northwestern Lake Erie shoreline, indicates that the private beaches have poorer water quality conditions than the public beaches, based on the parameters tested. This would tend to indicate that there is not enough control or regulation of the maintenance of these areas of the shoreline. One recommendation which should be implemented immediately is to monitor and test these areas regularly. This would help uncover any problems and could very well lead to the source of the problem(s). Not only do the water samples reveal a situation of reduced water quality but the general perception of those who use these vital areas is that there is a pollution problem.

Speaking for the entire study area, closer attention and better resource management must be initiated in order to maintain
this area as one of Canada's most valuable aquatic resource areas. In spite of the whole area being an open system, point sources of pollution, as detected through the findings of this study, represent a cause of degraded water quality. According to the data, these sources are having a greater impact on the private beaches.
REFERENCES


APPENDIX A
### Holiday Beach Conservation Area

#### Table 10

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<th>Month</th>
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<th>P. Collisions</th>
<th>pH</th>
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**Note:**
- **Water Temp:** Temperature of the water in degrees Celsius.
- **P. Collisions:** Number of power collisions in the area.
- **pH:** The pH level of the water.
- **P. Aerogenesis:** The presence of power aerogenesis.
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**Source:** Horrobin Fieldwork, 1988.
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**Source:** Horrobin Beachwork, 1988.
<table>
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**Source:** Horrobin, Pleidowork, 1988.

**Table 14**

**Point Pelee National Park**

**Water Temp.**
<table>
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<tr>
<th>Month</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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<th>September</th>
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APPENDIX B
1) Are you a public beach user or a private beach user/owner?
   - circle public
   - circle private

2) What recreational activities do you use the shoreline/beach area for?
   - circle swimming
   - circle fishing
   - circle boating
   - circle picnic
   - circle bird watching/nature study
   - circle relaxation

3) Do you feel the beaches of northwestern Lake Erie are polluted in any way?
   - circle yes
   - circle no
   - - don't know

4) What do you feel is the cause of pollution?
   - circle acid rain
   - circle inadequate sewage disposal
   - circle boating activities
   - circle high bather load
   - circle debris and discharge
   - circle inadequate control
   - circle runoff into the lake from regulation
   - circle surrounding land uses
   - circle effects of shoreline protection
   - circle other
   - circle structures and dredging

5) Do you feel the water at the beach presents a health hazzard?
   - circle yes
   - circle no
   - - don't know

6) Do you feel the government is doing an adequate job of maintaining suitable levels of water quality at local beaches?
   - circle yes
   - circle no
   - - don't know

7) At what type of beach do you feel water quality is better?
   - circle public
   - circle private
   - - don't know
8) On a scale from 0 - 10, how would you rank the water quality of the beaches in this area?

\[ \text{circle} \quad 0 \ 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10 \quad \text{very polluted, very clean} \]

Demographic Questions

1) Sex of respondent?

\[ \text{circle} \quad \text{male} \quad \text{female} \]

2) Which age category do you represent?

\[ \text{check} \quad \text{under 20 years} \quad \text{46-65} \quad \text{20-30} \quad \text{over 65} \quad \text{31-46} \]

3) To what extent is your educational background?

\[ \text{check} \quad \text{elementary school} \quad \text{secondary school} \quad \text{college} \quad \text{university} \quad \text{technical school} \]

4) What is the approximate value of your property? (private only)

\[ \text{check} \quad \text{under } $20,000 \quad \text{ } \quad \text{$20,000 - $35,000} \quad \text{ } \quad \text{$36,000 - $80,000} \quad \text{ } \quad \text{over } $80,000 \]
Private Beach Users/Owners Only

1) What type of sewage disposal do you have?
   circle septic tank other (specify) 

2) Is there a drainage ditch located on or near your property?
   circle yes no

3) What is your drinking water supply?
   circle Lake Erie nearby town well bottled

4) What type of dwelling is this?
   circle a house cottage

Public Beach Users Only

1) How many years have you been visiting beaches in this area?
   ____ years

2) How many times do you go to the beach each year?
   ____ times

3) Do you think public beaches are used extensively?
   circle yes no don't know
APPENDIX C
LOAD PEARSON CORRELATION

PEARSON CORRELATION

1
LIST

10 FEM - PEARSON PRODUCT MOMENT CORRELATION

20 PRINT: "-----------------------------"

30 PRINT " PEARSON CORRELATION"

40 PRINT "-----------------------------"

50 PRINT

60 INPUT "NUMBER OF VALUES OF EACH VARIABLE": NX

70 N = NX + NX

80 DIM X(N)

90 PRINT

100 PRINT " NOW TYPE IN VALUES OF X: "

110 PRINT " (MISTAKES CAN BE FIXED LATER)"

120 FOR I = 1 TO NX

130 PRINT I:" ":

140 INPUT X(I)

150 NEXT I

160 PRINT

170 PRINT " NOW TYPE IN VALUES OF Y: "

180 PRINT " (MISTAKES CAN BE FIXED LATER)"

190 FOR I = NX + 1 TO N

200 PRINT I:" ":

210 INPUT Y(I)

220 NEXT I

230 N1 = 1

240 N2 = NX

250 VS = "X"

260 GOSUB 560

270 N1 = NX + 1

280 N2 = N

290 VS = "Y"

300 GOSUB 560

310 FOR I = 1 TO NX

320 XM = XM + X(I)

330 YM = YM + X(I) * Y(I)

340 SX = SX + X(I) * 2

350 SY = SY + X(I) * Y(I) * 2

360 XY = XY + X(I) * X(I) * Y(I) * Y(I)

370 NEXT I

380 XM = XM / NX

390 YM = YM / NX

400 SX = SQRT(SX / NX - XM * 2)

410 SY = SQRT(SY / NX - YM * 2)

420 R = (XY / NX - XM * YM) / (SX * SY)

430 PRINT

440 PRINT "-----------------------------"

450 PRINT " PRODUCT-MOMENT CORR"
LATION "

460 PRINT "-----------------------------

470 PRINT
480 PRINT "MEAN OF X = ":XM
490 PRINT "STANDARD DEVIATION OF 
  X = ":EX
500 PRINT "MEAN OF Y = ":YM
510 PRINT "STANDARD DEVIATION OF 
  Y = ":SY
520 PRINT "r = " :R
530 DF = NX - 2
540 PRINT "WITH ":DF:" DEGREES OF
  FREEDOM"
550 END
560 REM - DATA CHECKING ROUTINE

570 PRINT
580 PRINT "DO YOU WISH TO CHECK/ 
  CORRECT ":V$;
590 INPUT "VALUE (Y/N) ":G$
600 IF G$ = "N" GOTO 710
610 IF G$ = "Y" GOTO 580
620 K = 0
630 PRINT "PRESS RETURN IF VALUE 
  IS CORRECT";
640 PRINT ": OTHERWISE TYPE COR 
 RECT VALUE"
650 FOR I = NI TO N2
660 K = K + 1
670 PRINT K: " :X(I) :
680 INPUT A$
690 IF A$ = "" :X(I) = VAL (A$)
700 NEXT I
710 RETURN

PEARSON CORRELATION  

P. aeruginosa vs. Fecal Coliforms  
- Public Beaches -

NUMBER OF VALUES OF EACH VARIABLE NOW TYPE IN VALUES OF X:  
(MISTAKES CAN BE FIXED LATER)  
1 72 74 75 76 77 78 79 81 72 73 74 75 76 77 78 79 7
MEAN OF X = 74.8888889
STANDARD DEVIATION OF X = 51.8244159
MEAN OF Y = 908.2222222
STANDARD DEVIATION OF Y = 733.2123909
r = .7112345699
WITH 7 DEGREES OF FREEDOM

SAMPLE PEARSON

PEARSON CORRELATION  

Wind Speed vs. Turbidity  
- Private Beaches -

NUMBER OF VALUES OF EACH VARIABLE NOW TYPE IN VALUES OF X:  
(MISTAKES CAN BE FIXED LATER)  
1 72 74 75 76 77 78 81 72 73 74 75 76 77 78 79 7
MEAN OF X = 17.7
STANDARD DEVIATION OF X = 8.76341978
MEAN OF Y = 21
STANDARD DEVIATION OF Y = 10.488088
r = .58123046
WITH 7 DEGREES OF FREEDOM
LIST

10 REM - CHI SQUARE TEST
20 PRINT "---------------------"
30 PRINT "CHI SQUARE TEST"
40 PRINT "---------------------"
50 PRINT
60 INPUT "NUMBER OF SAMPLES ":S
70 PRINT
80 INPUT "NUMBER OF CATEGORIES IN EACH SAMPLE ":NS
90 DIM X(S,NS), CT(NS), RT(S)
100 FOR I = 1 TO S
110 PRINT "NOW TYPE IN VALUES FOR SAMPLE ":I:";
120 K = 1
130 FOR J = 1 TO NS
140 PRINT "CATEGORY ":J":";
150 INPUT X(I,J)
160 NEXT J
170 RT(I) = 0
180 NEXT I
190 FOR I = 1 TO S
200 NI = 1
210 NC = NS
220 CT(I) = 0
230 NEXT J
240 PRINT "---------------------"
250 PRINT "CHI SQUARE TEST"
260 PRINT "---------------------"
270 PRINT
280 IF S = 1 OR NS = 2 GOTO 450
290 AD = X(1,1) * X(2,2)
300 BC = X(1,2) * X(2,1)
310 AB = X(1,1) * X(2,1)
320 CD = X(2,1) * X(2,2)
330 AC = X(1,1) * X(2,2)
340 N = AB - CD
350 CH = N * (ABS(AD - BC) - N / 2) / 2
360 CH = CH / (AB * CD * AC * BD)
370 PRINT "CHI SQUARE = ":CH
380 PRINT "WITH 1 DEGREE OF FREE DOM"
390 END
400 GT = 0
410 FOR I = 1 TO S
420 FOR J = 1 TO NS
430 RT(I) = RT(I) + X(I,J)
440 CT(J) = CT(J) + X(I,J)
450 GT = GT + X(I,J)
460 NEXT J
470 NEXT I
480 PRINT "EXPECTED VALUES"
490 NE = 0
500 NN = 0
510 FOR I = 1 TO S
520 PRINT "\.....\....."
580 PRINT "SAMPLE ":I:""
590 FOR J = 1 TO NS
600 E = CT(J) * PRT(I) / GT
610 CH = CH + (X(I,J) - E) ^ 2 / E
620 PRINT "CATEGORY ":I:""
630 IF E < 5 THEN NE = NE + 1
640 IF E > 1 THEN NN = NN + 1
650 NEXT J
660 NEXT I
670 E = NE * 100 / (NS * S)
680 PRINT
690 PRINT "% OF EXPECTED VALUES ":E
700 E = NN * 100 / (NS * S)
710 PRINT "% OF EXPECTED VALUES ":E
720 DF = (E - 1) * (NS - 1)
730 PRINT
740 PRINT "CHI SQUARE = ":CH
750 PRINT "WITH ":DF:" DEGREES OF FREEDOM"
760 END

### CHI SQUARE TEST

SAMPLE 1:

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<th>Expected Value</th>
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SAMPLE 2:

<table>
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% OF EXPECTED VALUES: 5 = 0
% OF EXPECTED VALUES: 6 = 0

CHI SQUARE = 17.443248
WITH 5 DEGREES OF FREEDOM
1965 - Born in Windsor, Ontario, Canada.

1978 - Graduated from Southwood Elementary Public School.


1987 - Obtained Honours Bachelor of Arts degree in Geography from the University of Windsor.

1989 - Obtained Master of Arts degree in Geography from the University of Windsor.