

KETTLE CREEK / LAKE ERIE TASK FORCE

WATER QUALITY SUMMARY REPORT

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EXECUTIVE SUMMARY

This water quality study was initiated by the Kettle Creek / Lake Erie Task Force. The study was established to meet one major goal - to investigate possible bacterial contributors from Kettle Creek to the Port Stanley beaches.

Storm Events were monitored during the summer of 1995 for bacterial contributors. The Kettle Creek / Lake Erie Task Force approved three bacterial indicators for the water quality study, *Escherichia Coliform (E. coli)*, *Faecal Streptococci*, and *Pseudomonas Aeruginosa*. *E. coli* is the primary bacterial indicator used by the Ministry of Health to monitor public beaches because it is most directly related to faecal pollution. *Pseudomonas aeruginosa* organisms are primarily related to human sewage. The water quality results showed elevated bacterial loadings to Kettle Creek during storm events. The loadings indicated various possible contributors to Kettle Creek including, harbour dredging, waste from boats, seagulls, livestock farms, faulty septic systems, and the City of St. Thomas.

The study revealed that further beach water quality investigations are needed in order to determine if there is a correlation between Kettle Creek water quality and Port Stanley beach postings. In August, the Main beach at Port Stanley was posted for the majority of the month. However, during the summer very limited rainfall occurred to produced elevated bacterial levels in Kettle Creek. Base flow water sampling showed lower *E. coli* counts within the harbour while the Ministry of Health samples showed higher *E. coli* counts at Main beach. This indicates that other unknown bacterial inputs may be affecting beach postings at Port Stanley beaches.

The lack of correlation is further demonstrated by the actual beach postings that occurred in 1995. The Main, Little, and Erie Rest beaches were posted for 30, 7, and 20 days, respectively. The latoral drift at Port Stanley is from East to West. However, Little beach which is located West of the harbour was posted the least. Again, this indicates that other factors may be coming into play.

1.0 INTRODUCTION

In January, 1995, the Kettle Creek / Lake Erie Task Force was created as a result of public concern about the 1994 beach postings. There was confusion and public misunderstanding of the overall water quality issue. In public opinion the cause of past beach postings varies from farmers, to the St. Thomas Sewage Treatment Plant, to lake storms and Health Unit postings. The Kettle Creek / Lake Erie Task Force was established to:

- co-operatively investigate, discuss and promote remedial measures to improve recreational water quality in Kettle Creek and in Lake Erie adjacent to Village beaches;
- explore avenues to educate the public about Health Unit swimming warnings; and
- inform the M.P. and M.P.P about the task force's findings

In response the Kettle Creek / Lake Erie Task Force has initiated a water quality study of Kettle Creek. The study entails sampling storm events and base flows only on Kettle Creek, not at beaches. The Health Unit performed weekly sampling at beaches according to Ministry of Health protocol.

1.1 THE GOAL

The goal of the Kettle Creek / Lake Erie Task Force water quality study is to investigate possible bacterial contributors from Kettle Creek to the Port Stanley beaches.

1.2 THE OBJECTIVES

The objectives of the Kettle Creek / Lake Erie Task Force water quality study are:

- 1) To report the results from the approved water sampling investigations.
- 2) To identify major bacterial contributors from Kettle Creek to Port Stanley beaches.
- 3) To recommend remedial measures to improve recreational water quality in Kettle Creek and at Port Stanley beaches.

1.3 KEY MESSAGES

The key messages that the Kettle Creek / Lake Erie Task Force wishes to accomplish are as follows (Sanders, 1995):

- Water quality is **EVERYONE'S** responsibility
- ▶ People need to be able to make an informed decision about water quality and swimming
- ▶ The study is based on a snapshot in time - results will be relative to the rainfall events and samples taken over the summer of 1995. Therefore, the study will provide useful information relative to the specific case for 1995.
- ▶ The Task Force is a co-operative effort of the Village of Port Stanley, City of St. Thomas, Elgin St. Thomas Health Unit, the Ministry of Environment and Energy and the Kettle Creek Conservation Authority and each agency can use the study to work toward mutual goals.
- ▶ The study will summarize the possible bacterial sources entering Kettle Creek.
- ▶ The Health Unit will be using a three-sign system to inform the general public about water quality at Elgin County beaches to ensure that water is safe for summer activities.

1.4 ROLES AND RESPONSIBILITIES

The roles and responsibilities of the agencies involved in the production of this water quality study include:

- 1) **KCCA** - Developed a water sampling strategy.
 - Collected water samples on Kettle Creek during storm events and base flows.
 - Compiled water quality results.
 - Prepared a written water quality summary of results.
- 2) **MOEE** - Provided technical support and advice.
 - Provided lab analysis for the three bacterial parameters.
- 3) **Health Unit** - Provided 1995 beach sampling information.

2.0 STUDY AREA

The Kettle Creek watershed drains directly into Lake Erie at Port Stanley. The land base is approximately 520 square kilometres in size (figure 2.1). The primary land use in the watershed is agriculture, with mixed farming predominate in the northern half of the watershed. The City of St. Thomas is the major urban centre within the watershed followed by two smaller villages, Belmont and Port Stanley.

The City of St. Thomas operates a sewage treatment plant with a capacity of 27.3 million litres per day of flow and the plant currently treats a yearly average of 15.2 million litres per day while servicing a population of about 30,000 (City of St. Thomas, 1995). The village of Belmont and Port Stanley both treat sewage by a lagoon system. The lagoons are generally released in the spring and fall of each year.

The majority of summer base flows in the Kettle Creek watershed are from the main tributaries of Kettle and Dodd's Creek. Inputs from Dalewood Reservoir, the Ford Talbotville Plant and the St. Thomas Sewage Treatment Plant contribute significantly to base flows especially in dry weather conditions (Mohring, 1995).

3.0 WATER QUALITY METHODOLOGY

3.1 BACTERIAL INDICATORS

The Kettle Creek / Lake Erie Task Force approved three bacterial indicators for the water quality study. The indicators include:

1) ***Escherichia Coliform (E. Coli)***

E. coli is the primary indicator organisms in water bacteriology and is used by the Ministry of Health to monitor public beaches. The guidelines for *E. coli* is less than 100 organisms per 100 ml of water to be safe for swimming *E. coli* is the predominant bacterial species found in the large intestine and is most directly related to faecal pollution. Once released into the environment, this bacteria can only grow in faeces (Depuydt, 1993). Studies have shown that among bacteria of the coliform, *E. coli* is the most suitable and specific indicator of faecal contamination (Huber, personal communication., 1995).

2) ***Faecal Streptococcus***

Faecal *Streptococci* are found in the alimentary tract of warm-blooded animals They are indicative of sanitary waste intrusion and/or faecal contamination (Depuydt, 1993). Faecal *Streptococci* are less abundant in human faeces and thus a less sensitive indicator.

3) ***Pseudomonas Aeruginosa***

These organisms are primarily found in human sewage. According to MOEE guidelines *Pseudomonas aeruginosa* organisms should be no more than 4 per 100 ml for safe bathing. If found in higher concentrations, swimmers may be exposed to ear, eye, and skin infections.

3.2 WATER SAMPLING PROCEDURE

Water Sampling took place during and after rainfall events when impacts are most prevalent. Three bacterial samples were taken at each station at 3 hour intervals. Sampling commenced approximately 6 hours after the storm event began (depending on whether 10mm of rain had fallen). Three types of rainfall events were identified by the Task Force for the water sampling protocol, these included:

- 1) A Light Storm Event - 10 mm to 19 mm
- 2) A Medium Storm Event - 20mm to 34 mm
- 3) A Heavy Storm Event - over 35 mm

Ideally, 6 events (two of each type) would have best fit the study. However, only 4 storm events were possible for sampling due to the dry summer conditions and the MOEE lab being closed on weekends.

When each water sample was taken, flows and water heights were measured, if possible. Flows were measured by dropping an apple into the main current of the stream and timed over a prearranged distance. At many of the sampling stations, water heights were taken by staff gauges or by measuring the distance down from bridges (if a bridge existed) to the water level. These measurements were then correlated to the hydrological surveying that was completed during the study. From this data, we were able to calculate bacterial loadings to Kettle Creek.

3.3 SAMPLING SEASON

The water sampling season started June 15th , 1995 and ended October 20th , 1995. Originally, the sampling season was to correspond with the swimming season at Port Stanley and with testing that is administered by the Elgin-St. Thomas Health Unit. However, due to the dry summer and very few storm events recorded, the sampling season was extended into the fall.

3.4 SAMPLING LOCATIONS

Nine sampling stations were chosen by the Task Force for the study. The locations were placed on the main tributaries throughout the Kettle Creek watershed, beginning above Dalewood Reservoir to Port Stanley Harbour. The sampling locations are described below and plotted on figure 3.1.

- 1) TF1 - Above Dalewood Reservoir at Highway #52
- 2) TF2 - Below Dalewood Reservoir, located just below the dam (approx. 100 meters)
- 3) TF3 - Dodd's Creek at Wellington Road before it reaches Kettle Creek
- 4) TF4 - Kaines Bridge, located upstream of the St. Thomas Sewage Treatment Plant
- 5) TF5 - Mouth of Mill Creek, above the Mill Creek's bypass outlet
- 6) TF6 - C and O Spur, located behind the Holy Angels Catholic Cemetery
- 7) TF7 - Kettle Creek at Highway #45 below St. Thomas
- 8) TF8 - Warren Street Bridge in Port Stanley
- 9) TF9 - Lift Bridge in Port Stanley

3.5 SAMPLING STATION SETUP

Hydrological surveying was completed at five of the nine sampling locations to obtain stream bottom cross-sections. At four of the locations, surveying was physically impossible or significant flows were unattainable. Also, staff gauges were setup or bridge measurements were taken in order to correlate storm event water heights to stream cross-sections. However, the above does not impact the results that were experienced in this exercise.

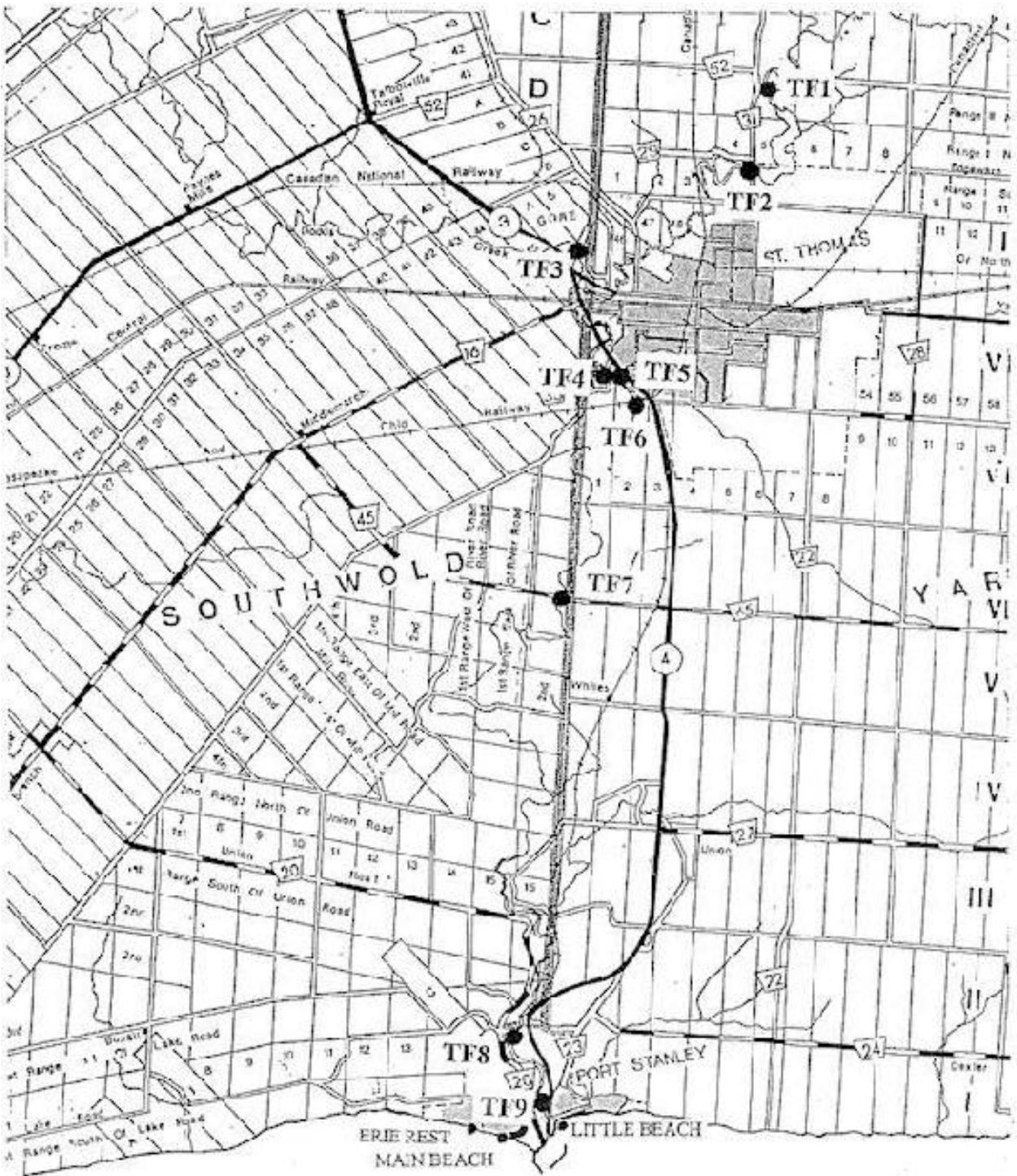


FIGURE 3.1: Sampling Locations

4.0 WATER SAMPLING RESULTS

The following results were collected during the summer of 1995. Base and storm event flows were sampled from June to October. Due to dry weather conditions, only 4 storm event sample runs were possible for collection. Even with these conditions, Port Stanley beaches were still posted - Main Beach, 30 days, Erie Rest, 20 days, and Little Beach, 7 days. Table 4.1 illustrates the daily precipitation received over the sampling season and the days beaches were posted (marked with *'s for the number of beaches closed). Also, table 4.1 shows the days base flow (light shade) and storm event (dark shade) sampling runs were completed.

4.1 BASE FLOW WATER QUALITY RESULTS

The flow that occurs between storms is called the base flow. There are two main contributions to base flow. The first is water held within the soil and released by excessively slow drainage through the small pores in the soil. The second contribution is from groundwater (Briggs, Smithson, & Ball, 1989).

Base flows in the Kettle Creek watershed are also influenced by artificial sources. These sources include constant discharge from various factories, schools, companies and household use throughout the watershed. Examples of these are Ford Production Plant, St. Thomas Sewage Treatment Plant, lawn watering, and the Freightliner Production Plant (Mohring, 1995).

Base flow samples were collected throughout the study for comparison purposes to storm events. Four water sampling runs were completed within the sampling season. A sample was taken at all nine sampling stations and was analyzed for the three bacterial indicators, *E. coli*, Faecal *Streptococcus*, and *Pseudomonas Aeruginosa*. Two base flow sampling runs were taken approximately a day after a small rain fall of 5mm to 6mm on the August 3rd and September 13th, 1995. The other two base flow sampling runs were taken on August 30th and October 3rd, 1995 and no rain had fallen for at least 10 days prior to sampling (see figures 4.1 & 4.2).

TABLE 4.1: 1995 Daily Precipitation Summary

DATE	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
	----- units - mm -----				
1			6		
2			1	15	
3					
4			22.5		14
5	3		*** 7		62
6			***		5
7		*4	***	5	
8	11	*	***	2	
9		*	***		
10		*	* **		
11		*	*** 1		
12			**	5	
13		8	** 8		
14			**		5
15			** 9.5		
16		1.5	**		
17			**	1.5	
18		1.5	**		
19			**		
20		3.5	**	8	
21		5.5	**	4	
22			**	2	
23			**		----
24		1.5	**		----
25	2		*		----
26	9	7	*		----
27	3.5		*		----
28			*		----
29	13				---
30	12				---
31	----			----	----
TOTAL	53.5	32.5	55	42.5	86

Appendix A shows the results from base flow sampling. Overall, Kettle Creek base flows support poor water quality. Samples taken when no rain was reported for at least 10 days indicated that the *E. coli* pollution is non-human related due to low *Pseudomonas* counts. At sampling station TF7, high *E. coli* counts are seen during most base flows, this is probably due to the livestock operation located directly above this station. Nonetheless, small amounts of rain can elevate both *E. coli* and *Pseudomonas* counts significantly below St. Thomas; thus, connecting inputs to human waste.

However, in two of the base flow sampling runs, high *Pseudomonas* counts were found at the Port Stanley Harbour, but acceptable counts were seen at the above station, Warren Street Bridge (see TF8 and TF9 9, figure 4.2). This, indicates that human bacterial inputs may be coming from within the harbour itself and not from upstream sources during base flows.

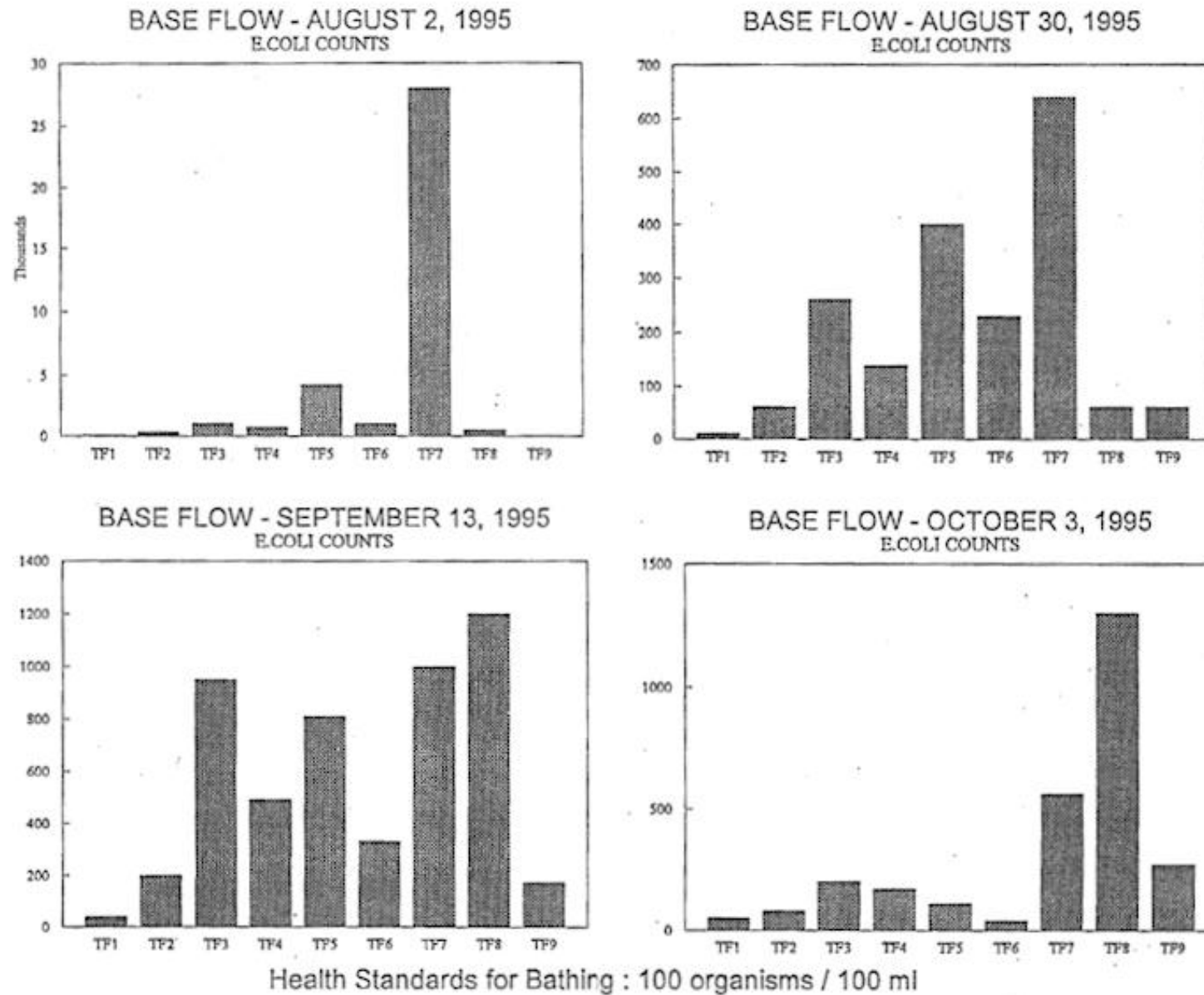


FIGURE 4.1: Base Flow Counts - *E. coli* / 100 mL

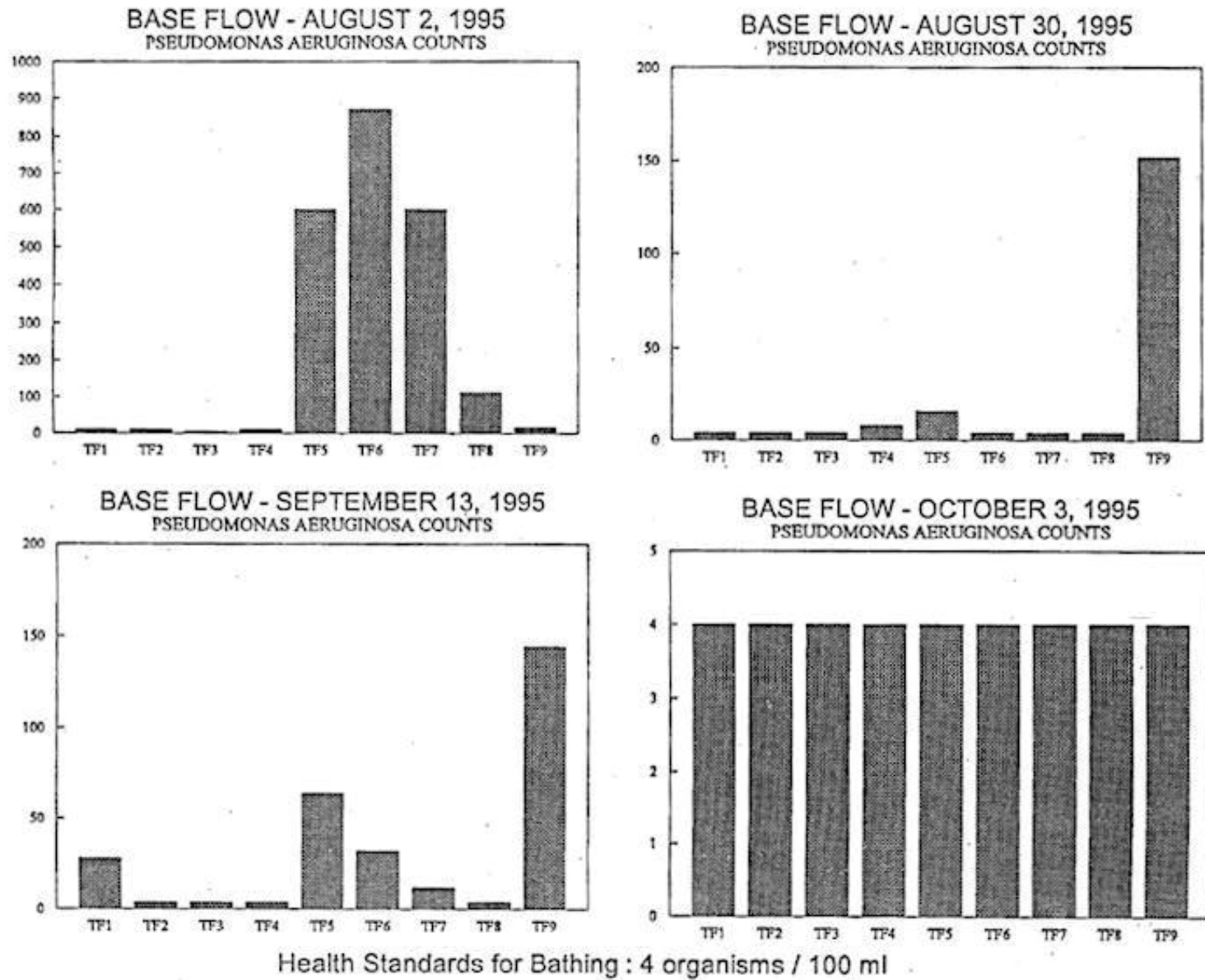


FIGURE 4.2: Base Flow Counts - *Pseudomonas* / 100ml

4.2 STORM EVENT WATER QUALITY RESULTS

Over the sampling season, four storm events were monitored. All of the storm events were characteristically different. Three events were classified as light (10mm to 19mm) and one event was classified as medium (20mm to 34mm) There were no events monitored within the heavy classification range. For each storm event, three samples at each location were analyzed for *E. coli*, Faecal streptococci and *Pseudomonas aeruginosa*.

Bacterial counts are measured in organisms per 100 ml of water and represent one sample in time. They do not accurately predict the amount of bacteria passing a certain point per second. Thus, for a more representative reading the bacterial loadings were calculated. Finding bacterial loadings to a stream involve calculating the hydrological cross section and multiplying it by the stream flow and the bacterial count.

The results of bacterial counts for all four storm events are shown numerically in appendix B. The *E. coli* and *Pseudomonas* counts are graphically illustrated in figures 4.3 and 4.5. The results of bacterial loadings are shown numerically in appendices C and D. The *E. coli* and *Pseudomonas* loadings are graphically illustrated in figures 4.4 and 4.6. The following describes the characteristic and results of each storm event in more detail.

Storm Event 1

Sampling for storm event 1 took place on June 29, 1995 and started approximately 10 hours after the beginning of the storm event. The late start was because the majority of rain occurred overnight. Storm event 1 was classified a light event with 13 mm of rain in total.

The *E. coli* and Faecal *streptococci* counts for storm event 1 were only analyzed by the lab up to counts of 1000 and 1500, respectively. The counts beyond this range were

not identified and thus, are not representative for this study. *E. coli* counts are shown on graph 1 in figure 4.3. The results of the *E. coli* counts do indicate that bacteria levels elevate throughout and after St. Thomas, however, decreasing downstream by round 3 of sampling.

Pseudomonas counts were analyzed within the a representative range that could be used in the calculation of loadings. The *Pseudomonas* loadings indicate an increase in human waste inputs throughout and after St. Thomas (figure 4.6). Flow measurements were unattainable in the Port Stanley area, therefore loadings could not be calculated. However, the *Pseudomonas* counts at Warren Street Bridge (TF8) and the Lift Bridge (TF9) show a drastic decline in *Pseudomonas* bacteria. It is possible that this is due to the fact that the storm event flows had not yet reached the Port Stanley area.

Storm Event 2

Storm Event 2 was the only medium event sampled within the study. Approximately, 23mm of rain fell during the night of August 3rd and early morning of August 4th, 1995. About 13 mm of rain had fallen when sampling began 6 hours after the start of the event. A downpour occurred about an hour before round 2 added an additional 10mm of rain to the total.

Both bacterial counts and loadings show an increase in bacteria levels on Mill Creek (TF5) and below St. Thomas (TF6), shown in figures 4.3 & 4.5. The bacteria levels are from human waste due to the extreme levels of *Pseudomonas* loadings.

It was determined during this storm event that the response time of St. Thomas to rainfall is very quick. The *E. coli* and *Pseudomonas* loadings (figure 4.4 & 4.6) shown in round 2 were taken 1 hour after the downpour producing drastically increased bacteria levels. This increase was quickly reversed by round 3, especially at TF5 and TF6.

Storm Event 3

This storm event started in the early morning of September 20th, 1995 and sampling commenced approximately 6 hours after the start of the event. When sampling began, only 8mm of rain had fallen, but more was expected. However, the rain terminated leaving a total of only 8mm for the event. Due to the limited number of storm events, this event was kept on record even though it did not meet the light storm event classification.

This event did show that even small amounts of precipitation can cause elevations in bacteria levels on Mill Creek (TF5) and below St. Thomas (TF6). *E. coli* and *Pseudomonas* loadings (figure 4.4 & 4.6) shows high levels in round 1, but these levels diminished quickly in rounds 2 and 3. Again, this illustrates the quick response rate to rainfall in St. Thomas, especially on Mill Creek.

Storm Event 4

Sampling began 8 to 9 hours after the 14mm storm event started on October 4th, 1995. This storm event is classified as a light event. The rainfall of this event tended to be a steady light rain without intermitted peaks, unlike the previous two events.

Due to the steady, light rainfall the bacterial responses within the stream reacted slightly different. The *E. coli* loadings were more uniform over the sampling locations (figure 4.4), with comparatively less inputs from Mill Creek (TF5). This reduction in loadings from Mill Creek could be attributed to the quick response of the creek.

Pseudomonas loadings were still most prevalent on Mill Creek (TF5) and below St. Thomas (TF6), but found at lower levels (figure 4.6) . Thus, indicating again that bacterial loadings coming from Mill Creek are most likely human in nature.

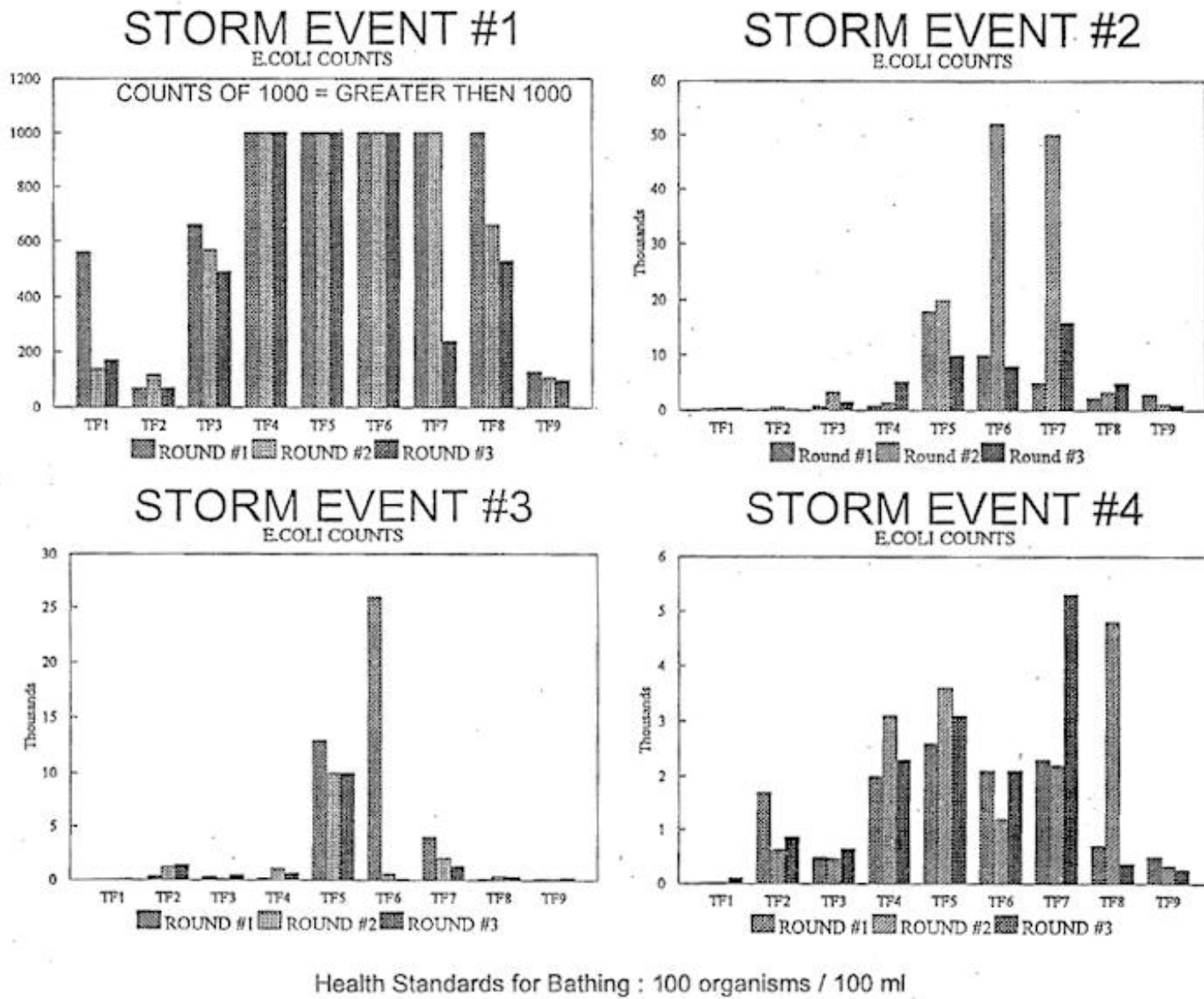


FIGURE 4.3: Storm Event Counts - *E. coli* / 100 ml

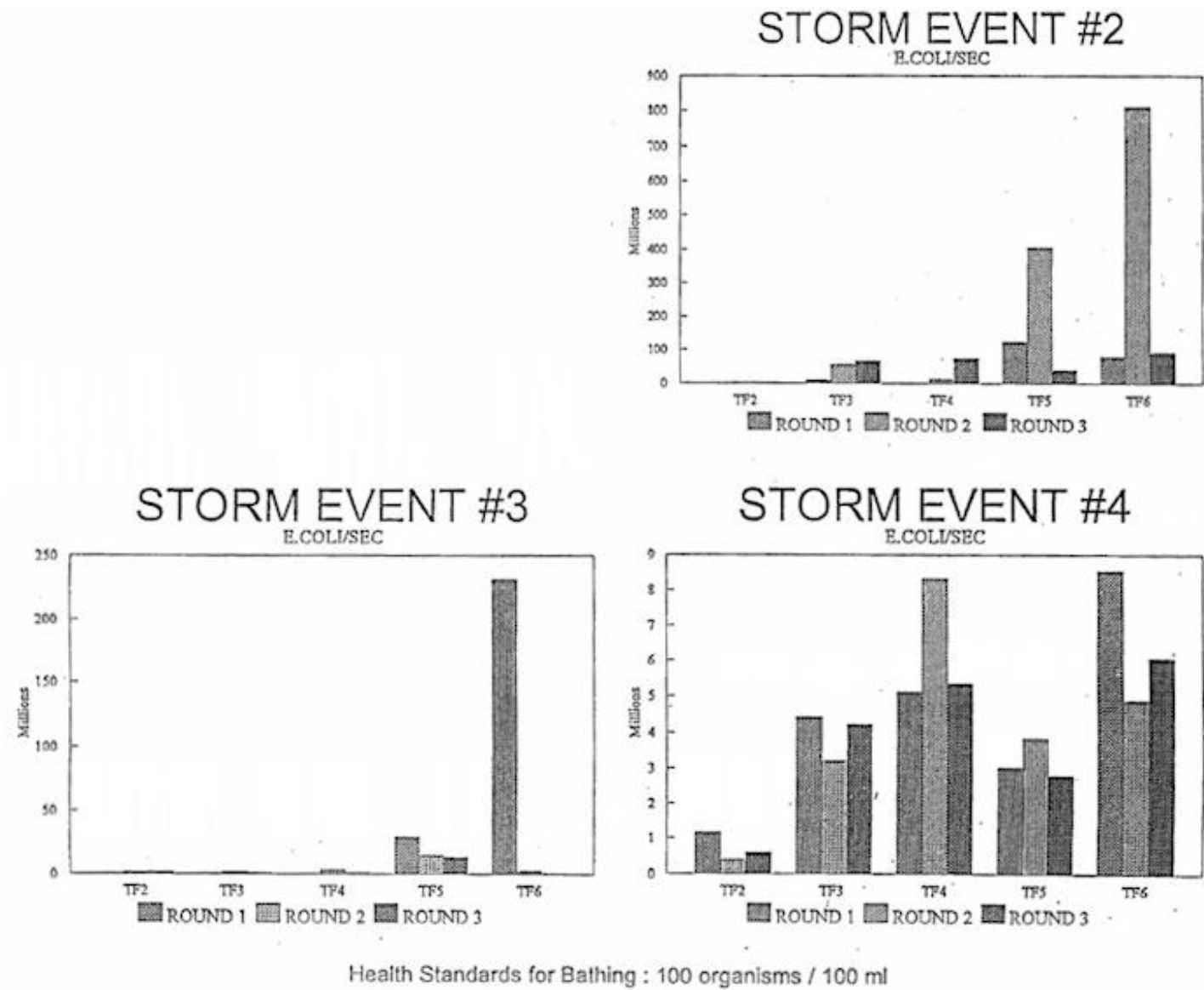


FIGURE 4.4: Storm Event Loadings - *E. coli* / SEC

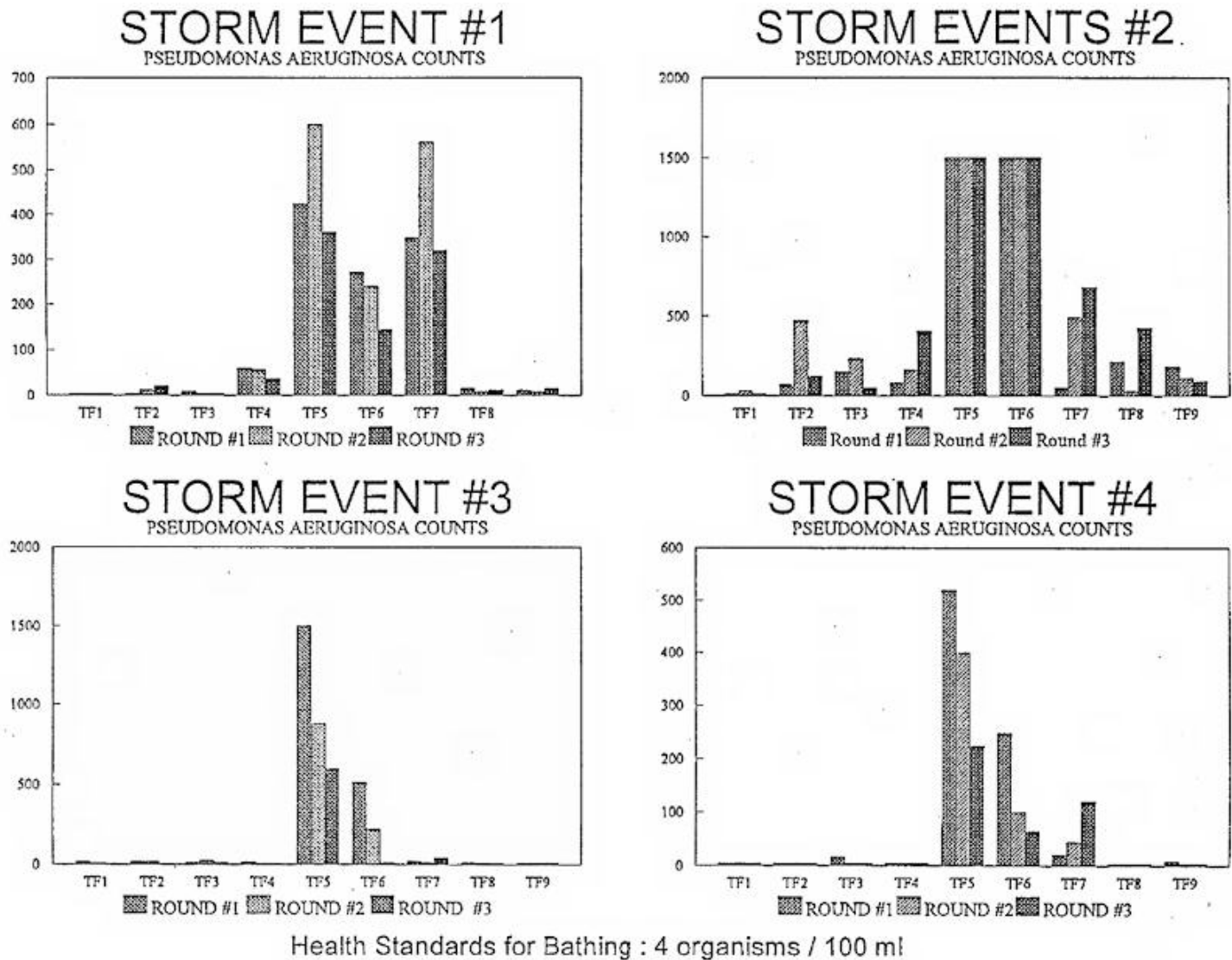
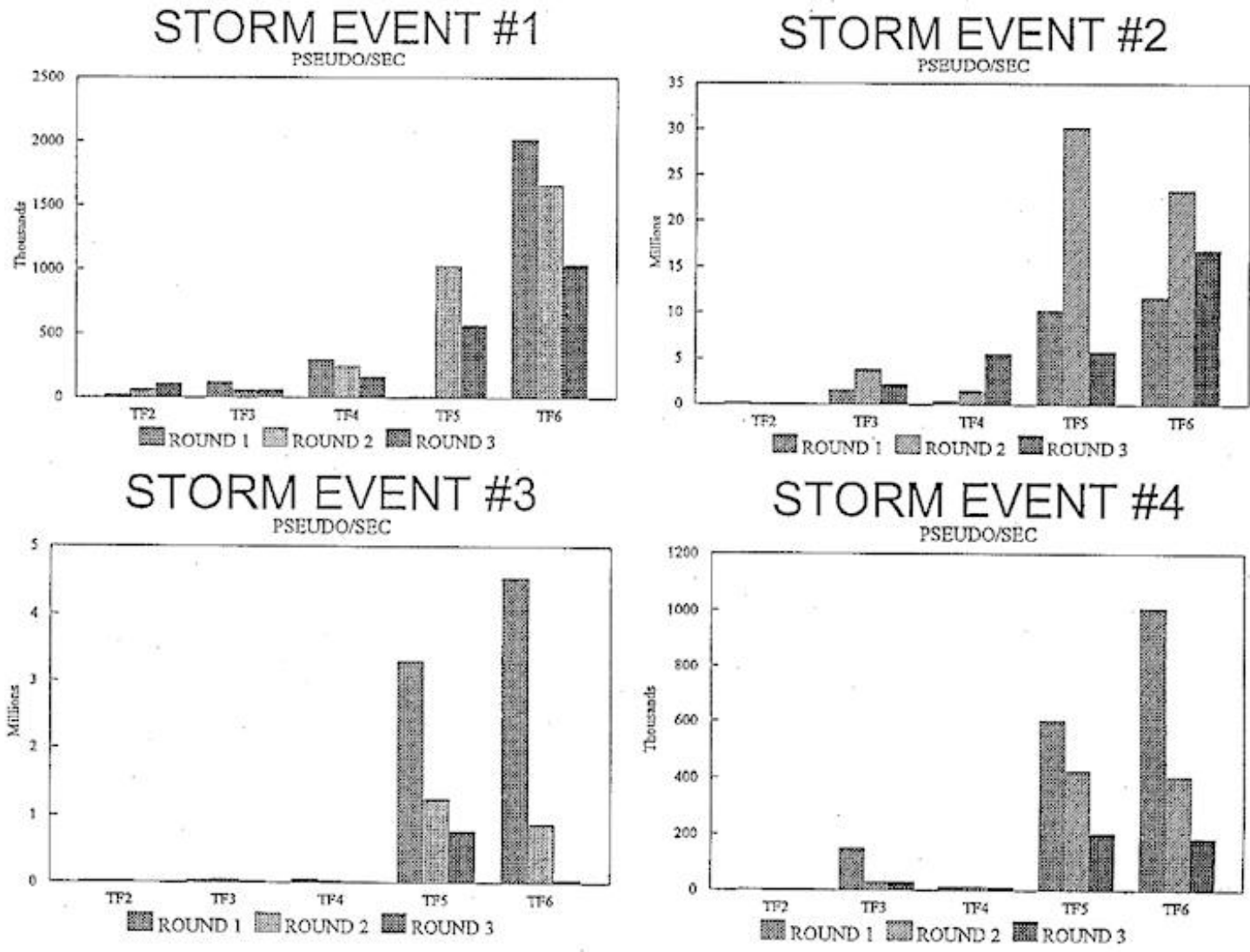


FIGURE 4.5: Storm Event Counts - *Pseudomonas* / 100 ml



Health Standard for Bathing : 4 organisms / 100 ml

FIGURE 4.6: Storm Event Loadings - *Pseudomonas* / SEC

5.0 CONCLUSIONS

- 1) This study is an indication of 1995 bacterial contributions to Kettle Creek.
- 2) Bacterial contamination is found throughout the Kettle Creek watershed, with a number of potential input sources contributing.
- 3) No average impact can be quantified for any bacterial input source due to a lack of storm events required for modelling.
- 4) There was no correlation between water quality in the Port Stanley harbour and the water quality at the beaches (see 4.1).
- 5) St. Thomas is a major bacterial contributor to Kettle Creek (see 4.4 and 4.6)
- 6) Port Stanley has human-related bacterial inputs getting into the inner and outer harbour (see 4.2).
- 7) There is an impact to Kettle Creek from rural inputs (see 4.1).
- 8) Other unknown inputs or influences are affecting beach postings.
- 9) Water testing for *Pseudomonas* at Port Stanley beaches in 1996 may identify if the bacterial sources are human-related.
- 10) Sediment samples taken at the beaches in 1996 would determine if beach sediments have high bacterial counts.
- 11) Summer beach postings may not be directly related just to bacterial loadings experienced during summer months. This means that off-season loadings and/or in-lake sources may be affecting the beach.

6.0 RECOMMENDATIONS

The recommendations for remedial measures and initiatives will be discussed and prepared by the Kettle Creek / Lake Erie Task Force upon receiving the 1995 water quality study. The following are recommendations for specific areas where remedial measures and initiatives could be implemented. This is just a guideline for facilitation.

- 1) To reduce high bacterial levels in Kettle Creek and Lake Erie by developing initiatives in the following target areas:
 - ▶ Boating
 - Marina operations
 - recreational boating practices
 - commercial fishing
 - in lake and in harbour affects
 - ▶ Dredging
 - outer harbour
 - inner harbour
 - disposal of sediments
 - ▶ Water Sampling
 - consolidation of sampling
 - water sampling criteria
 - protocol standardization
 - sediment sampling
 - ▶ St. Thomas Sewage Treatment
 - upgrading of the plant
 - combined sewer system separation
 - other bypasses
 - ▶ Rural Impacts
 - septic systems
 - livestock in streams

- manure management
 - milkhouse operations
 - ▶ Natural Inputs
 - gulls
 - waterfowl
 - at the beach and in the creek
 - ▶ Beach Activity Impacts
 - people
 - waves
 - watercrafts
- 2) Develop comprehensive information and education activities for:
- ▶ results of the water quality study
 - ▶ remedial actions for the identified above recommendations
 - ▶ beach water quality signage protocols
 - ▶ advertising Port Stanley beaches and other attractions
- 3) Further study could be undertaken to attempt to determine and analyze the unknown inputs and/or influences affecting beach postings, especially during base flows.
- ▶ sediment sampling along the beach and in the harbour
 - ▶ bacterial water sampling along the beach (including *Pseudomonas* testing)
 - ▶ study wave and wind action at the beach
 - ▶ continue storm event sampling throughout Kettle Creek

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APPENDIX A

BASE FLOW WATER QUALITY RESULTS

Date	Station	<i>E. coli</i>	Faecal Strep.	Pseudo	Date	Station	<i>E. coli</i>	Faecal Strep.	Pseudo
Aug.2/95	TF1	100	200	10	Aug.30/95*	TF1	10	40	4
	TF2	300	400	10		TF2	60	190	4
	TF3	1,000	1,200	4		TF3	260	370	4
	TF4	700	1,100	10		TF4	140	210	8
	TF5	4,200	6,100	600		TF5	400	880	16
	TF6	1,000	1,600	870		TF6	230	360	4
	TF7	28,000	6,100	600		TF7	640	380	4
	TF8	500	1,100	110		TF8	60	220	4
	TF9	64	110	16		TF9	60	10	152

Date	Station	<i>E. coli</i>	Faecal Strep.	Pseudo	Date	Station	<i>E. coli</i>	Faecal Strep.	Pseudo
Sep.13/95	TF1	40	180	28	Oct.3/95*	TF1	50	20	4
	TF2	200	150	4		TF2	80	60	4
	TF3	950	320	4		TF3	200	150	4
	TF4	490	120	4		TF4	170	100	4
	TF5	810	1,040	64		TF5	110	420	4
	TF6	330	150	32		TF6	40	210	4
	TF7	1,000	650	12		TF7	560	280	4
	TF8	1,200	310	4		TF8	1,300	360	4
	TF9	170	150	144		TF9	270	280	4

* No Rain For 10 Days Prior

APPENDIX B

STORM EVENT WATER QUALITY RESULTS

STORM EVENT #1 : JUNE 29,1995 (13mm)

LOCATION	ROUND #1				ROUND #2				ROUND #3			
	Time	<i>E. coli</i>	F. Strep	Pseudo.	TIME	<i>E. coli</i>	F. Strep	Pseudo.	Time	<i>E. coli</i>	F. Strep	Pseudo.
TF1	08:40	560	810	4	11:45	140	430	4	14:30	170	270	4
TF2	09:00	70	200	4	11:54	120	120	12	14:35	70	190	20
TF3	09:15	660	1300	8	12:07	570	610	4	14:47	490	600	4
TF4	09:25	>1000	>1500	60	12:15	>1000	>1500	56	15:00	>1000	>1500	36
TF5	09:35	>1000	>1500	424	12:25	>1000	>1500	600	15:10	>1000	>1500	360
TF6	09:55	>1000	>1500	272	12:42	>1000	>1500	240	15:25	>1000	1230	144
TF7	10:15	>1000	>1500	348	13:07	>1000	>1500	560	15:42	240	>1500	320
TF8	10:30	>1000	>1500	16	13:20	660	1100	8	15:55	530	900	12
TF9	10:37	130	550	12	13:29	110	380	8	16:00	100	350	16

STORM EVENT #2 : AUGUST 3-4, 1995 (25mm)

LOCATION	ROUND #1				ROUND #2				ROUND #3			
	Time	<i>E. coli</i>	F. Strep	Pseudo.	Time	<i>E. coli</i>	F. Strep	Pseudo.	Time	<i>E. coli</i>	F. Strep	Pseudo.
TF1	22:45	200	200	10	01:50	300	3700	30	04:50	400	900	10
TF2	23:00	100	700	70	01:55	600	8100	470	05:00	200	1300	120
TF3	23:20	800	2200	150	02:15	3300	6100	230	05:15	1500	2600	50
TF4	23:35	800	1500	80	02:25	1400	2800	160	05:22	5200	20000	400
TF5	23:50	18000	43000	1500	02:40	20000	63000	1500	05:35	10000	56000	1500
TF6	00:10	10000	17000	1500	03:10	52000	51000	1500	06:00	8000	23000	1500
TF7	00:34	5000	3700	50	03:30	50000	25000	490	06:17	16000	16000	680
TF8	00:47	2200	2000	210	03:50	3300	13000	30	06:40	4900	19000	420
TF9	00:50	2900	2200	180	03:55	1200	2700	110	06:44	900	2200	90

STORM EVENT #3 : SEPTEMBER 20,1995 (8mm)

LOCATION	ROUND #1			Time	ROUND #2			Time	ROUND #3			
	Time	<i>E. coli</i>	F. Strep		Pseudo.	<i>E. coli</i>	F. Strep		Pseudo.	Time	<i>E. coli</i>	F. Strep
TF1	11:40	50	160	16	14:40	60	60	8	17:45	10	120	4
TF2	11:45	380	330	16	14:45	1200	380	16	17:50	1400	420	4
TF3	11:52	330	580	12	15:04	100	400	24	18:10	470	430	12
TF4	11:56	170	330	16	15:15	1100	150	4	18:17	640	490	4
TF5	12:05	13000	15000	1500	15:25	10000	15000	880	18:25	10000	1300	600
TF6	12:20	26000	24000	510	15:40	600	1400	220	18:45	100	200	12
TF7	12:40	4000	2200	20	15:55	2100	2400	12	19:00	1300	1500	-40
TF8	12:55	100	100	12	16:11	340	380	8	19:10	300	300	4
TF9	13:00	100	100	8	16:13	120	110	12	19:15	220	120	12

STORM EVENT #4 : OCTOBER 4,1995 (14mm)

LOCATION	ROUND #1			Time	ROUND #2			Time	ROUND #3			
	Time	<i>E. coli</i>	F. Strep		Pseudo.	<i>E. coli</i>	F. Strep		Pseudo.	Time	<i>E. coli</i>	F. Strep
TF1	08:42	20	130	4	11:40	20	100	4	14:37	100	50	4
TF2	09:05	1700	420	4	11:45	630	250	4	14:49	860	410	4
TF3	09:24	480	340	16	12:00	460	680	4	15:05	640	240	4
TF4	09:32	2000	4700	4	12:09	3100	3300	4	15:12	2300	1900	4
TF5	09:45	2600	9300	520	12:14	3600	7400	400	15:19	3100	4000	224
TF6	10:00	2100	4600	248	12:20	1200	1800	100	15:30	2100	1000	64
TF7	10:04	2300	2500	20	12:25	2200	2900	44	15:34	5300	2400	120
TF8	10:22	700	510	4	12:46	4800	3800	4	15:50	360	280	4
TF9	10:29	490	240	8	12:50	320	2000	4	15:55	260	150	4

APPENDIX C

STORM EVENT *E. COLI* LOADINGS

Loadings On Kettle Creek During Storm Events (*E. coli*/SEC)

Storm Event #1

	Rounds		
	1	2	3
TF2	3151546	583470	369343
TF3	9941003	7900266	7488017
TF4	4952836	4472328	4505955
TF5	2200596	1716000	1562786
TF6	7411579	6913500	7200000

Storm Event #2

	Rounds		
	1	2	3
TF2	268809	1786781	690543
TF3	8344960	54314878	64047750
TF4	384969	12456257	71455098
TF5	122749714	403104000	38809756
TF6	78142105	810014400	89790968

Storm Event #3

	Rounds		
	1	2	3
TF2	385387	1217011	1421653
TF3	520273	1514631	688801
TF4	514668	3008265	911097
TF5	28607745	14207143	12628571
TF6	230987586	2362645	286756

Storm Event #4

	Rounds		
	1	2	3
1F2	1151544	393019	566206
TF3	4414800	3207896	4213412
TF4	5120898	8312416	5349661
TF5	3008815	3818880	2784600
TF6	8544900	4882800	6054300

APPENDIX D

STORM EVENT *PSEUDOMONAS* LOADINGS

Loadings On Kettle Creek During Storm Events (Pseudo/sec)

Storm Event #1

	<u>Rounds</u>		
	1	2	3
TF2	18008	58347	105527
TF3	120497	55440	61127
TF4	297170	250450	162214
TF5	9331	1029600	562603
TF6	2015949	1659240	1036800

Storm Event #2

	<u>Rounds</u>		
	1	2	3
TF2	188008	58347	105527
TF3	1564680	3785582	2134925
TF4	384967	1423572	5496546
TF5	10229143	30232800	5821463
TF6	11721316	23365800	16835806

Storm Event #3

	<u>Rounds</u>		
	1	2	3
TF2	16227	16227	4062
TF3	18919	36351	17586
TF4	48439	10939	5694
TF5	3300894	1250229	757714
TF6	4530910	866303	34411

Storm Event #4

	<u>Rounds</u>		
	1	2	3
TF2	2710	2495	2634
TF3	147160	27895	26334
TF4	10242	10726	9304
TF5	601763	424320	201210
TF6	1009112	406900	184512