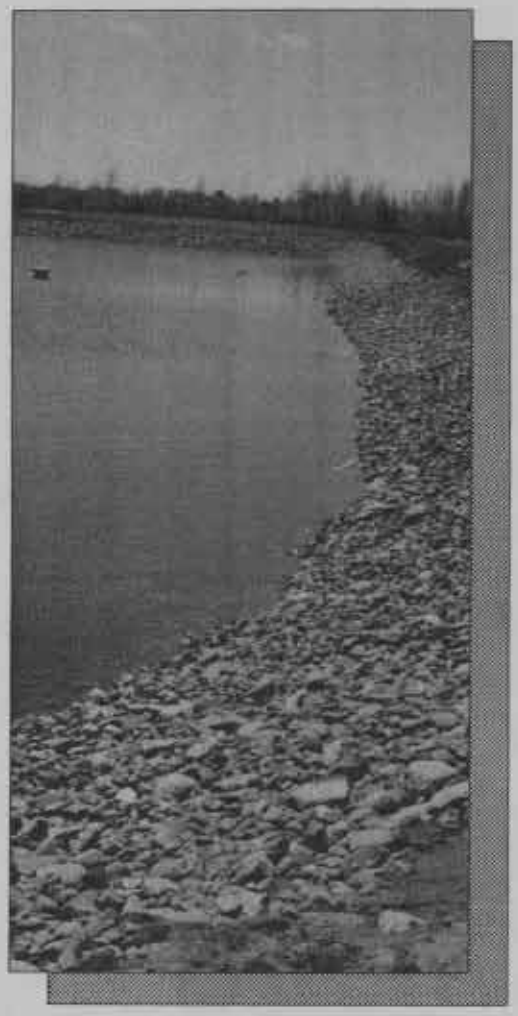
REPORT ON EVALUATION OF MINNESOTA WATER BALANCE TEST



Minnesota Pollution Control Agency
Consulting Engineers Council of Minnesota

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REPORT ON EVALUATION OF

MINNESOTA WATER BALANCE TEST

April 1989

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Twin City Testing, Incorporated

The cover photo shows one of the Kettle River Sewage Stabilization Ponds. The photo was taken by a Water Balance Task Force member during the water balance test.

DISCLAIMER

This report has been reviewed by the Minnesota Pollution Control Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Minnesota Pollution Control Agency or the Consulting Engineers Council of Minnesota, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

All newly constructed wastewater treatment ponds and existing ponds undergoing upgrades in Minnesota are required to assess the seepage rate of the pond seal by the Minnesota Water Balance Test. A Water Balance Task Force consisting of representatives from the Consulting Engineers Council and the Minnesota Pollution Control Agency (MPCA) was formed in June 1987 to evaluate the test.

The purpose of the Task Force was to (1) provide guidance for evaluation and review of water balances, (2) generate improvements in materials and techniques for operation of the test, (3) evaluate the test in a statistical manner to determine its reliability, (4) consider the implications of combining a performance test with prescriptive specifications, and (5) study the impacts of freezing on the water balance.

To accomplish these goals, the Task Force reviewed data from six previous water balance tests, conducted two field water balances, sent questionnaires to other regulatory agencies in the United States and Canada, and sought legal counsel for assessing the contractual implications of combined specifications.

The Task Force concluded that the Minnesota Water Balance Test is an effective tool for evaluating seepage loss from ponds and that the methods used to analyze the data collected during the test have an accuracy to within +/- 1,000 gallons/acre/day.

Recommendations developed by the Task Force for modification and standardization of the test are presented in this report. The recommendations address both physical changes in testing procedures and modifications of the analytical evaluation of test data.

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1. INTRODUCTION

The Minnesota Water Balance test for determining seepage loss from ponds was developed to determine whether newly constructed or existing stabilization ponds were properly sealed. The test was seen as an inexpensive and effective method of assessing the integrity of the lining seal.

Over the last 30 years, design requirements for wastewater stabilization ponds have become progressively more restrictive. The changes in design criteria reflect the broadening of concerns related to stabilization ponds.

Initially, the prime concern defining design requirements was the need to maintain adequate water levels. An early theory held that, over time, the cells would seal themselves with the solids loading if the original seal was sufficient to maintain water.

Later the design standard called for the removal of porous topsoil and compaction of the subgrade to enhance sealing; a liner was required only in areas where porosity was "excessive." These requirements were meant to avoid nuisance conditions and weed growth in the bottom of the cells that provided prime conditions for mosquito breeding.

A heightened awareness of the potential for ground water contamination was the impetus for the next development in pond design. The 1975 Recommended Design Criteria for Stabilization Ponds by the Minnesota Pollution Control Agency (MPCA) included the best available technology to achieve a sealed pond with a seepage loss of less than of 500 gallons/acre/day. This seepage rate was interpreted by the MPCA as meeting its nondegradation standard.

The Agency contracted a study to determine the effectiveness of this standard in protecting the ground water in the vicinity of several existing stabilization ponds. The study was conducted by Eugene A. Hickok and Associates and showed that where ponds leaked approximately 3,000 gallons/acre/day some localized contamination of ground water resulted. The 500 gallon per acre per day seepage limit was determined to be acceptable and remains in effect to ensure that localized contamination does not occur.

In 1987, a Water Balance Task Force (WBTF) was formed to evaluate the accuracy of the Minnesota Water Balance test and to see if any changes could be made to improve the test without significantly increasing its cost. The WBTF consisted of staff from the MPCA and representatives of the Consulting Engineers Council (CEC). At their first meeting on June 16, 1987, Task Force members outlined the scope of work for the WBTF:

1. Provide guidance for MPCA staff reviewing new stabilization pond systems.

2. Develop a data sheet for uniform recording of information.

3. Study the issue of water balances extending into a freeze-up period, versus deferring the test until the spring thaw.

4. Generate improvements in testing techniques.

5. Review water balance data in a statistical manner to determine if reliability and confidence can be obtained from the number of readings currently specified.

6. Recommend contract specification requirements in regard to the water balance test.

7. Identify any substitute standard method tests that may be utilized.

8. Assess implications associated with using both prescriptive and performance style specifications in a contract.

9. Collect information from other states on how they protect ground water from pond seepage and how they determine pond seepage rates.

The Task Force met on a monthly basis. In order to address a range of issues, it conducted water balances at two new sewage stabilization ponds sites. One system was located in Cleveland, Minnesota; the tests there went from October 14, 1987, to November 13, 1987. The second test was conducted at Kettle River, Minnesota, from May 10, 1988, to June 24, 1988. The Kettle River test was interrupted on May 20 for construction repairs and restarted on May 23.

Participants in the Water Balance Task Force were:

Consulting Engineering Council members

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Tom Noyes, P.E. McCombs-Frank, Roos and Associates, Inc.
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The following chapters outline the work, conclusions and recommendations of the Water Balance Task Force.

2. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Water Balance Task Force reached the following conclusions:

1. The Minnesota Water Balance Test is adequate to determine if newly constructed ponds are properly sealed to achieve a seepage loss of less than 500 gallons/acre/day with a 95 percent confidence interval of plus or minus 1,000 gallon/acre/day if the test is run according to the criteria contained in this report. This barrel test is only acceptable for insuring an adequate seal if the installation of the pond seal is done with adequate inspection as outlined in the prescriptive specifications.

2. Although the task force did not study testing of seepage from existing ponds extensively, it concluded that, with some changes, this test can be applied to them. Test accuracy may not be as good with existing ponds because of the problems of dealing with incoming sewage, settling of barrels and uneven pond floors. Evaluation of the seepage from existing ponds may be done by the Minnesota Water Balance or other methods that can be demonstrated to Minnesota Pollution Control Agency staff as being acceptable.

Recommendations

The Water Balance Task Force recommended that the Minnesota Water Balance test should continue to be required for the evaluation of the performance of newly constructed sewage stabilization ponds (both aerated and nonaerated). The task force made recommendations for changes in the test and in the evaluation of the data.

The following recommendations for physical changes in the test are also included in the recommended criteria in Chapter 8:

1. The color of the barrels should be standardized to pure white.

2. The baffle that protects the barrel from splash-over of water from wave action should be standardized.

3. The barrels should be firmly attached to a concrete pad to minimize movement during the test.

4. A minimum of three evaporation-rainfall barrels should be placed in each pond.

5. To reduce errors in reading measurements, the ruler for measuring water level in the barrels should be in millimeters and securely attached to the inside of the barrels for the entire test.

6. All test barrels shall be made of steel with a capacity of 55 gallons. Barrels whether new or used, should have an inside diameter dimension of 22.5, inches plus or minus one inch, and a height a of 35 inches, plus or minus two inches. The barrels dimensions must not be reduced for the test.

7. The water depth and concrete pad in the ponds should be such that the water depth on the outside of the barrels is about two-thirds of the barrel height at the beginning of the test.

8. Because of the uncertainty of weather conditions, the bidding documents for conducting the test should cover costs for a test period of four weeks.

9. The test can be continued into the freeze up period if ice has not permanently formed in the barrels for the winter. In any case the test must be started so as to be concluded by November 20.

10. Evaporation pans are not recommended to be used to measure evaporation. If this is the only method available, a pan evaporation coefficient of 0.6 shall be used.

11. The number of perforated barrels should be increased to a minimum of three.

The following recommendations are for changes in the evaluation of the test and described more fully in Chapters 7 and 8:

1. The minimum number of readings allowable for any water balance test will be nine. The readings may be made up of combinations of barrel data from different barrels. However, for a barrel to be included in a combined analysis, that barrel must contribute at least five readings to the analysis.

2. The water balance test periods should be run concurrently for all newly constructed stabilization pond cells on a project. This is due to the seasonal fluctuations of the mean seepage rate. In dry, hot summers, infiltration rates of up to 2,000 gallons/acre/day and higher have been recorded. This is thought to be due to accelerated evaporation from the water in the barrel when compared to the pond evaporation. By checking pond against pond, localized conditions can be accounted for on a broad scale.

3. The water balance should be evaluated using the least squares analysis. The confidence interval band given by the least squares analysis is to be used in combination with the mean seepage rate. Passing the water balance test requires: that the sum of the estimated mean seepage rate plus the confidence interval not exceed 1500 gallons/acre/day, and the correlation coefficient for each of the two estimated slopes be greater than 0.8. Only one properly evaluated data set is needed to meet this criteria in order for a pond to pass the Minnesota Water Balance test.

4. Ice in the barrel or the pond makes it impossible to make accurate readings. When free of ice the barrel may again be read, and the time between readings recorded. In order for the time span during freezing conditions to be used, a reading before the ice occurred and after the ice melted must be recorded.

5. Although the contract for the test must cover a period of four weeks, actual evaluation of the test may only require a two-week period, depending upon variability of the readings collected.

6. Dike runoff should be considered in the data analysis if major storms occur during the test. The smaller the pond, the greater the effect and the more intense the storm, the greater the effect.

The task force also recommended that:

1. The MPCA staff develop and maintain a data file of future water balance tests. Additional refinement of the standardized test is foreseeable and a good data base will be required to support that effort.

2. To avoid biases in design or evaluation of the liner, a soils engineer must be retained by the pond owner, preferably hired through the consulting engineer, for both the predesign and construction testing. Soils testing during construction should not be the responsibility of the contractor. Further, selection of the engineer by the pond owner should be based on qualifications, rather than price or a combination of qualifications and price. Typically at the time a soils engineer is selected, there is not enough information available for reasonable pricing of the design investigation, so no valid price comparisons are possible. Selection of a firm with the best qualifications should result in the lowest overall cost for design and construction.

3. TASK FORCE STUDIES AT CLEVELAND AND KETTLE RIVER

The Water Balance Task Force (WBTF) set up and operated two water balance tests to collect information. The first test was conducted on the Cleveland wastewater stabilization ponds from October 20, 1987 to November 13, 1987. The Cleveland ponds were designed by Bolton and Menk, Incorporated. The three ponds are approximately six (6) acres each and are sealed with 18 inches of clay. Additional information of the Cleveland water balance study is contained in a report entitled "Report of Water Balance Study, Wastewater Stabilization Ponds, Cleveland, Minnesota" by Twin City Testing, dated December 9, 1987.

The second water balance test was conducted on the Kettle River wastewater stabilization ponds from May 10, 1988 to June 20, 1988. It was interrupted on May 20th for repairs to pipes and the subsequent lowering of the water levels in the cells. It was restarted on May 23, 1988. The Kettle River pond system was designed by John Baker Engineering, Incorporated. Additional information on the Kettle River water balance study is contained in a report entitled "Water Balance Study, Wastewater Treatment Pond Project, Kettle River, Minnesota" by Braun Engineering Testing, Incorporated dated August 3, 1988. The Kettle River ponds are sealed with 30 mil polyvinyl chloride liner. Each of the three cells are approximately two acres.

A special thanks is given to Braun Engineering Testing, Incorporated, Bolton and Menk, Incorporated and Twin City Testing Corporation for assisting the Agency staff by donating time and equipment to conduct these tests.

Cleveland

The following is a discussion of the tasks that were performed at the Cleveland wastewater stabilization ponds. Bolton and Menk, Inc. collected daily readings for the water balance test and MPCA staff was onsite several times per week to take independent readings. Comparisons between the readings taken by Bolton and Menk, Inc. and the MPCA were used to determine a level of accuracy for the readings. The water balance test was conducted as outlined in the MPCA 1985 Recommended Design Criteria for Stabilization Ponds and revisions published in the Construction Grants Memorandum dated March 1986. The results were used as the basis of control for the investigation.

Three metal barrels were placed in the corners of each pond (Figure 3.6). A fourth barrel was placed near the center of each pond. The center barrel was used to determine if proximity to the dikes affects the amount of evaporation.

One stock tank was placed in each pond near one of the three barrels used for control. Comparisons between the barrels and the stock tanks were used to determine if the size of the barrel's or stock tank's opening affects evaporation. It appeared that the size of the container used to measure evaporation and rainfall could affect the test. In ponds 1 and 2, the stock tanks indicated more seepage from the ponds than the barrel. Since the stock tanks in pond 3 showed the opposite effect, it is not possible to draw any conclusion. It should be noted that the confidence interval for the stock tank in pond 3 is more than 20 percent greater than that of any of the pond 3 barrels. This indicates that other outside variables may have had a greater

impact on the results for pond 3. Based on this information, additional experiments could be conducted to evaluate how the size of the barrel opening affects evaporation.

Continuous measurements of the temperature of the water in the barrel, stock tank, and pond were recorded. This was done to find out if the surface temperatures of the water in the barrels, tanks or pond were significantly different, which could explain varying evaporation rates. Temperature readings were taken in the top inch of water. These tests, were taken from the stock tank, barrel, and pond all located in the northwest corner of pond 1 (Table 3.1). Although there were differences found in the temperatures measured in the pond, barrel and stock tank they do not appear to be significantly different. Figure 3.1 is a plot of the maximum and minimum daily temperatures recorded in the pond, barrel, and stock tank. Figures 3.2, 3.3, and 3.4 are plots of hourly temperature readings for four days (October 28 and 30 and November 10 and 11, 1987). These field observations showed that the barrels and stock tanks warmed up and cooled down slightly faster than the pond. This could have an effect on evaporation rates. On some mornings ice had formed in the barrel and stock tank but did not form on the pond. This indicates that the barrel and stock tank cooled faster than the pond or that wave action prevented the ponds from freezing.

It was concluded that during periods of freezing weather the barrel would typically freeze first (Figure 3.4). It was not determined whether this is due to energy storage by the pond, wind action on the pond or other factors. It is clear that the majority of energy is expended in melting the ice in the barrel or stock tank. It is assumed that the temperature of the water in the barrel remained close to freezing because the available energy was used melting the ice, much the same way ice is used to cool drinks. The pond, however, shows fluctuation in its surface temperature until the presence of ice on its surface. Therefore, this inaccurate modeling of the pond with barrels containing ice should be accounted for. As a side note, other tests have indicated that the type of material used to make the barrel may affect temperatures.

Evaporation out of the barrels and stock tanks were measured from the top rim with a hand-held scale. The pond level was measured on the outside of the barrels and in the control structures to find out what, if any, effect the wind has on the pond surface. Pond levels in cell #1 were also measured using a perforated barrel near the center of the cell.

The most useful benefit of this experiment came from observing the way the water balance was performed. It appeared that stricter quality control measures were needed. During these tests, the barrels rocked noticeably and settling of the barrels was possible, which could cause errors in reading water levels. Another possible source of error can be in the actual reading of water levels. A ruler was used to measure from the rim of the barrels down to the water surface. Errors can occur using this method. It is difficult to hold one end of the ruler at the water surface while reading the ruler at the rim of the barrel. To improve quality, the following changes are suggested:

-- Specifications should be more precise on how the test is to be conducted.

-- Barrels should be placed on solid surfaces such as splash pads to prevent settling. If this is not possible, the elevation of the barrel rims should be determined at the start of the test and checked again at the conclusion of the test. If the barrels settle, this could be taken into account when evaluating the results.

-- The scale used to measure the water levels should be permanently mounted. It is also easier to read a millimeter scale instead of reading 1/32nd of an inch.

Two evaporation pans were set up on the dikes to determine the correlation between the evaporation pans and the barrels. The data that was collected at Cleveland from the evaporation pans was inconsistent and determined not reliable, therefore no conclusions can be made.

One automatic recording and five manual rain gauges were installed at the pond site. Rain data were used to estimate the amount of runoff from the dikes and to determine if barrel location had an effect on how the barrel performed as a rain gauge. There was a total of 0.96 inches of rainfall during the study period. Wind directions and speed were also recorded.

The following are the seepage rates calculated from the data in the Cleveland water balance study.

	Statistical Method		End Point Method	
	Maximum Seepage Rate (upper limit of 95% confidence interval)		Average Seepage Rate	
	Using Barrels	Using Stock Tanks	Using Barrels	Using Stock Tanks
Pond	Gal/Acre/Day	Gal/Acre/Day	Gal/Acre/Day	Gal/Acre/Day
1	117	580	-355	94
2	410	556	-310	-255
3	752	743	323	-967

Negative numbers indicate the pond gained water
Positive numbers indicate the pond lost water

The statistical method consists of performing a linear regression to find the best fit line describing the data for each pond and barrel. The slopes of these lines are compared to determine a mean seepage rate and the 95% confidence interval is calculated assuming a t-distribution. The maximum seepage rate is obtained by adding the confidence interval to the mean seepage rate.

NOTE: The confidence interval equation used to determine these Cleveland intervals is different than that used in the proposed criteria. Chapter 3's values reflect a purely additive band width derived from the 95 percent level of the evaporation barrels added to the 95 percent band width of the pond barrels. The criteria formula takes into account that two worse case scenarios will not occur within the 95 percent band width. The new numbers are found in Table 6.3.

Kettle River

This section outlines the data and conclusions made from the water balance study performed at Kettle River, Minnesota in May and June of 1988. The Kettle River study was intended to gather information on various methods of conducting water balances. Starting the week of May 9, 1988, Braun Engineering Testing provided a staff person to check readings of the barrels every Monday and Thursday. The MPCA provided staff to take barrel readings, evaporation pan readings and check wind/run recorders and temperature recorders every Tuesday and Friday. The test ran until June 21, 1988. Water levels were altered on May 20 to allow for pond piping repairs and the test was restarted on May 23, 1988.

The test equipment supplied was as follows:

1. Six metal evaporation barrels.
2. Six plastic evaporation barrels.
3. Three stock tanks.
4. Three perforated metal control barrels.
5. Two evaporation pans.
6. Two rain gauges (manual reading)
7. One wind/run measuring recorder.

Approximate equipment locations are shown on Figure 3.7.
The analysis used in the study is as follows:

1. Use the unpaired t-Test to determine if the evaporation/rainfall rate, (i.e., the average daily change in water level) varies significantly between the metal barrels, plastic barrels and stock tanks.

    a. Check for significant differences between the two common evaporation barrels in each pond. If there are no significant differences within ponds then check for:

        (1) significant differences among all six metal barrels.
        (2) significant differences among all six plastic barrels.
        (3) significant differences among all three stock tanks.

    B. If the rates do not vary significantly over the whole pond system, then there is no need to analyze the vessels within each individual cell (i.e., if the rates among all six metal evaporation barrels do not vary significantly then all six may be used when calculating seepage rates for each cell).

        (1) Check for significant differences between the metal barrels and the plastic barrels for each pond (or for the system as a whole if the above note is applicable).

(2) Check for significant differences between the metal barrels and the stock tanks.

(3) Check for significant differences between the plastic barrels and the stock tanks.

2. Use the Paired t-Test to determine if the use of a hook gauge gives significantly different results from the metal ruler. Calculate the confidence interval for the mean of the average daily water level change for both methods.

3. Determine if the average daily evaporation/rainfall rate varies significantly between the two evaporation pans. Determine if the rate varies significantly between the evaporation pans and the plastic barrel on the dike. Determine if the rate varies significantly between the plastic barrel on the dike and those in the ponds.

4. Calculate the seepage rate for each pond using the metal barrels, plastic barrels, stock tanks and evaporation pans. Calculate the confidence interval for each.

5. Determine if the hourly temperatures of the pond, metal barrel, plastic barrel and stock tank vary significantly. If so, determine which vessel most closely approximates the pond temperature.

The Kettle River Stabilization Ponds passed the water balance and accepted for use. The Braun report indicated the end point method results as follows:

ALL UNITS IN GALLONS PER ACRE PER DAY

Pond	Dike Run Off	End Point Seepage	Adjusted Seepage
Braun's Readings			
Cell A	299	-447	-148
Cell B	405	-228	177
Cell C	405	420	825
MPCA's Readings			
Cell A	299	-324	-25
Cell B	482	-248	234
Cell C	482	-97	385

Braun's staff suspected that the first 10 days of their readings were inaccurate for cell C. Comparing the data from the MPCA and the remainder of the 18 day period of Braun's test, shows that a disproportionately large amount of seepage occurred in the first ten days, from Braun's data. This aids as a demonstration of the variability in tests due to operation methods since the same time period and same equipment resulted in two different findings.

The following are the results of the statistical analysis proposed.

NOTE: All test data were run using like time period windows. Since Braun and MPCA alternated readings, a data set that had only MPCA readings available was compared to the other sets using only MPCA dates of record. The least squares correlation uses day rates and the sample variance to estimate a best fit line. Slopes of the means of the different data sets can be compared for seepage loss rates.

A. Observations on the above calculated results

1. The Unpaired t-Test demonstrates there are no significant differences among all three cells for:

   a. metal barrels.
   b. plastic barrels.
   c. stock tanks.
   d. metal barrels and stock tanks.
   e. stock tanks and plastic barrels.
   f. evaporation pan one and evaporation pan two.
   g. the plastic barrel loss, on the dike, when compared with the evaporation pans.

2. The Paired t-Test demonstrates no significant differences between the readings collected using the hook gauge and the readings collected using the mm rule.

3. The least squares analysis for the water balance indicates:

   a. Cell A

      Metal barrels had a gain of 460 gallons/acre/day and a loss of 345 gallons/acre/day (this barrel had a dead bird removed from it during the test period). The plastic barrel had a gain of 1292 gallons/acre/day and the stock tank had a gain of 661 gallons/acre/day.

      The confidence interval for 95% was approximately +/- 730 gallons/acre/ day, +/- 710 gallons/acre/day, +/- 695 gallons/acre/day, respectively, for metal, plastic and stock tank readings.

b. Cell B

The metal barrel seepage average was 27 gallons/acre/day loss and 182 gallons/acre/day gain. The plastic barrel results were 1412 and 1542 gallons/acre/day gain. The stock tank in Cell B indicated a 603 gallon/acre/day gain.

The 95% confidence interval as approximately +/-650 gallons/acre/day, +/-645 gallons/acre/day and +/-603 gallons/acre/day for the metal, plastic and stock tank readings, respectively.

c. Cell C

The metal barrel seepage rates were 465 and 450 gallon/acre/day loss. The plastic barrel seepage rates were a 59 gallon/acre/day loss and a 914 gallon/acre/day gain. The stock tank had a 380 gallon/acre/day gain.

The 95% confidence interval is approximately +/-675 gallons/acre/day, +/- 630 gallons/acre/day and +/-670 gallons/acre/day for the metal, plastic and stock tank readings, respectively.

[Note: The confidence interval bands are calculated using the additive equation discussed in the Cleveland results. The confidence interval data on the metal barrels calculated by the criteria method are found in Table 7.1]

4. Temperature Measurements

Temperature measurements were taken during the survey of the top one inch of water in the pond, steel barrel, plastic barrel, and stock tank. Figure 3.5 is a plot of the 4-hour temperature readings in the steel barrel, plastic barrel, stock tank and the pond from June 1 through the June 15th. The surface water temperatures do not appear to be signficantly different in the four vessels. Compared to the variations that can occur due to wind, precipitation and scale of the test, effects of surface water temperatures may be slight.

5. The Evaporation Pan Data

The least square analysis was run on cell A using the two evaporation pans to check against the pond level. Evaporation pan coefficients of 0.6, 0.7 and 0.8 were used to correct the pan data for shallow reservoir results. Results using the first pan varied between a seepage rate of 1098 gallons/acre/day loss to a gain of 316 gallons/acre/day. The 95% confidence interval is +/- ~ 820. The second pan varied between a loss of 1033 gallons/acre/day to a gain of 402 gallons/acre/day. The 95% confidence interval is +/- ~ 800. The wider confidence interval for pans, as opposed to barrel tests, can be attributed to the fact that pan readings were taken only by MPCA staff (i.e., the sample size is one half of the other sets).

The level of accuracy for the test limit of 500 gallon/acre/day was not obtained. Also, the confidence interval did not significantly improve by use of one type of equipment instead of another. However, the seepage rates show large differences in the results of projected gallons/acre/day of each pond. This shows that the variance of the results may not show a detectable improvement in testing methods until the test is standardized.

The remaining question is which barrel more truly reflects the pond's actual seepage rate? Kettle River's data seems to indicate that the metal barrels came the closest. Deleting the data from the barrel with the dead bird, the metal barrels gave closer seepage rates to each other than the plastic barrels; and the metal barrels had lower gain rates. Gain rates above ground water tables may be attributed to evaporation of the barrel exceeding evaporation of the pond. Assuming the synthetic seal to be above the ground water table, the metal barrels depict pond evaporation better in this test.

Wind/run data was gathered during the test period. Exact time and duration of wind storm events was not defined. However, the levels of winds or average wind speeds may be determined for the months in question. Approximately six wind events occurred during the test period ranging from 15 to 30 miles per hour. The remainder of recordings showed that the month had equal parts of 0 to 5 mile per hour winds and 5 to 10 mile per hour winds.

Method Observations

Several MPCA staff members commented on their observations made during the test. These observations are presented below for information and future reference.

-- Plastic barrels required a large area (half the submerged volume of the barrel) to be filled with rock for stability. It is not known if this amount of rock mass has a significant effect on evaporation.

-- Plastic barrel sidewalls were extremely sensitive to deflection. The waves set up by wading to the barrel for a reading, created a problem with accurately reading the water level in the barrel.

-- High winds were not visually observed at Kettle River, however it is questioned if the plastic barrels (with rock in them) would be stable enough to withstand a wind storm.

-- One problem associated with both plastic and metal barrels was the difficulty in reading the ruler when the water level was down deep inside the barrel.

-- The sun's reflection from the water surface to the ruler increased the difficulty of water level readings. Attaching the ruler on the south side of the barrel should help.

-- Three different types of baffles were used during the test: the metal baffle welded to the top of the metal barrels, the pallets tied together around the barrel and a snow fence arrangement similar to pallet baffles. Both wood products sank after seven to ten days. If used in the future, flotation devices such as bleach bottles should be affixed to the baffles.

-- The hook gauge was easier to read.

-- To quantify possible settling, elevation of the perforated barrels should be taken at the beginning and end of the test.

-- Also due to settling, level measurements of the top rim of the barrel should be required before each reading.

°C - Cleveland - Stock Tank

Table 3.1

Time (hr.)	Date 10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23
1		9.5	10.5	9.5	9.5	7.5	7.5	2.5	5	5
2		9.5	10.5	9.5	9.5	7.5	7.5	2	5	5
3		9.5	10.5	9	9	7	7	1	5	5
4		9.5	10.5	9	9	7	7	1.5	4.5	5
5		9.5	10.5	9	9	7	6.5	1.5	4.5	5.5
6		9.5	10	9	8.5	6.5	6.5	1.5	4	5.5
7		9.5	10	8.5	8.5	6.5	6	1.5	4	5.5
8		9.5	10	8.5	7.5	7	6	2	3.5	5.5
9		9.5	10	8.5	8.5	7.5	6	3	2	5.5
10		9.5	10.5	9	8.5	8.5	6	?	1.5	5.5
11		10	10.5	10	9	9	6	?	4.5	5
12		10.5	10.5	11	9.5	9.5	6	?	4.5	5
13		10.5	10.5	11.5	9.5	9.5	6	5	5.0	5
14	10	10.5	11	12	9.5	9	6	5	5.0	5
15	10.5	10.5	11	12	9.5	9	6	5.5	5.5	5
16	11	10.5	11	12	9.5	9	6	5.5	5.5	5
17	10.5	11	11	11.5	9.5	9	5.5	5.5	5.5	5
18	10	11	11	11	9.5	8.5	5.5	5.5	5.5	5.5
19	10	11	10.5	11	9	8.5	5	5.5	5.5	5.5
20	10	11	10.5	11	9	8.5	5	5.5	5.5	5
21	10	11	10	11	8.5	8	4.5	5.5	5.5	5
22	10	11	10	10.5	8.5	8	4.5	5.5	5	5
23	10	11.5	10	10	8	8	4	5	5	5
24	10	10.5	9.5	10	8	8	3.5	5	5	5

Time (hr.)	Date 10/24	10/25	10/26	10/27	10/28	10/29	10/30	10/31	11/1	11/2
1	5	2	4.5	4	1.5	4	6	6.5	8.5	7.5
2	4.5	1	4.5	4	1	4	6	6	9.5	10
3	4.5	1	4.5	3.5	0.5	4	5.5	6	8.5	10.5
4	4	1	4.5	3.5	0	4	5.5	6	8.5	10.5
5	4.5	1	4	3	-0.5	4	5.5	6	8.5	10.5
6	4.5	1	4	3	-1	3.5	5	6	8	11
7	4	1	4	2	0.5	3.5	5	5.5	8	11
8	3.5	1	4.5	1.5	0.5	3	5.5	5.5	8	11
9	3.5	1	4.5	3.5	1.5	3.5	7.5	6	8	12
10	3	2	4.5	4	1.5	4	8	6.5	8.5	12.5
11	3.5	3	5	4.5	2	4.5	9	7.5	9	13
12	3.5	3.5	5.5	5	4	5	10	7.5	9	13.5
13	3.5	4	6	5.5	5	6	10.5	8	9	14
14	4	4.5	6	5.5	5.5	6.5	10.5	8.5	9.5	14.5
15	4	5	6.5	5.5	5.5	7	10	8.5	9.5	14
16	4.5	5	6.5	5.5	5	7	9.5	9	9.5	14
17	4.5	5	6.5	5	5	7.5	8.5	9	9.5	14
18	4	5.5	6.5	5	5	7	8	8.5	9.5	13
19	4	5	6	5	5	7	8	8.5	9.5	13.5
20	4.5	5	6	4.5	4.5	7	7.5	8.5	9.5	13.5
21	4	5	5.5	3	4.5	7	7.5	8.5	9.5	14
22	4	5	5.5	2	4	6.5	7	8.5	9.5	14
23	3.5	4.5	5	1.5	4	6.5	7	8.5	9.5	13
24	2.5	4.5	4.5	2	4	6.5	6.5	8.5	9.5	12.5

°C - Cleveland - Stock Tank

Table 3.1

Time (hr.)	Date 11/3	11/4	11/5	11/6	11/7	11/8	11/9	11/10	11/11
1	12.5	12	6	3	4	7.5	0	0.5	0
2	12.5	11.5	5.5	3	4	7.5	0	0.5	0
3	12.5	11.5	5	3	4	7.5	0.5	0.5	0.5
4	12.5	11	4.5	3	3.5	7	0.5	0	0
5	12.5	11	4	3	3.5	6.5	0.5	0	0
6	12.5	10.5	3	3	4	6	0.5	0	0
7	12.5	10.5	3.5	3.5	4.5	6	0.5	0.5	0.5
8	12.5	10.5	4.5	4.5	5	5.5	0.5	0.5	2.5
9	12.5	10.5	5	5	5.5	6	1.5	1.5	4
10	13	11	5.5	5.5	6	6	3.5	4	6
11	13	11	6	6.5	6.5	6.5	5	5.5	6
12	14	11	6.5	7	6.5	7	6	5	6.5
13	13.5	11	7	8	7	7	4.5	4.5	5
14	13.5	11	7	8	7	6.5	2	2	4.5
15	13	11	7	8	7.5	5.5	1	1	3.5
16	12.5	10	6	6.5	7.5	5	0	0.5	1.5
17	12.5	10	6	6	7.5	4	0.5	1	2
18	12.5	9.5	5.5	6	7	3	0	1	1.5
19	12.5	9	5	6	7	2.5	0	1	2.5
20	12.5	8.5	5	5.5	7	1.5	0	0.5	1
21	12	8	4.5	5	7	1	0	0	1
22	12	7.5	4	4.5	7	-0.5	0	0.5	1
23	12	7	4	4.5	7.5	0	0.5	0.5	0.5
24	12	6.5	3.5	4	7.5	0	0.5	0.5	1

°C - Cleveland - Stock Tank

Time (hr.)	Date 11/12	11/13
1	0.5	2.5
2	0.5	2
3	0.5	1.5
4	1	1.5
5	1	1
6	1.5	1.5
7	2	2
8	5	5
9	7	8
10	8.5	?
11	10	
12	10.5	
13	9	
14	8.5	
15	6.5	
16	5.5	
17	5	
18	4.5	
19	4	
20	3.5	
21	3	
22	3	
23	2.5	
24	2.5	

BARREL TEMPS. (°C)

Table 3.1

Date	10/14/87	10/15/87	10/16/87	10/17/87	10/18/87
Time					
0100		9.5	10.0	9.0	9.25
0200		9.0	10.0	9.0	9.0
0300		9.0	10.0	9.0	8.75
0400		9.0	10.0	9.0	8.5
0500		9.0	9.5	8.5	8.5
0600		9.0	9.5	8.5	8.0
0700		9.0	9.5	8.5	8.0
0800		9.0	9.5	8.5	8.0
0900		9.0	9.5	8.5	8.0
1000		9.0	10.0	8.5	8.2
1100		9.5	10.0	9.0	8.4
1200		10.0	10.5	10.0	8.5
1300		10.0	10.5	10.5	9.0
1400	10.0	10.0	10.5	11.0	9.0
1500	10.0	10.0	10.5	11.0	9.0
1600	10.0	10.5	10.5	11.0	9.0
1700	10.0	10.5	10.5	11.0	9.0
1800	9.5	10.5	10.0	10.5	9.0
1900	9.5	10.5	10.0	10.5	8.75
2000	9.5	10.5	10.0	10.5	8.5
2100	9.5	10.5	10.0	10.0	8.25
2200	9.5	10.5	9.5	10.0	8.0
2300	9.5	10.5	9.5	9.75	8.0
2400	9.5	10.0	9.0	9.5	7.5

Date	10/19/87	10/20/87	10/21/87	10/22/87	10/23/87
Time					
0100	7.5	7.1	3.25	4.5	4.5
0200	7.0	7.0	2.5	4.0	4.25
0300	7.0	6.75	1.5	3.5	4.5
0400	6.5	6.5	1.0	3.5	4.4
0500	6.5	6.25	1.0	3.0	4.4
0600	6.3	6.0	0.9	2.5	4.0
0700	6.0	5.75	0.75	2.0	3.8
0800	6.00	5.5	1.0	1.5	3.8
0900	6.2	5.5	1.5	2.0	4.0
1000	7.0	5.5	2.5	3.0	4.0
1100	7.5	5.5		5.0	4.8
1200	8.0	5.5	2.5	5.0	5.0
1300	8.5	5.5	3.0	5.5	5.0
1400	8.5	5.5	5.0	5.5	5.0
1500	8.5	5.5	5.0	5.5	5.0
1600	8.5	5.4	5.0	5.2	5.0
1700	8.5	5.0	5.0	5.1	5.0
1800	8.3	5.0	5.0	5.0	4.6
1900	8.0	4.5	5.0	5.0	4.6
2000	8.0	4.0	5.0	5.0	4.6
2100	7.5	4.1	4.5	5.0	4.6
2200	7.5	4.0	4.5	4.8	4.5
2300	7.5	3.5	4.5	4.6	4.3
2400	7.4	3.0	4.5	4.6	4.0

Table 3.1

	10/24/87	10/25/87	10/26/87	10/27/87	10/28/87	10/29/87
0100	4.0	0.4	3.9	4.0	0.0	2.9
0200	3.9	0.1	3.8	3.7	0.2	2.5
0300	2.8	0.5	3.8	3.3	0.0	2.0
0400	4.0	0.5	3.4	3.0	0.0	2.0
0500	3.5	0.5	3.4	2.5	0.0	2.0
0600	3.0	0.5	3.4	2.6	0.0	2.8
0700	2.5	0.7	3.6	3.3	0.2	3.6
0800	2.4	1.0	4.0	3.5	1.0	4.0
0900	2.5	1.9	5.0	4.0	1.5	4.5
1000	2.5	3.0	4.7	4.0	2.6	5.5
1100	3.0	3.6	5.0	4.9	4.0	6.0
1200	3.1	4.0	5.1	4.9	4.5	6.9
1300	3.2	4.2	5.5	5.0	4.1	7.1
1400	3.2	4.5	6.0	5.0	4.1	6.0
1500	3.2	4.5	6.0	4.8	4.0	6.5
1600	3.2	4.5	6.0	4.5	3.9	6.5
1700	3.1	4.3	5.5	4.5	3.0	6.2
1800	3.0	4.5	5.4	3.8	2.8	6.1
1900	3.0	4.4	5.1	2.8	3.0	6.1
2000	2.6	4.3	5.0	2.0	3.0	6.0
2100	2.1	4.0	4.8	2.1	3.0	5.9
2200	1.4	3.9	4.8	2.0	2.9	5.5
2300	1.0	3.9	4.3	1.3	3.0	5.5
2400	0.9	3.9	4.0	1.0	2.9	5.4

	10/30/87	10/31/87	11/1/87	11/2/87	11/3/87	11/4/87
0100	5.1	5.5	7.6	10.6	12.0	10.5
0200	5.0	5.5	7.5	10.5	12.0	10.4
0300	5.0	5.2	7.5	10.6	12.0	10.0
0400	4.5	5.0	7.5	11.0	12.0	10.0
0500	4.5	5.0	7.5	11.5	12.0	10.0
0600	5.5	5.4	7.6	12.0	12.4	10.0
0700	6.1	6.0	7.7	12.4	12.5	10.0
0800	7.0	7.0	8.2	12.8	12.9	10.2
0900	8.0	7.5	8.5	13.5	13.0	10.5
1000	8.5	8.0	8.5	14.0	13.0	10.5
1100	9.0	8.5	9.0	13.5	12.2	10.3
1200	9.0	8.5	9.0	13.5	12.0	9.9
1300	9.0	8.2	9.0	13.5	12.0	9.1
1400	8.5	8.2	8.9	13.4	11.9	8.9
1500	7.6	8.0	8.9	13.0	11.8	8.4
1600	7.4	8.0	8.9	13.2	11.5	8.0
1700	7.0	7.8	8.8	13.2	11.5	7.5
1800	7.0	7.8	8.8	13.5	11.5	7.0
1900	6.75	7.9	8.9	13.0	11.5	6.4
2000	6.5	7.9	9.1	12.5	11.5	6.0
2100	6.4	7.9	9.4	12.4	11.4	5.0
2200	6.0	7.8	9.5	12.0	11.2	4.5
2300	5.9	7.6	9.8	12.0	11.0	4.0
2400	5.6	7.6	10.5	12.0	10.6	4.6

Table 3.1

	11/5/87	11/6/87	11/7/87	11/8/87	11/9/87	11/10/87
0100		4.3	1.0	2.0	5.5	-2.4
0200		3.5	1.0	2.1	5.0	-2.2
0300		2.6	1.5	2.5	4.5	-2.0
0400		2.5	3.5	3.4	4.6	-1.0
0500		3.0	4.0	5.0	4.6	0.0
0600		4.0	4.6	5.8	5.0	1.0
0700		4.5	5.6	6.5	5.0	1.5
0800		4.8	6.2	7.0	5.2	1.9
0900		5.3	7.0	7.0	5.2	2.0
1000		5.5	7.2	7.4	5.0	1.2
1100		5.6	7.2	7.0	4.5	0.0
1200		5.5	7.0	7.0	3.3	-0.2
1300		5.0	5.6	7.2	3.0	-1.0
1400		5.0	5.2	7.0	2.2	-1.0
1500		4.9	5.0	7.0	1.5	-1.0
1600		3.4	4.5	7.0	0.5	-1.2
1700		3.0	4.2	7.0	-0.2	-1.2
1800		2.4	4.0	7.0	-2.0	-1.0
1900		2.5	4.0	7.0	-1.3	-0.8
2000		3.0	3.5	7.0	-1.2	-0.8
2100		2.0	3.0	7.0	-2.0	-1.0
2200		2.0	3.0	7.2	-2.0	-1.2
2300		1.5	2.5	7.2	-2.0	-1.2
2400		1.0	2.2	7.0	-2.1	-2.0

	11/11/87	11/12/87	11/13/87	11/14/87	11/15/87	11/16/87
0100	-2.0	-1.0	1.0	2.0		
0200	-1.2	0.0	2.1	4.0		
0300	-0.8	2.0	4.9	5.0		
0400	0.0	3.5	7.4			
0500	0.2	5.0	9.0			
0600	1.0	6.0	10.5			
0700	1.0	6.5	11.2			
0800	1.0	7.0	11.3			
0900	1.0	6.0	9.0			
1000	1.0	4.5	6.2			
1100	-0.5	2.0	5.6			
1200	-0.3	2.1	4.3			
1300	-0.2	2.0	4.3			
1400	0.2	2.1	4.0			
1500	0.0	1.2	3.0			
1600	-0.2	1.0	2.5			
1700	-0.3	1.0	2.8			
1800	-0.3	0.9	2.2			
1900	-0.4	1.0	2.2			
2000	-0.6	0.0	2.2			
2100	-1.0	0.0	1.0			
2200	-1.5	-0.5	1.4			
2300	-1.5	-0.1	0.5			
2400	-1.4	0.2	1.0			

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
10/14/87	1:00 AM		10/16/87	1:00 AM	10.3	10/18/87	1:00 AM	9.5
	2:00			2:00	10.2		2:00	9.4
	3:00			3:00	10.1		3:00	9.3
	4:00			4:00	10.1		4:00	9.0
	5:00			5:00	10.1		5:00	8.9
	6:00			6:00	10.0		6:00	8.8
	7:00			7:00	9.9		7:00	8.6
	8:00			8:00	9.9		8:00	8.5
	9:00			9:00	9.9		9:00	8.5
	10:00			10:00	10.0		10:00	8.7
	11:00			11:00	10.3		11:00	9.0
	Noon			Noon	10.5		Noon	9.6
10/14/87	1:00 PM		10/16/87	1:00 PM	10.6	10/18/87	1:00 PM	9.7
	2:00 PM	9.7		2:00	10.7		2:00	9.7
	3:00	9.9		3:00	10.7		3:00	9.7
	4:00	9.9		4:00	10.7		4:00	9.7
	5:00	10.0		5:00	10.7		5:00	9.5
	6:00	10.0		6:00	10.6		6:00	9.3
	7:00	9.9		7:00	10.6		7:00	9.1
	8:00	9.8		8:00	10.4		8:00	9.0
	9:00	9.8		9:00	10.1		9:00	8.8
	10:00	9.8		10:00	10.0		10:00	8.5
	11:00	9.6		11:00	9.9		11:00	8.2
	Midnight	9.6		Midnight	9.8		Midnight	8.0
10/15/87	1:00 AM	9.5	10/17/87	1:00 AM	9.5	10/19/87	1:00 AM	7.8
	2:00	9.5		2:00	9.3		2:00	7.5
	3:00	9.3		3:00	9.1		3:00	7.5
	4:00	9.1		4:00	9.0		4:00	7.1
	5:00	9.1		5:00	9.0		5:00	7.0
	6:00	9.2		6:00	8.8		6:00	6.9
	7:00	9.2		7:00	8.6		7:00	6.6
	8:00	9.2		8:00	8.5		8:00	6.6
	9:00	9.1		9:00	8.4		9:00	6.8
	10:00	9.0		10:00	8.7		10:00	7.5
	11:00	9.5		11:00	9.2		11:00	8.0
	Noon	9.9		Noon	10.1		Noon	8.7
10/15/87	1:00 PM	10.0	10/17/87	1:00 PM	10.5	10/19/87	1:00 PM	9.1
	2:00	10.0		2:00	11.3		2:00	9.2
	3:00	10.1		3:00	11.5		3:00	9.0
	4:00	10.3		4:00	11.3		4:00	8.9
	5:00	10.3		5:00	11.2		5:00	8.9
	6:00	10.5		6:00	11.1		6:00	8.7
	7:00	10.4		7:00	11.0		7:00	8.5
	8:00	10.4		8:00	10.5		8:00	8.3
	9:00	10.4		9:00	10.2		9:00	8.1
	10:00	10.4		10:00	10.1		10:00	8.0
	11:00	10.4		11:00	10.0		11:00	7.8
	Midnight	10.4		Midnight	9.8		Midnight	7.5

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
10/20/87	1:00 AM	7.4	10/22/87	1:00 AM	4.3	10/24/87	1:00 AM	4.7
	2:00	7.2		2:00	4.1		2:00	4.4
	3:00	7.1		3:00	4.0		3:00	4.3
	4:00	7.0		4:00	3.9		4:00	4.3
	5:00	6.6		5:00	3.8		5:00	4.1
	6:00	6.3		6:00	3.4		6:00	3.9
	7:00	6.0		7:00	3.3		7:00	3.8
	8:00	5.9		8:00	3.0		8:00	3.6
	9:00	5.8		9:00	3.1		9:00	3.6
	10:00	5.8		10:00	3.8		10:00	3.6
	11:00	5.8		11:00	4.3		11:00	3.6
	Noon	5.8		Noon	4.9		Noon	3.8
10/20/87	1:00 PM	5.8	10/22/87	1:00 PM	5.1	10/24/87	1:00 PM	3.9
	2:00	5.8		2:00	5.3		2:00	4.0
	3:00	5.9		3:00	5.3		3:00	4.0
	4:00	5.9		4:00	5.3		4:00	4.0
	5:00	5.6		5:00	5.3		5:00	4.0
	6:00	5.3		6:00	5.3		6:00	4.0
	7:00	5.2		7:00	5.2		7:00	3.9
	8:00	4.9		8:00	5.1		8:00	3.8
	9:00	4.8		9:00	5.1		9:00	3.8
	10:00	4.6		10:00	5.1		10:00	3.7
	11:00	4.4		11:00	5.0		11:00	3.2
	Midnight	4.3		Midnight	4.9		Midnight	3.2
10/21/87	1:00 AM	4.1	10/23/87	1:00 AM	4.9	10/25/87	1:00 AM	1.9
	2:00	3.9		2:00	4.8		2:00	0.5
	3:00	3.8		3:00	4.8		3:00	0.6
	4:00	3.3		4:00	4.7		4:00	1.9
	5:00	3.3		5:00	4.7		5:00	2.0
	6:00	3.1		6:00	4.7		6:00	1.9
	7:00	2.9		7:00	4.5		7:00	1.9
	8:00	3.3		8:00	4.5		8:00	1.9
	9:00	3.7		9:00	4.5		9:00	2.1
	10:00	4.5		10:00	4.5		10:00	2.7
	11:00	4.5		11:00	4.5		11:00	3.1
	Noon	4.5		Noon	4.8		Noon	3.5
10/21/87	1:00 PM	4.9	10/23/87	1:00 PM	5.0	10/25/87	1:00 PM	3.8
	2:00	5.5		2:00	5.0		2:00	4.1
	3:00	5.6		3:00	5.0		3:00	4.3
	4:00	5.7		4:00	5.0		4:00	4.4
	5:00	5.6		5:00	5.0		5:00	4.5
	6:00	5.4		6:00	5.0		6:00	4.5
	7:00	5.1		7:00	4.9		7:00	4.4
	8:00	5.0		8:00	4.9		8:00	4.3
	9:00	4.9		9:00	4.9		9:00	4.2
	10:00	4.8		10:00	4.9		10:00	4.1
	11:00	4.8		11:00	4.9		11:00	4.0
	Midnight	4.5		Midnight	4.8		Midnight	3.9

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
10/26/87	1:00 AM	3.9	10/28/87	1:00 AM	3.7	10/30/87	1:00 AM	5.4
	2:00	3.8		2:00	1.4		2:00	5.3
	3:00	3.7		3:00	1.0		3:00	5.1
	4:00	3.6		4:00	0.0		4:00	5.0
	5:00	3.5		5:00	0.0		5:00	5.0
	6:00	3.5		6:00	0.2		6:00	4.9
	7:00	3.6		7:00	0.2		7:00	4.9
	8:00	3.8		8:00	0.4		8:00	5.0
	9:00	3.8		9:00	1.6		9:00	5.5
	10:00	4.0		10:00	2.6		10:00	6.0
	11:00	4.5		11:00	3.0		11:00	6.5
	Noon	4.9		Noon	3.3		Noon	7.0
10/26/87	1:00 PM	5.0	10/28/87	1:00 PM	3.7	10/30/87	1:00 PM	7.8
	2:00	5.5		2:00	4.0		2:00	8.0
	3:00	5.9		3:00	4.2		3:00	8.0
	4:00	6.1		4:00	4.3		4:00	8.0
	5:00	6.1		5:00	4.4		5:00	7.9
	6:00	5.9		6:00	4.4		6:00	7.3
	7:00	5.6		7:00	4.3		7:00	7.1
	8:00	5.4		8:00	4.1		8:00	7.0
	9:00	5.3		9:00	3.9		9:00	7.0
	10:00	5.5		10:00	3.7		10:00	6.4
	11:00	4.9		11:00	3.7		11:00	6.7
	Midnight	4.8		Midnight	3.6		Midnight	6.5
10/27/87	1:00 AM	4.8	10/29/87	1:00 AM	3.7	10/31/87	1:00 AM	6.4
	2:00	4.4		2:00	3.6		2:00	6.0
	3:00	4.3		3:00	3.5		3:00	5.8
	4:00	5.1		4:00	3.3		4:00	5.7
	5:00	3.9		5:00	3.2		5:00	5.3
	6:00	3.6		6:00	3.0		6:00	5.0
	7:00	3.5		7:00	2.9		7:00	5.0
	8:00	3.4		8:00	2.9		8:00	5.3
	9:00	3.4		9:00	3.3		9:00	5.8
	10:00	3.7		10:00	3.7		10:00	6.4
	11:00	4.1		11:00	4.5		11:00	7.0
	Noon	4.4		Noon	5.0		Noon	7.2
10/27/87	1:00 PM	4.8	10/29/87	1:00 PM	5.7	10/31/87	1:00 PM	7.5
	2:00	5.0		2:00	6.2		2:00	7.6
	3:00	5.0		3:00	6.5		3:00	7.8
	4:00	4.9		4:00	6.7		4:00	7.8
	5:00	4.7		5:00	6.6		5:00	7.8
	6:00	4.5		6:00	6.2		6:00	7.8
	7:00	4.4		7:00	6.3		7:00	7.8
	8:00	4.2		8:00	6.2		8:00	7.8
	9:00	4.0		9:00	6.1		9:00	7.7
	10:00	3.8		10:00	6.0		10:00	7.7
	11:00	3.7		11:00	5.9		11:00	7.7
	Midnight	3.7		Midnight	5.9		Midnight	7.7

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
11/1/87	1:00 AM	7.7	11/3/87	1:00 AM	11.7	11/5/87	1:00 AM	6.1
	2:00	7.7		2:00	11.6		2:00	6.0
	3:00	7.7		3:00	11.6		3:00	5.3
	4:00	7.7		4:00	11.6		4:00	5.1
	5:00	7.7		5:00	11.6		5:00	5.0
	6:00	7.7		6:00	11.5		6:00	4.9
	7:00	7.6		7:00	11.5		7:00	4.9
	8:00	7.6		8:00	11.7		8:00	5.0
	9:00	7.6		9:00	11.8		9:00	5.3
	10:00	7.8		10:00	11.9		10:00	5.9
	11:00	8.0		11:00	12.0		11:00	6.1
	Noon	8.1		Noon	12.1		Noon	6.6
11/1/87	1:00 PM	8.2	11/3/87	1:00 PM	12.2	11/5/87	1:00 PM	6.8
	2:00	8.4		2:00	12.1		2:00	6.9
	3:00	8.5		3:00	12.1		3:00	6.4
	4:00	8.5		4:00	12.1		4:00	6.2
	5:00	8.5		5:00	12.0		5:00	6.0
	6:00	8.5		6:00	12.0		6:00	6.0
	7:00	8.5		7:00	11.9		7:00	5.2
	8:00	8.5		8:00	11.8		8:00	4.9
	9:00	8.6		9:00	11.8		9:00	4.9
	10:00	8.6		10:00	11.7		10:00	4.9
	11:00	8.7		11:00	11.7		11:00	4.9
	Midnight	8.8		Midnight	11.7		Midnight	4.8
11/2/87	1:00 AM	8.9	11/4/87	1:00 AM	11.4	11/6/87	1:00 AM	4.1
	2:00	9.0		2:00	11.1		2:00	4.0
	3:00	9.4		3:00	11.0		3:00	4.0
	4:00	9.2		4:00	10.8		4:00	3.8
	5:00	9.3		5:00	10.6		5:00	3.3
	6:00	9.4		6:00	10.4		6:00	3.6
	7:00	9.4		7:00	10.4		7:00	3.8
	8:00	9.6		8:00	10.4		8:00	4.0
	9:00	10.1		9:00	10.7		9:00	4.9
	10:00	10.8		10:00	10.8		10:00	5.6
	11:00	10.7		11:00	11.0		11:00	6.1
	Noon	10.9		Noon	11.1		Noon	6.5
11/2/87	1:00 PM	11.3	11/4/87	1:00 PM	11.1	11/6/87	1:00 PM	7.0
	2:00	11.6		2:00	10.8		2:00	7.1
	3:00	11.7		3:00	10.4		3:00	6.7
	4:00	11.9		4:00	10.0		4:00	6.3
	5:00	12.2		5:00	9.4		5:00	6.0
	6:00	12.3		6:00	9.0		6:00	6.1
	7:00	12.6		7:00	8.8		7:00	5.9
	8:00	12.6		8:00	8.4		8:00	5.7
	9:00	12.2		9:00	7.8		9:00	5.6
	10:00	12.1		10:00	7.5		10:00	5.4
	11:00	12.0		11:00	7.0		11:00	5.3
	Midnight	11.9		Midnight	7.5		Midnight	5.1

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

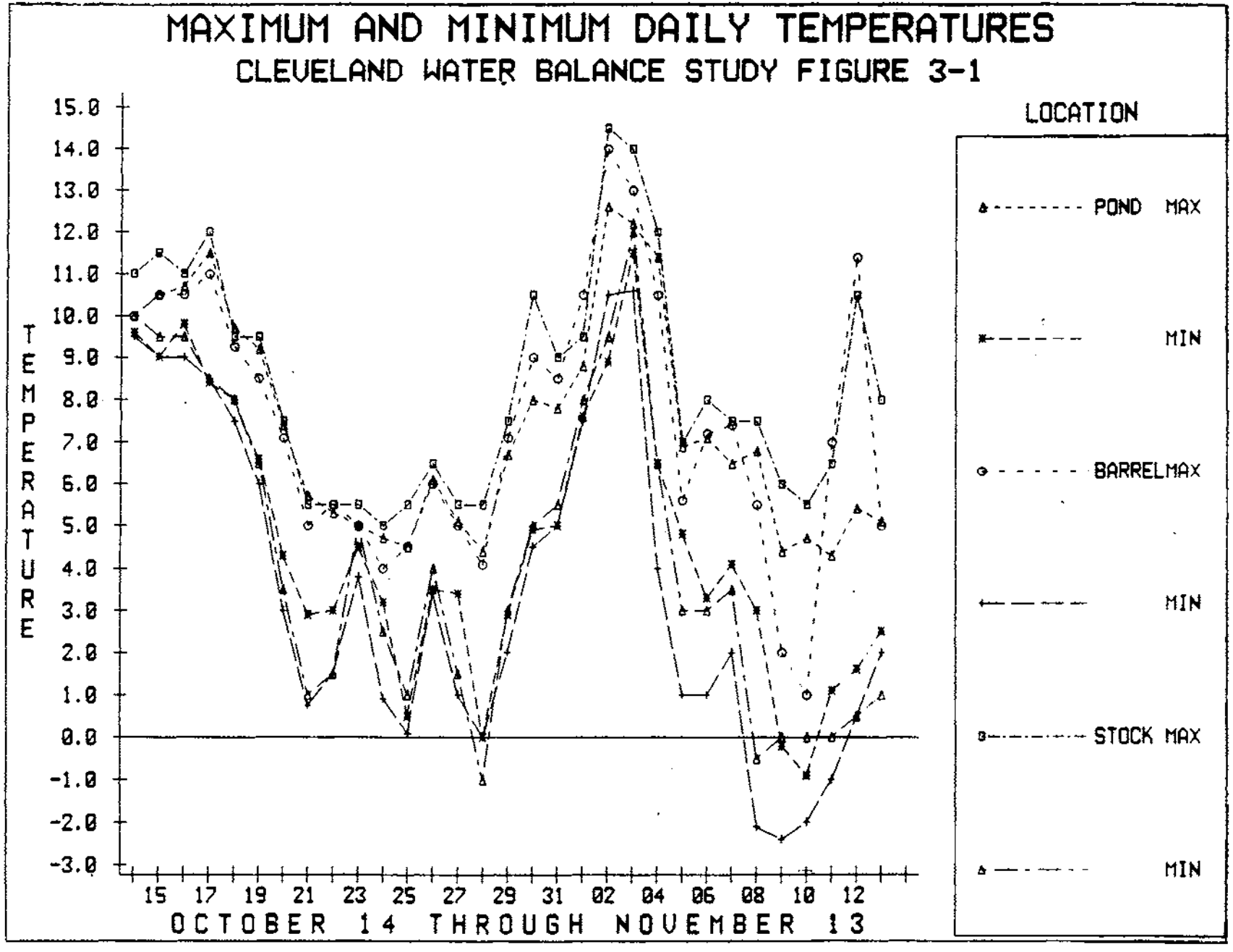
Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
11/7/87	1:00 AM	4.9	11/9/87	1:00 AM	3.4	11/11/87	1:00 AM	1.9
	2:00	4.7		2:00	0.1		2:00	1.7
	3:00	4.6		3:00	0.0		3:00	1.6
	4:00	4.4		4:00	0.0		4:00	1.4
	5:00	4.2		5:00	0.0		5:00	1.1
	6:00	4.1		6:00	0.0		6:00	1.2
	7:00	4.8		7:00	2.1		7:00	1.5
	8:00	4.5		8:00	3.4		8:00	2.0
	9:00	4.7		9:00	3.5		9:00	2.7
	10:00	5.1		10:00	3.9		10:00	3.3
	11:00	5.4		11:00	4.2		11:00	3.7
	Noon	5.7		Noon	4.2		Noon	4.0
11/7/87	1:00 PM	5.9	11/9/87	1:00 PM	4.4	11/11/87	1:00 PM	4.3
	2:00	5.9		2:00	4.0		2:00	3.9
	3:00	6.0		3:00	2.1		3:00	3.0
	4:00	6.0		4:00	1.7		4:00	3.2
	5:00	5.9		5:00	2.0		5:00	3.2
	6:00	6.0		6:00	0.5		6:00	3.2
	7:00	6.0		7:00	0.0		7:00	3.1
	8:00	6.1		8:00	0.0		8:00	3.0
	9:00	6.2		9:00	0.0		9:00	2.9
	10:00	6.4		10:00	0.0		10:00	2.8
	11:00	6.5		11:00	-0.2		11:00	2.7
	Midnight	6.5		Midnight	-0.2		Midnight	1.1
11/8/87	1:00 AM	6.5	11/10/87	1:00 AM	-0.2	11/12/87	1:00 AM	1.8
	2:00	6.3		2:00	-0.2		2:00	1.7
	3:00	6.2		3:00	-0.5		3:00	2.0
	4:00	6.0		4:00	-0.8		4:00	1.6
	5:00	5.8		5:00	-0.9		5:00	1.8
	6:00	5.6		6:00	-0.6		6:00	2.0
	7:00	5.6		7:00	-0.1		7:00	2.3
	8:00	5.5		8:00	0.0		8:00	3.2
	9:00	5.8		9:00	0.1		9:00	4.0
	10:00	6.1		10:00	1.0		10:00	4.9
	11:00	6.4		11:00	2.1		11:00	5.1
	Noon	6.7		Noon	2.8		Noon	5.2
11/8/87	1:00 PM	6.8	11/10/87	1:00 PM	4.7	11/12/87	1:00 PM	5.4
	2:00	6.5		2:00	4.1		2:00	5.3
	3:00	5.9		3:00	2.5		3:00	5.1
	4:00	5.4		4:00	3.3		4:00	5.0
	5:00	5.1		5:00	3.3		5:00	4.8
	6:00	4.9		6:00	3.0		6:00	4.7
	7:00	4.5		7:00	3.1		7:00	4.1
	8:00	4.1		8:00	2.9		8:00	4.0
	9:00	3.8		9:00	2.9		9:00	3.7
	10:00	3.5		10:00	2.8		10:00	3.9
	11:00	3.0		11:00	2.5		11:00	3.6
	Midnight	3.0		Midnight	2.1		Midnight	4.0

TEMPERATURE RECORD OF
CLEVELAND'S PONDS

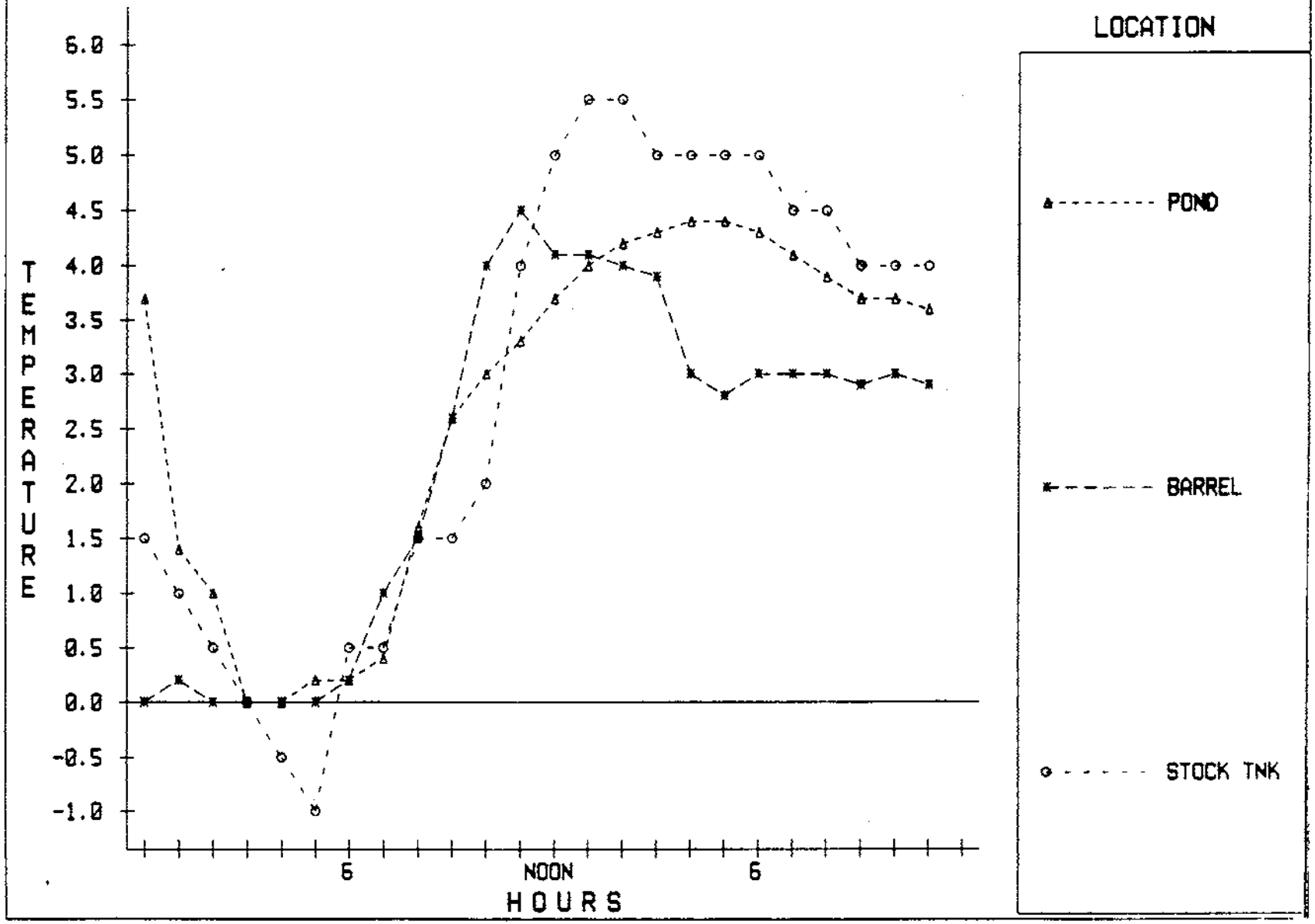
Table 3.1

Date	Time	Temp°C	Date	Time	Temp°C	Date	Time	Temp°C
11/13/87	1:00 AM	3.7		1:00 AM			1:00 AM	
	2:00	3.8		2:00			2:00	
	3:00	2.5		3:00			3:00	
	4:00	3.0		4:00			4:00	
	5:00	3.8		5:00			5:00	
	6:00	3.7		6:00			6:00	
	7:00	4.4		7:00			7:00	
	8:00	5.1		8:00			8:00	
	9:00			9:00			9:00	
	10:00			10:00			10:00	
	11:00			11:00			11:00	
	Noon			Noon			Noon	


MAXIMUM AND MINIMUM DAILY TEMPERATURES
CLEVELAND WATER BALANCE STUDY FIGURE 3-1
TEMPERATURE
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
15 17 19 21 23 25 27 29 31 02 04 06 08 10 12
OCTOBER 14 THROUGH NOVEMBER 13
LOCATION
POND MAX
MIN
BARREL MAX
MIN
STOCK MAX
MIN

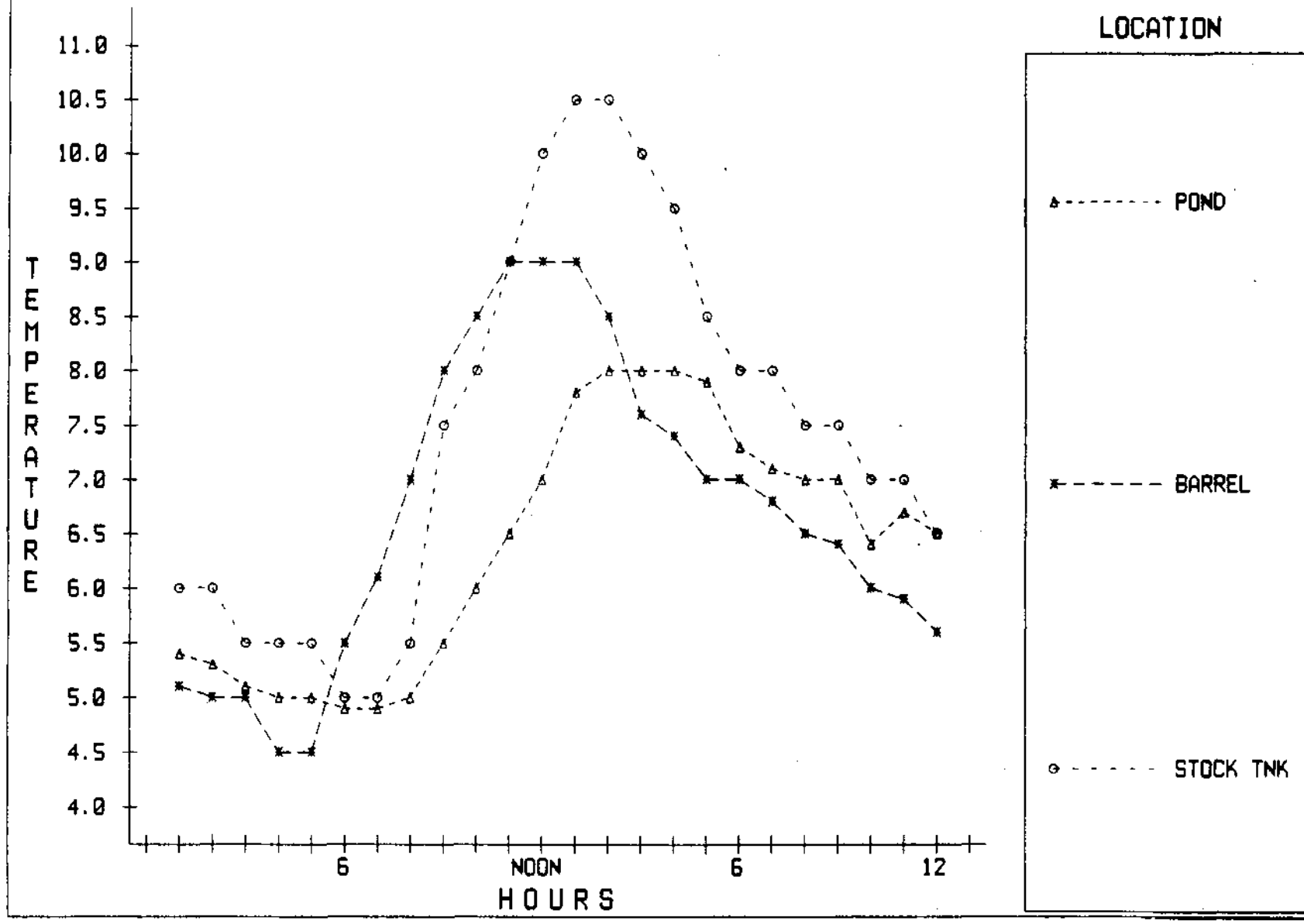
HOURLY TEMPERATURES OCTOBER 28, 1987

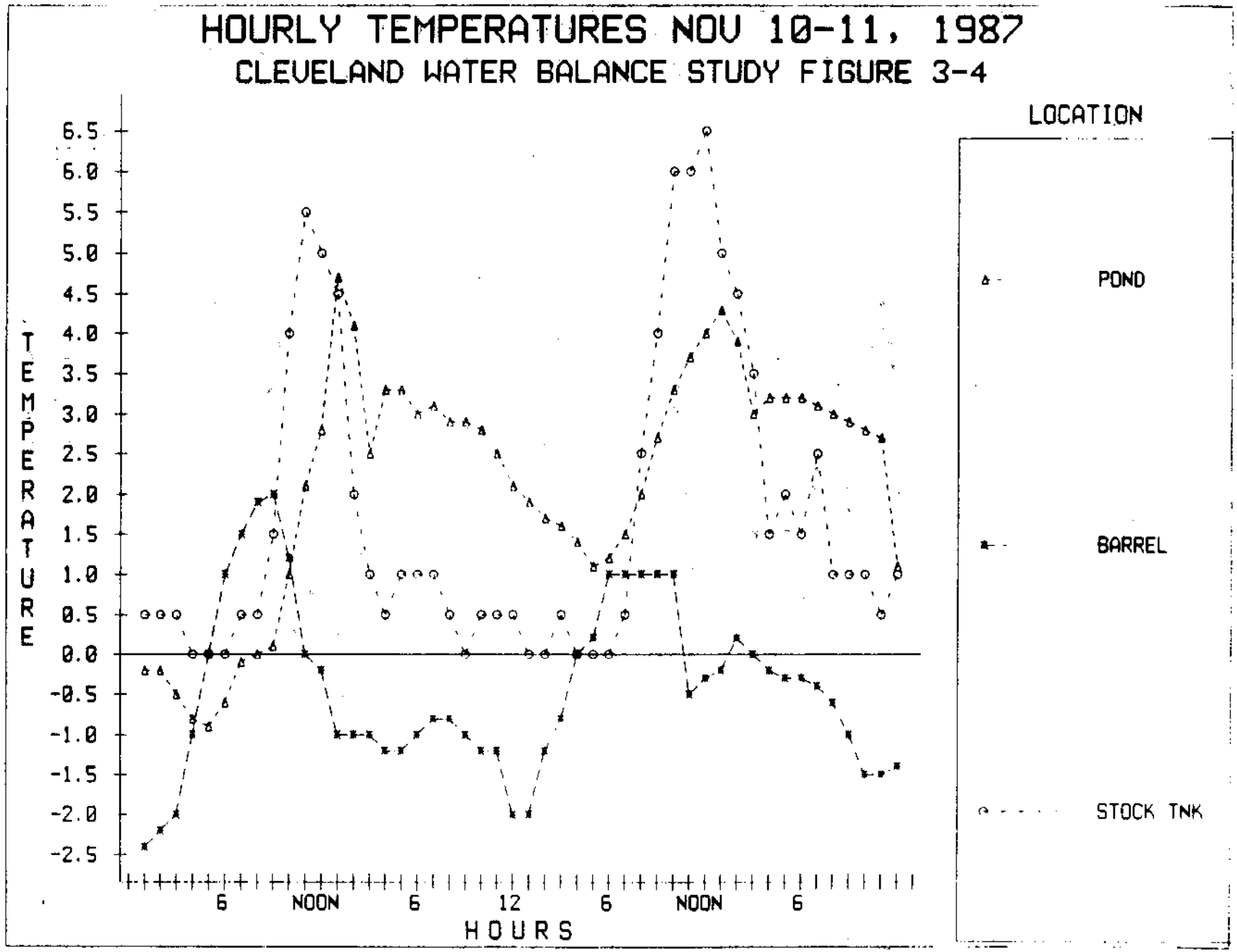
CLEVELAND WATER BALANCE STUDY FIGURE 3-2



HOURLY TEMPERATURES OCTOBER 30, 1987

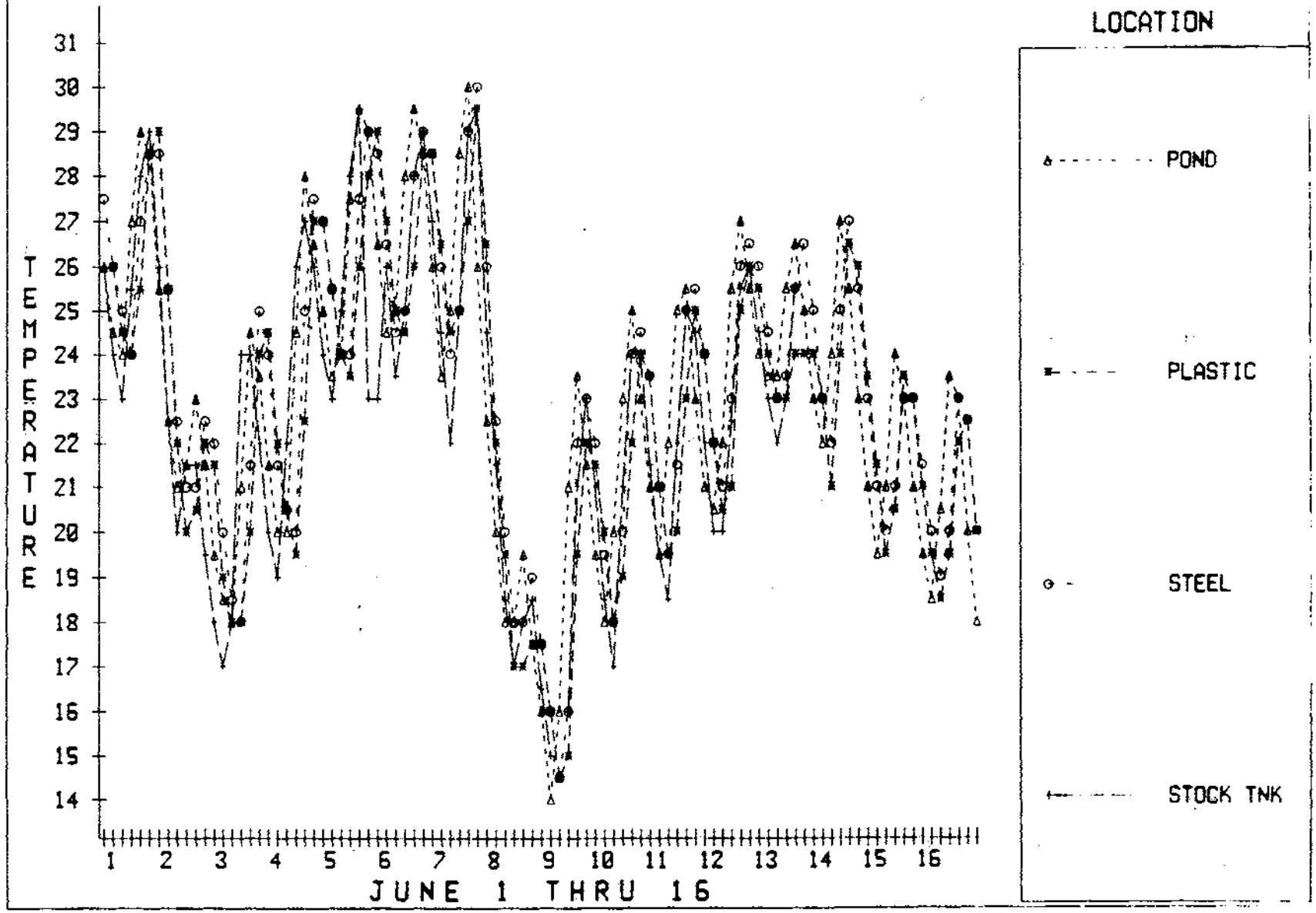
CLEVELAND WATER BALANCE STUDY FIGURE 3-3




HOURLY TEMPERATURES NOV 10-11, 1987
CLEVELAND WATER BALANCE STUDY FIGURE 3-4
TEMPERATURE
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
6
NOON
6
12
6
NOON
6
HOURS
LOCATION
POND
BARREL
STOCK TNK

KETTLE RIVER TEMPERATURE READINGS

KETTLE RIVER WATER BALANCE STUDY FIGURE 3-5



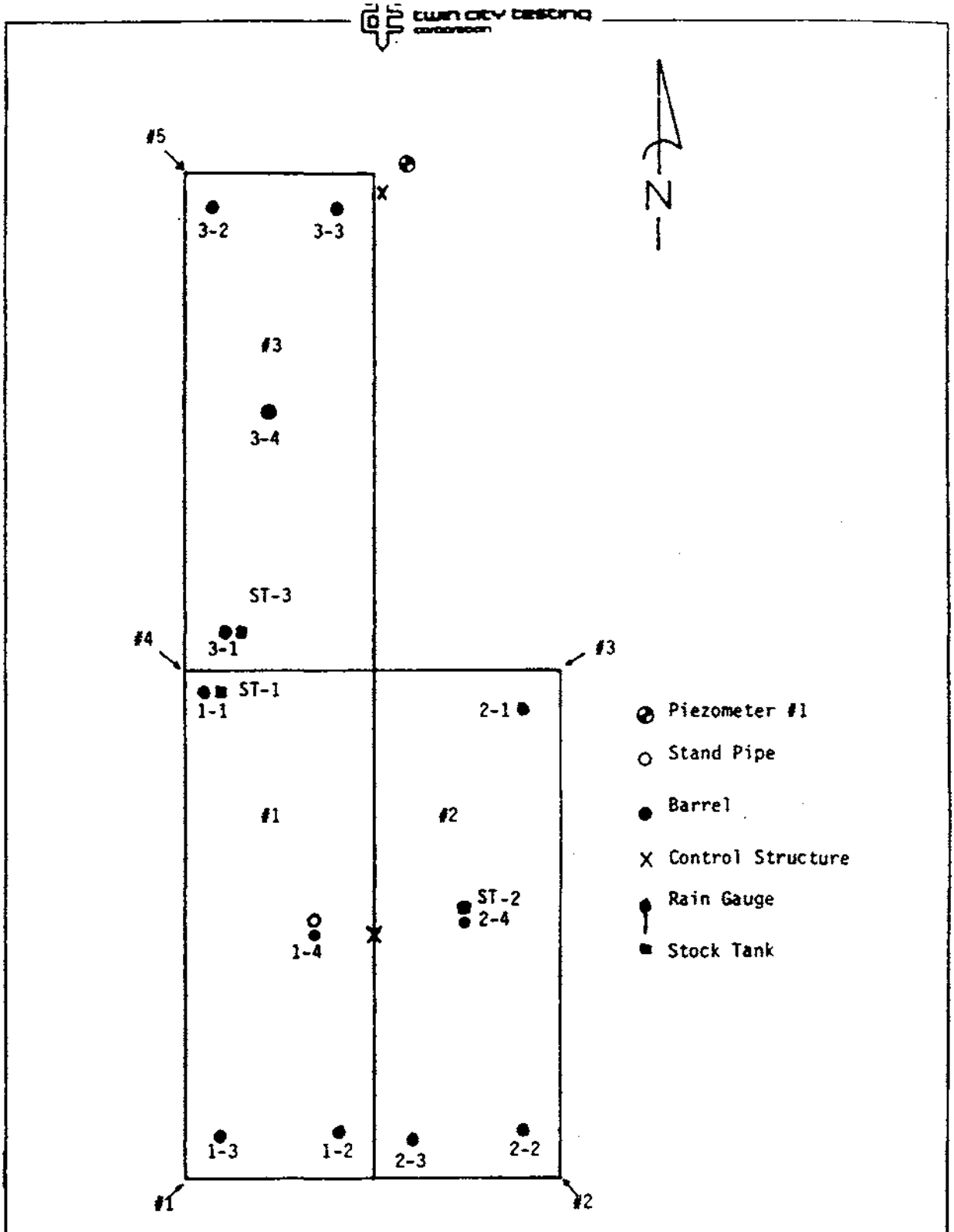


FIGURE 3.6

JOB NO. 4900 87-641	SCALE: 1"=200'	DRAWN BY SG	CHECKED BY MS

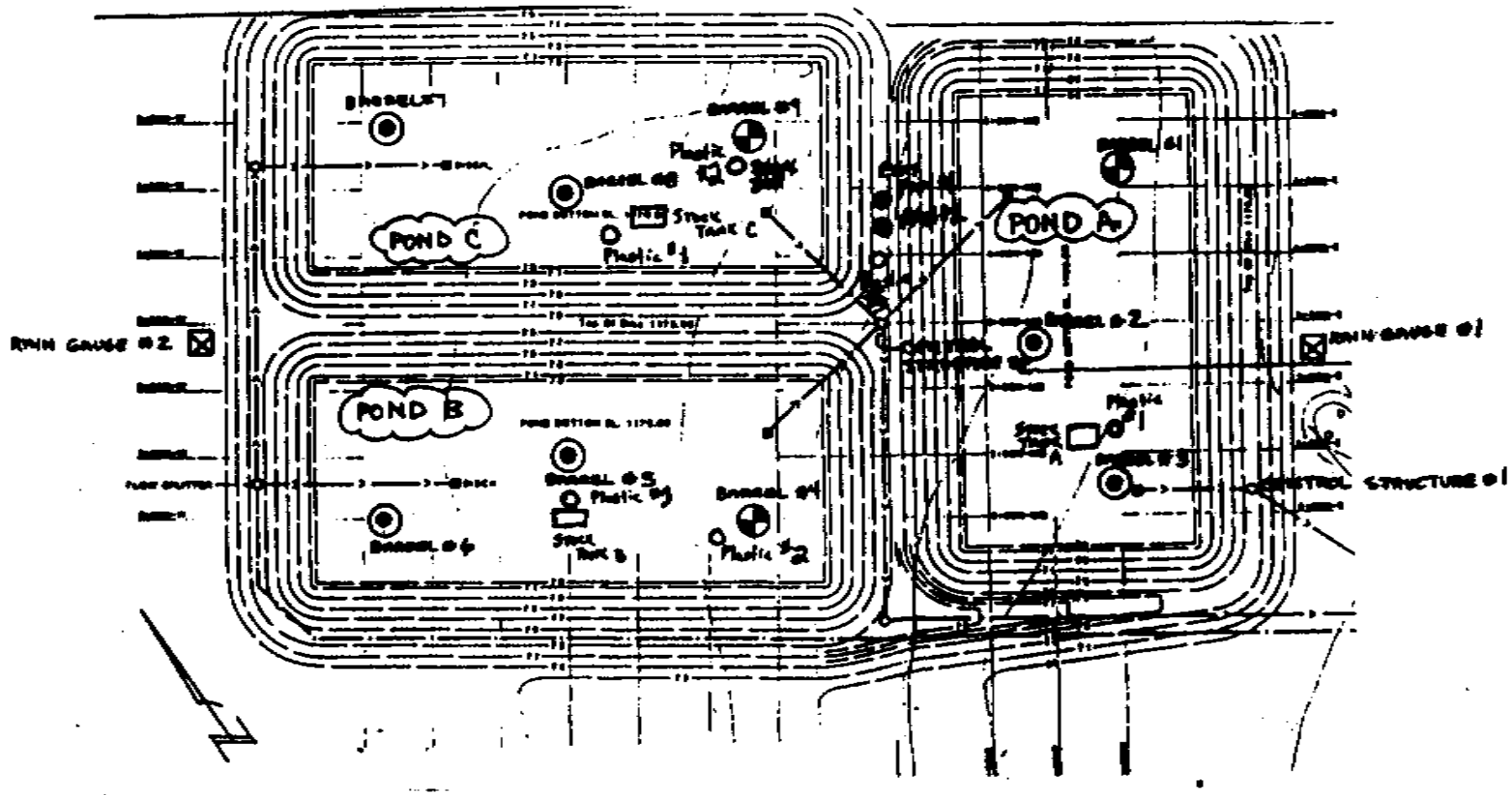


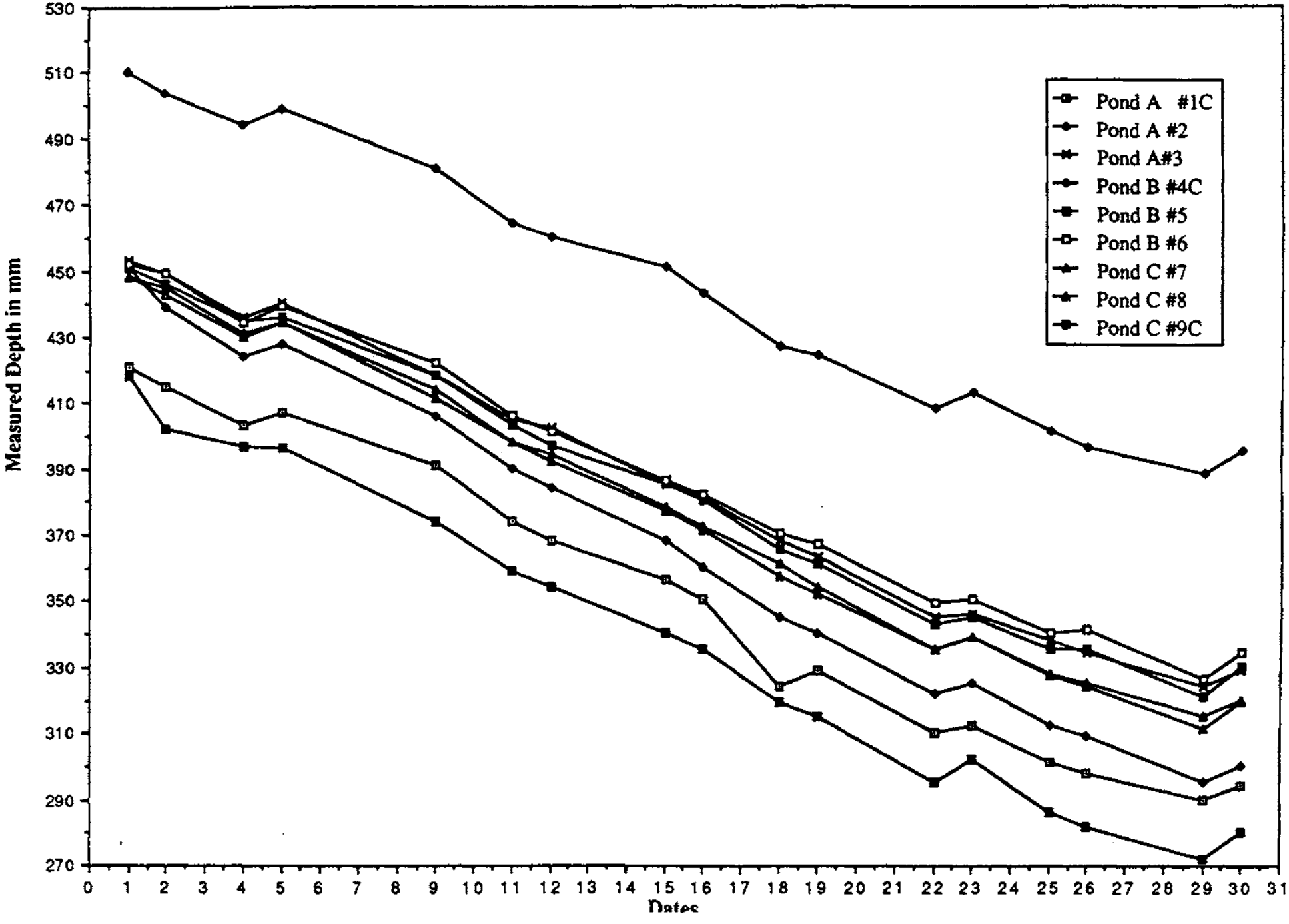
FIGURE 3.7

BRAUN

NBS-01 PROPOSED WATER BALANCE STUDY
Wastewater Stabilization Ponds
Kettle River, MN

Date: 10/12/87
Revised:
Drawn: TRB
Scale: Layout Reduction

Figure 3.8


Water Balance Data from Kettle River, Mn
Measured Depth in mm
Dates
Pond A #1C
Pond A #2
Pond A#3
Pond B #4C
Pond B #5
Pond B #6
Pond C #7
Pond C #8
Pond C #9C
530
510
490
470
450
430
410
390
370
350
330
310
290
270
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

KETTLE RIVER WATER BALANCE DATA RESULTS
FROM THE STUDENT T TEST CALCULATIONS

WATER BALANCE TASK FORCE DECEMBER 1988

Table 3.2

POND & PAN DATA	BARREL TYPE	T TEST NUMBER	n 1 n 2	DEGREE OF FREEDOM	SIGMA	t alpha/2 +/-	T	ASSUME NULL HYPOTH	NUMBER OF BARRELS
POND A EVAP PANS 1 & 2	METAL	# 3	43 23	64	0	2.000	3.316	NO	4
	PLASTIC	# 3	22 23	43	0	2.021	1.033	YES	3
0.6 RESV. COEF.	STOCK	# 3	23 23	44	0	2.020	1.809	YES	3
POND B EVAP PANS 1 & 2	METAL	# 3	43 23	64	0	2.000	3.905	NO	4
	PLASTIC	# 3	42 23	63	0	2.000	0.5932	YES	4
0.6 RESV. COEF.	STOCK	# 3	23 23	44	0	2.020	2.173	NO	3
POND C EVAP PANS 1 & 2	METAL	# 3	46 23	67	0	1.999	3.570	NO	4
	PLASTIC	# 3	44 23	65	0	2.000	2.444	NO	4
0.6 RESV. COEF.	STOCK	# 3	23 23	44	0	2.020	1.961	YES	3
PLASTIC BARREL VERSUS PLASTIC DIKE BARREL	POND A	# 3	23 23	44	0	2.020	-0.6537	YES	2

KETTLE RIVER WATER BALANCE DATA RESULTS
FROM THE STUDENT T TEST CALCULATIONS

WATER BALANCE TASK FORCE DECEMBER 1988

Table 3.2

POND	BARREL TYPE	T TEST NUMBER	n 1 n 2	DEGREE OF FREEDOM	SIGMA	t alpha/2 +/-	T	ASSUME NULL HYPOTH	NUMBER OF BARRELS
A & C	METAL	# 4	46 46	90	0	1.990	0.141	YES	4
	PLASTIC	# 3	22 45	65	0	1.999	-0.497	YES	3
	STOCK	# 4	23 23	44	0	2.020	-0.076	YES	2
B & C	METAL	# 4	46 46	90	0	1.990	-0.328	YES	4
	PLASTIC	# 3	42 45	85	0	1.995	-0.209	YES	4
	STOCK	# 4	23 23	44	0	2.020	-0.315	YES	2
A,B & C	METAL PLASTIC	# 2	138 108	244	0	1.960	Z -2.459	NO	11
	METAL STOCK	# 2	138 69	205	0	1.960	Z -1.006	YES	9
	PLASTIC STOCK	# 2	69 108	175	0	1.960	Z -1.174	YES	8
EVAP PANS 1 & 2	0.6 COEF EVAP	# 4	11 12	21	0	2.080	-0.084	YES	2
	0.7 COEF EVAP	# 4	11 12	21	0	2.080	-0.084	YES	2
	0.8 COEF EVAP	# 4	11 12	21	0	2.080	-0.084	YES	2

KETTLE RIVER WATER BALANCE DATA RESULTS
FROM THE STUDENT T TEST CALCULATIONS

WATER BALANCE TASK FORCE DECEMBER 1988

Table 3.2

POND	BARREL TYPE	T TEST NUMBER	n 1 n 2	DEGREE OF FREEDOM	SIGMA	t alpha/2 +/-	T	ASSUME NULL HYPOTH	NUMBER OF BARRELS
A	METAL	# 4	23 23	44	0	2.020	0.566	YES	2
	PLASTIC							YES	1
	STOCK							YES	1
B	METAL	# 4	23 23	44	0	2.020	0.080	YES	2
	PLASTIC	# 4	21 21	40	0	2.021	0.261	YES	2
	STOCK							YES	1
C	METAL	# 4	23 23	44	0	2.020	-0.019	YES	2
	PLASTIC	# 3	23 22	43	0	2.020	-1.168	YES	2
	STOCK							YES	1
A & B	METAL	# 4	43 43	84	0	1.970	0.461	YES	4
	PLASTIC	# 4	22 42	62	0	2.000	0.469	YES	3
	STOCK	# 4	23 23	44	0	2.020	-0.315	YES	2

4. SUMMARY OF RESPONSES TO QUESTIONNAIRE

A questionnaire for determination of what other regulatory agencies are doing to estimate seepage from wastewater treatment ponds, was sent to the 48 contiguous states, Alaska and the twelve provinces of Canada. After an initial response period, the task force members contacted all nonresponding agencies to make sure they had received the questionnaire and to ask whether the agency still wished to participate in the survey. Some questionnaires were filled out by the task force subgroup by phone. A total of 41 responses were received, including Minnesota.

Due to the nature of some of the questions and the fact that some states and provinces do not build ponds or do not participate to much degree in evaluating seepage rates, all the states do not have responses to all the questions. The summary generally counts a positive response. Other notes are made for each item in the questionnaire. Copies of the questionnaires received are available for review at the MPCA. The following are the questions asked, with a summary of the responses received.

#1 What is the current maximum allowable seepage rate for new stabilization ponds? Existing ponds?

The following was reported in gallons/acre/day or in inches equivalent to this:

gallons/acre/day	227	500	850	1000	1700	3400	4300	6800
no. of agencies	1	10	1	2	1	3	1	3

Five responded by specifying a permeability or hydraulic conductivity (K) of 1×10^{-7} cm/sec and do not specify a minimum liner thickness. One of these also specified a minimum liner thickness of 2 feet in conjunction with the K. Six responded by stating that they do not build ponds. The other seven responses ranged from none, to varies with ground water quality, and 20% of the inflow.

Responses about existing ponds were in three groups: The first group (twenty) could be characterized by the response of no maximum allowable seepage rate specified/case by case basis determination/or non-degradation requirements. A second group (fourteen) responded with the same requirements as new ponds. The third group (five) allowed seepage greater than new ponds - usually 1/4 to 1/16 of an inch which is approximately 1700 to 3400 gal. per acre per day.

#2 Is this rate based on state rules and regulations or agency policy?

	Rules and Regulations	Both	Agency Policy (design standards & guidelines)
No. of Agencies	9	1	23

#3 What testing methods do you allow and/or require to determine whether the seepage rate has been properly obtained? What party conducts these tests . . . engineers, contractor, soils testing firm, etc.?

The responses can be divided into the following categories: Of the Water Balance type (measuring infiltration over the whole area), we have Barrel or Evaporation pan and meteorological data collection. Eight responses indicated they would use or allow the barrel test and 14 would use the evaporation pan method. Two of these indicated they would use a floating pan.

For ASTM testing methods, there were 16 favorable responses. Other methods mentioned were in-situ permeameter, and ground water monitoring. Two responses indicated nothing specific was used. Two other responses indicated it was up to the engineer and stated in the specifications.

The second part of this question indicated that five agencies have the engineer assisted by the contractor, do the testing. Sixteen had the engineer in conjunction with an independent soil firm do the testing. One agency responded that the owner/contractor do the testing.

#4 & #5 If water balances are used, how are rainfall and evaporation determined and used in determining the seepage rate? If the barrel method is used to measure evaporation/rainfall, what type of correction, if any, is used between the barrel and the pond to determine the seepage rate?

These two items are grouped together because of the nature of the responses. As indicated in #3, it seemed that the water balance was taken to mean the use of the barrel or collection of meteorological data. Ten responses indicated they would use some version of collection of precipitation and evaporation data using evaporation pans. Idaho sent very detailed requirements and a description of how to calculate results. Nine agencies would use or allow the use of the barrel method. Five agencies indicated direct correlation for either method.

#6 What is your agency's role in quality control relating to the test and the testing techniques?

Generally, the response to this item indicates no role in quality control. A few responses indicated that they have some quality control by reviewing and approving the plans and specifications. Three responded that some observation of testing was done through construction inspection.

#7 Do you allow or require engineers to use performance specifications, prescriptive specifications, or both for new stabilization ponds which must not exceed a specific seepage rate?

We felt the answers to this question were difficult to interpret. In general, the choice was not made between the words allow or require. Require was used in 11 responses. They were divided as follows: performance - 7, prescriptive (design) - 1, both - 3. When the word require was not stated, we interpreted this to mean allow. The results were performance - 11, prescriptive (design) - 5, and both - 13.

#8 Approximately how many new pond systems are installed each year? Approximately what percentage of these fail to meet the proper seepage rate?

Under this question, some agencies included lagoons for livestock manure or stated "all categories," which would include industrial. Some separated grant from nongrant. We created some groups of ranges for these numbers of ponds constructed per year.

No. of Ponds	1-3	4-10	11-20	25	100-125
Agencies	9	10	9	2	2

Of these, the range given for failure rate was:

No. of Ponds Failing	0-10%	10-25%	30-50%	Unknown
Agencies	7	3	3	13

Other responses included were: any failures are corrected, 15-30% need extra effort, and all are synthetic.

#9 Approximately how many existing ponds are tested each year? Approximately what percentage of these fail to meet the proper seepage rate?

There was little response to this question. It would appear not much is done in the line of testing older ponds for seepage.

#10 Do you have strict guidelines for your agency's staff to use when reviewing seepage rate data to determine whether the proper rates have been obtained? Who reviews the seepage reports? Do these reviewers have flexibility to use their discretion, judgement or risk analysis in determining if the seepage rate was properly met?

Four agencies do and nineteen do not have strict guidelines for review of reports.

Fourteen indicated reviews done by the agency's project engineer or field staff/inspection department. Three stated that no one did reviews. Two had reviews done by consulting engineers. Two other stated it varies.

Seventeen indicated staff had discretion, while one replied they did not.

#11 What corrective measures must be taken if the seepage rate fails to meet the prescribed limits? Please list some examples of what has been done to correct a problem situation.

The following responses were given:

- additional seepage control/whatever is necessary to meet specifications
- N/A - little regulatory control
- engineers discretion
- negotiation
- no final payment
- no measures specifically required
- depends on the specific situation
- seams are corrected after failing

Examples of methods used to correct a problem were:

- dewater and reline
- bentonite slurry or drain and mix bentonite in soil
- drain, recompact and cover with asphalt
- cement/concrete
- additional soil or soil importation
- drainage interceptor trenches with pumping
- cutoff walls
- chemical sealant
- abandon lagoon
- synthetic collars around structures
- attempt by engineer to show that fractured bedrock in a steep sided lagoon was impermeable
- improved surface drainage
- purchase adjoining land

#12 Have any court cases resulted due to a pond not meeting the proper seepage rate? If so, what was the outcome of the case(s)?

No Court Case	Have Court Case	Settled Out of Court
23	5	6

Four of the 5 responding "yes," indicated pending decisions or still in court, while one stated the engineer had to disperse the costs.

The Task Force was interested in the legal aspects with regard to performance and/or descriptive (prescriptive) specifications. Interest in this aspect of pond construction by the MPCA stems from our requirements for using both descriptive and performance specifications. In other words, if both are used, how is this treated in court if a contractor meets one and not the other? We were able to contact five of the six agencies reporting cases, however, none of the cases pertained to descriptive and/or performance specifications. So, the states and provinces which stated they had a court case were contacted again.

In the case for which it was stated that the engineer had to disperse the costs, the ponds visibly leaked.

#13 Do you have specific guidelines on how the tests must be run, data collected, and results submitted? If you have any written rules, guidelines or criteria related to seepage rates, seepage test procedures, specific soil requirements for liner construction, etc. Please enclose copies of them when you return the survey.

No	Yes	Some
3	18	1

The following is a list of the states and provinces responding to the questionnaire.

Utah
Colorado
Virginia
Illinois
British Columbia
Alaska
Michigan
Manitoba
Rhode Island
Kentucky
Massachusetts
Saskatchewan
New Hampshire
Maine
Idaho
New York
Wisconsin
Missouri
Florida
Montana
Alabama
Georgia
Texas
Kansas
Oklahoma
Quebec
North Dakota
Alberta
Iowa
Wyoming
New Brunswick
Pennsylvania
North Carolina
Nebraska
West Virginia
Mississippi
Delaware
Connecticut
Newfoundland/
Labrador
Nevada

5. ASSESSMENT OF COMBINATION PERFORMANCE/PRESCRIPTIVE SPECIFICATIONS

Introduction

In the 1960's and early 1970's, stabilization pond design criteria required only that pond seal maintain a satisfactory water level in the pond. Since 1975, Minnesota stabilization pond design criteria has required that pond liners limit seepage to a maximum rate of 500 gallons per acre per day. This seepage rate was set in an attempt to minimize groundwater contamination. This current allowable maximum seepage rate is equivalent to one inch of seepage every 54 days.

Historically, stabilization pond designers have written combination performance/prescriptive specifications (i.e., simultaneous use of performance and prescriptive specifications). The performance specification required the completed stabilization ponds to meet the maximum allowable seepage rate, with the rate determined by the Minnesota Water Balance Test. The prescriptive specification, also known as a "design" or "detail" specification, specifically established minimum work procedures and tasks necessary to construct the stabilization pond seals. Unfortunately, when both performance and prescriptive requirements are cited, the potential for conflict is present.

The Water Balance Task Force completed a study of the implications of using combination performance/prescriptive specifications for stabilization pond liners. The major issues researched included:

- Evaluation of responsible parties involved in stabilization pond construction.
- Potential problems associated with simultaneous use of performance and prescriptive specifications.
- Legal implications of using combination specifications.
- Alternatives to simultaneous use of performance and prescriptive specifications.
- Identification of possible improvements to the current practice.

The following contains a discussion of each of these major issues.

Evaluation of Responsible Parties

In a typical stabilization pond situation, many parties share responsibility for a project's success or failure. Obviously, the Engineer that designs and the Contractor that builds a stabilization pond share primary project responsibility. However, the Engineer typically will rely upon a goetechnical subconsultant to provide specialized expertise - especially on clay sealed pond projects. The Contractor, likewise, may use subcontractors to construct portions of the work. Typically, an earthwork subcontractor may construct a clay liner or an experienced synthetic membrane liner installer may construct ponds sealed with man-made materials. In addition, the MPCA is indirectly involved in the design of stabilization ponds through creation of design guidelines and review of project plans and specifications. And, of course, the City, as the owner and permit holder, is always responsible for achieving a properly constructed project.

Potential Problems

Generally, there are only two types of stabilization pond performance tests - comprehensive tests, such as the Minnesota Water Balance Test, and spot tests, such as permeability tests for clay liners and seam tests for synthetic membrane liners. Unfortunately, both types of performance tests have good as well as bad points.

The most significant bad aspect of the water balance test is that a large number of factors may combine to yield a large standard deviation. The factors which contribute to the deviation include water level measurement errors, rainfall runoff assumption errors, and evaporation rate differences between the ponds and the barrels. The most significant good aspect of the water balance test is that the entire liner is tested.

Spot tests do not test the entire seal but the deviation range is much smaller at the spot tested. The margin for error is reduced as the the number of spot tests is increased, but some potential margin for error is inherent with all spot test methods. Spot test errors are typically due to the non-homogeneous nature of clay soil liners and the non-uniform seam quality typically found on synthetic membrane liners.

Therefore, both types of stabilization pond performance testing have a deviation range and for this reason, it is possible for projects to appear to exceed specified performance limit - even though the project is designed, specified, and constructed properly. Conversely, it is also possible for projects to appear to meet the specified performance limit - even though the pond system may be leaking. Due to the margin of error of pond performance tests, as described in the above scenarios, the potential for conflict between performance and prescriptive tests always exists.

Legal Implications

The primary concern of all responsible parties is whether corrective work is legally enforceable in the following situation. A Contractor may perform all prescriptive requirements perfectly, all interim testing may indicate acceptable work, all inspections may look good, and the Engineer's specification may not be faulty, but still the final water balance test may indicate that the ponds appear to exceed the maximum allowable pond seepage rate. The Contractor at this point would not have met the performance requirements of the specification, would be required to correct the problem, and would need to retest the pond to prove compliance with the performance specification. The source of the excessive seepage is unknown (and possibly may not be present), the cost of trying to locate, correct, and retest a failing pond may be very great.

Attorneys David Sand and Thomas Larson, of the law firm of Briggs and Morgan, addressed this specific question at the November 18, 1987 meeting of the CEC/MPCA Water Balance Task Force. They stated that in cases where both prescriptive and performance requirements were specified, the tendency of the legal system is to provide relief to a Contractor who had properly met all detailed requirements of the contract, but was unable to meet the performance

requirement. Also, in cases of specification ambiguity, relief is generally provided to the Contractor, because he did not prepare the specifications. The remaining parties, the City, Engineer, Geotechnical Subconsultant, and MPCA, may then become directly responsible for correcting pond systems which appear to be leaking.

The legal implications, therefore, of simultaneously using performance and prescriptive specs, are undesirable. This is especially true for stabilization ponds, because the reliability of the various performance test methods unquestionable. Therefore, the simultaneous use of both performance and prescriptive specifications on stabilization pond projects could create a situation that is difficult to enforce. The question remains is there on acceptable alternative?

Alternatives

The most apparent alternatives to the simultaneous use of performance and prescriptive specifications is exclusive use of one or the other.

A performance specification without prescriptive requirements is not an acceptable alternative because we lack suitable performance tests and it provides the Contractor too many options and doesn't provide the Engineer/Owner/MPCA adequate control over the project. Contractors faced only with a performance specification may have the option to construct a liner from on-site soils, borrow materials, or synthetic membrane materials. The risk is too great that a contractor selected by the low bid system would build a project that didn't work, then go bankrupt and result in loss of time and money for the City, MPCA and EPA. As the construction progressed and/or as the construction was completed, performance tests would be conducted to determine whether the project met the specified performance criteria. Due to the margin of error of water balance testing methods, the performance testing may not accurately reflect the actual seepage rate of the pond system. For the above reasons, exclusive use of performance specifications would not be acceptable.

Contractors faced only with a prescriptive specification would be required to follow specified steps and/or procedures during construction of the project. Continuous inspection would be provided to ensure that each of the steps and procedures is performed properly. This type of specification would not require performance test criteria to be met.

The basic problem with this type of specification is an inability of the responsible parties to prove that the completed pond system does not negatively impact the underlying groundwater. State rules require non-degradation of ground water and the success of a project is determined to a large extent by verification of non-degradation. Exclusive use of prescriptive specifications is not an acceptable alternative because only a small percentage of the total project is spot tested.

Therefore, since exclusive use of either performance or prescriptive specifications does not appear to be a viable alternative, the responsible parties associated with pond projects must attempt to reduce the possible problems associated with simultaneous use of performance and prescriptive specifications.

Possible Improvements to Current Practice

Assuming that the current practice of specifying both performance and prescriptive requirements will continue, it is important that steps be taken to minimize the possibility of incorrectly assessing success or failure of stabilization pond projects. To reduce this possibility, it is imperative that the current pond seal performance criteria be evaluated and revised as necessary.

Currently, pond seal performance is evaluated by use of the Minnesota Water Balance Test. Therefore, an obvious first step toward accurately evaluating pond seal performance would be to increase the accuracy of all component factors involved in water balance tests. Methods for standardizing the test are contained in Chapter 8.

Some prescriptive specifications spot indicators of pond seepage rates include gradation tests, moisture content tests, field density tests, plasticity indices, Atterburg Limits, lab or field permeability tests, and visual inspection of clay liner installations. Synthetic membrane liners, spot indicators include physical property tests on the liner, lab or field seam tests, and visual inspections. The minimum spot indicators, as recommended by the MPCA, are contained in other publications concerning pond design. Improvements in these spot indicators can be made as deficiencies are identified.

In summary, many parties share responsibility for successful stabilization ponds, either directly or indirectly. It is possible for projects to appear to exceed the maximum allowable seepage rate, even though the project is designed, specified, and constructed properly. Conversely, it is also possible for projects to appear to meet the specified performance limit, even though the pond system may be leaking.

The legal implications of using combination performance/prescriptive specifications are undesirable, but no viable alternatives have been identified. Therefore, it is essential to improve the accuracy of the water balance tests, carefully analyze the reliability of the test, and develop spot testing methods to evaluate stabilization pond performance.