# Performance Assessment of the Toronto Eastern Beaches Detention Tank - Toronto, Ontario

2004

Ministry of the Environment
Ontario

TORONTO

# PERFORMANCE ASSESSMENT OF THE EASTERN BEACHES DETENTION TANK

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# TORONTO, ONTARIO

a report prepared by the

STORMWATER ASSESSMENT MONITORING
AND PERFORMANCE (SWAMP) PROGRAM

for

Great Lakes Sustainability Fund
Ontario Ministry of the Environment
Toronto and Region Conservation Authority
Municipal Engineers Association of Ontario
City of Toronto

July, 2004

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An earlier version of this report and various memoranda on specific technical issues related to this project were prepared by SWAMP. Additional data analysis and interpretation, probabilistic modeling and report editing/writing were undertaken by Lijing Xu and Barry J. Adams from the University of Toronto's Department of Civil Engineering under contract to the SWAMP program, as represented by the City of Toronto.

## PUBLICATION INFORMATION

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## THE SWAMP PROGRAM

The Stormwater Assessment Monitoring and Performance (SWAMP) Program is an initiative of the Government of Canada's Great Lakes Sustainability Fund, the Ontario Ministry of the Environment, the Toronto and Region Conservation Authority, and the Municipal Engineer's Association. A number of individual municipalities and other owner/operator agencies have also participated in SWAMP studies.

Since the mid 1980s, the Great Lakes Basin has experienced rapid urban growth. Stormwater runoff associated with this growth has been identified as a major contributor to the degradation of water quality and the destruction of fish habitats. In response to these concerns, a variety of stormwater management technologies have been developed to mitigate the impacts of urbanization on the natural environment. These technologies have been studied, designed and constructed on the basis of computer models and pilot-scale testing, but have not undergone extensive field-level evaluation in southern Ontario. The SWAMP Program was intended to address this need.

The SWAMP Program's objectives are:

* to monitor and evaluate new and conventional stormwater management technologies; and
* to disseminate study results and recommendations within the stormwater management industry.

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Additional information concerning SWAMP and the supporting agencies is included in Appendix A.

## ACKNOWLEDGEMENTS

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- the Government of Canada's Great Lakes Sustainability Fund,
- the Ontario Ministry of the Environment,
- the Toronto and Region Conservation Authority,
- the Municipal Engineers Association of Ontario.

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The following individuals provided technical advice and guidance:

- Dale Henry — Ontario Ministry of the Environment
- Sonya Meek — Toronto and Region Conservation Authority
- Pat Chessie — City of Toronto
- Carmelo Pompeo — City of Toronto
- Sandra Kok — Great Lakes Sustainability Fund, Environment Canada
- Peter Seto — National Water Research Institute, Environment Canada
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# EXECUTIVE SUMMARY

## Background and Objectives

The City of Toronto has a long history in combating wet weather flow pollution in the form of combined sewer overflows and separated stormwater runoff. Particularly, much effort has been spent to improve the recreational value of the beaches within the City area by protecting the near-shore water from the pollution of uncontrolled discharges from storm sewers and combined sewer overflows. One of the many measures employed by the City to mitigate this source of water pollution is that of detention facilities. The Maclean Avenue detention tank (Figure 1), which was put into operation in 1995, is one such measure implemented to decrease the adverse impacts of both stormwater and CSOs in the Eastern Beaches area.

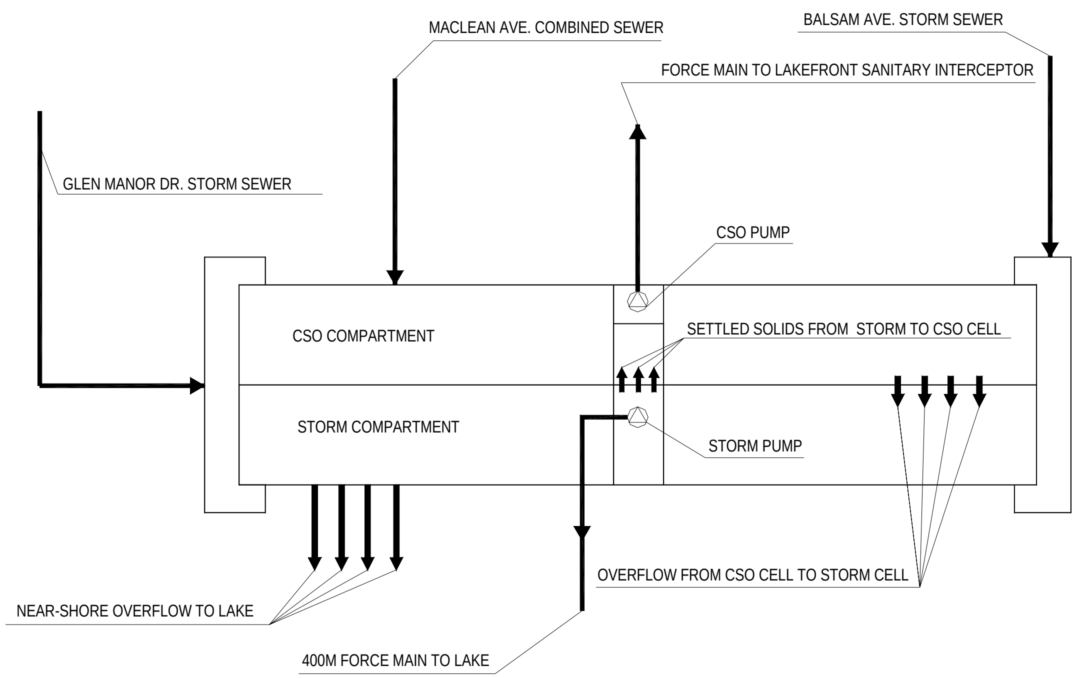


***Figure 1:*** Schematic of the Maclean Avenue detention tank

The Tank is located at the south end of Maclean Avenue in the Eastern Beaches area between Glen Manor Drive and Balsam Avenue and has a total storage volume of 8000 $m^3$. Currently, the total tank storage volume of 8000 $m^3$ is equally divided into two compartments: a combined sewer overflow (CSO) control compartment and a stormwater control compartment. The CSOs are collected and detained in the CSO compartment and pumped to the Lakefront Interceptor (LFI) when capacity in the interceptor is available to convey them to the treatment plant. An overflow from the CSO compartment to the storm compartment may occur if the CSO volume is greater than the storage volume. The storm compartment receives and detains stormwater for an 8-hour period after the runoff event ceases. After detention, the supernatant is pumped 400 m off-shore to Lake Ontario and the subnatant is drained to the CSO compartment and eventually conveyed to the treatment plant. When the water level in the storm compartment rises to a certain height during the runoff event, the storm pump is initiated to pump the excess runoff 400 m off-shore to the Lake. If the water level rises to the weir height then a near-shore overflow is triggered through the weir to the Lake. In the future, when the Kingswood Trunk Relief Sewer (KTRS) along Queen Street East is constructed, the proposed KTRS will be oversized to provide in-line storage for the CSOs currently discharged to the tank. As a result, the Maclean Avenue detention tank would ultimately receive stormwater only. The two compartments would be interconnected, and the settled sludge after the detention would be pumped to the LFI for further treatment at the Ashbridges Bay treatment plant.

Since field data on the performance of underground detention facilities are scarce, a monitoring program was undertaken under the auspices of the Stormwater Assessment Monitoring and Performance (SWAMP) program on the Maclean Avenue tank from July 1995 to December 1996, to collect inlet and outlet water samples from the tank for analysis of the influent and effluent water chemistry. Monitoring equipment installed in the tank by the City recorded water depths every five minutes in the tank during a runoff event after the tank was put into operation. In order to bring the Eastern Beaches detention tank study to a conclusion, the present work has the following objectives:

- Based on the data available, conduct an assessment of the pollution control performance of the Eastern Beaches Detention Tank, both on an event-by-event basis as well as on a continuous basis.
- Ascertain whether the facility is sized appropriately in relation to its control frequency requirements.

**Monitoring Program and Data Analysis Protocol**

After the tank was put into operation in 1995, equipment was installed to record water depths in the tank every 5 minutes during each runoff event year-round, with data records maintained by City staff. Based on these data and the system geometry, quantities such as the total runoff volume, the detained runoff volume, and the overflowed runoff volume can be calculated event-by-event; consequently, tank performance measures on runoff quantity control can be obtained either on event basis or yearly basis.

With the City providing the flow monitoring data, SWAMP staff focused on other monitoring components that include influent and effluent water chemistry, water toxicity and sediment analysis. Since the 1995 water quality data were judged to be invalid, water quality data monitored for the entire year in 1996 are used in this study. Influent and effluent Event Mean Concentrations (EMCs) of pollutants are obtained and tabulated.

Statistical analyses are conducted with consideration of seasonal factors. According to the influent and effluent pollutant EMCs and runoff quantity monitoring data in 1996, pollutant mass loads into the system and out of the system are calculated and the tank performance effectiveness for pollutant removal can be subsequently obtained. Performance of the storm compartment of the Maclean Avenue detention tank is evaluated based on two scenarios: a "system" performance scenario and a "tank" performance scenario. The "system" scenario considers the influence of overflows on the tank performance while the "tank" scenario only evaluates the pollutant mass removal of the portion of runoff captured and detained by the tank. Therefore, the "tank" scenario allows an evaluation of the performance of detention tank itself, which is widely considered to be one of the most effective stormwater management practices. In both of the scenarios, two methods of expressing the pollutant removal efficiency are used: one is based on the evaluation of each individual event which is called individual event performance (IEP); the other method is to calculate the total pollutant load reduction for the entire year, summer season, and winter season, respectively, which is called the total load performance (TLP).

**Data Analysis Results**

***Runoff Quantity Control***

A total of 73 rainfall-runoff events were detected in 1996 in the storm compartment. Twenty-two of those generated either near-shore or off-shore overflows to the Lake and 7 of those were near-shore overflows. The total near-shore overflow volume was 3,939 $m^3$ which represents 1.4% of the 1996 total inflow volume to the tank. The 400 m off-shore overflow volume was 117,397 $m^3$, which represents 41% of the total inflow volume. The system pumped out almost half of the total inflow runoff, without detention, to the Lake 400 m off-shore in 1996. It might be concluded that the substantial decrease in beach posting frequency is due to a large fraction of undetained runoff directly pumped to the Lake 400 m off-shore. In the CSO compartment, a total of 18 events occurred and only 2 events triggered overflows to the storm compartment. Since both the number of CSO events and the CSO volume captured by the CSO compartment are not large, a likely future strategy is to store the CSO volumes in-line by oversizing the proposed KTRS in the future.

***Pollutant Removal***

The pollutant removal efficiencies calculated from the "system" scenario and the "tank" scenario are obviously different. The performance of the "tank" itself is noticeably better than for the "system" due to the overflows considered in the "system" scenario. In the "tank" scenario, the TSS removal is 50.5% for the yearly average IEP and 68.5% for the yearly TLP. These values might represent the pollutant removal efficiency of the Maclean Avenue detention tank itself under the 8-hour detention period. In the "system" scenario, the yearly average IEP for TSS removal is 30.6% and the yearly TLP for TSS removal is 56.9%. Most of the heavy metals show obvious removal by the tank. The greatest heavy metal reduction is 94.7% for chromium, and most of the other heavy metals are removed by about 50%. These heavy metals are often attached to TSS and removed by sedimentation during the detention period. Ironically, the removal of bacteria (E. coli) is negative after detention, although the main objective in the implementation of the tank was to reduce the number of beach postings due to the public health concerns posed by elevated concentrations of bacteria.  The removal of microbiological pollutants can usually be achieved through biological decay which requires a longer detention time.  It is obvious that the 8-hour detention time does not help with bacterial reduction.  Other measures, such as ultraviolet radiation or chemical disinfection might be options to satisfy the Provincial Water Quality Objective of 100 coliforms/100 ml.

**Modelling Results**

Analytical probabilistic models are developed according to the Maclean Avenue detention tank operational features and the principles of model development to predict and optimize the current and future tank performance.  In the current stage, tank performance on runoff quantity control in terms of the average annual number of overflows obtained from the five-year observed data is 10.2, from the simulation of the QQS model is 4.5, and from the prediction of derived analytical probabilistic model is 13.3.  The modeling results suggest that the optimal operation condition in the future stage might be: the tank storage volume is $8000m^3$ (equivalent to $9800m^3$ of combined tank and submerged pipe storage), the pumping rate is 2280 $m^3$, and the detention time is 8 hours, then, the average annual number of overflows (from March to November) is 9.6.

**Conclusions and Recommendations**

- The tank performance analysis results based on the data monitored in 1996 suggest that the current storage volume of the storm compartment is insufficient due to the large fraction of undetained urban runoff overflow to the Lake. The CSO volumes captured by the CSO compartment are not large, thus, it might be reasonable for the City to convert the CSO compartment to detain stormwater runoff in the future which would improve the tank performance for stormwater control.
- The set points for the overflow pumping process during the event need careful consideration. The study suggests that the pump removed undetained runoff to the Lake more than is necessary, which substantially decreases the tank performance for pollution control.
- The detention time is a key factor governing the pollutant removal efficiency of the detention tank. For the purpose of bacterial removal, either a longer detention time or other disinfection techniques are required.

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# 1.0 INTRODUCTION

The City of Toronto has a long history in the prevention of water pollution. A particularly problematic source of water pollution is that derived from wet weather flows in the urban area in the form of combined sewer overflows (CSOs) and separated stormwater runoff. One of the many alternatives employed by the City of Toronto to combat this source of water pollution is that of detention storage facilities. Examples of such alternatives are the Eastern Beaches Detention Tanks – the Kenilworth Avenue Tank which was put into operation in 1990 and the Maclean Avenue Tank which was put into operation in 1995.

The design of detention facilities is complicated by a number of factors.

1. The system is subject to meteorological loadings that are highly stochastic, varying constantly through time.
2. The rainfall-runoff transformation is complex and is characterized by many hydrological parameters that vary spatially and temporally.
3. The pollutant buildup and washoff processes are complex and similarly vary through space and time.
4. The pollutant removal efficiency of detention facilities varies with storage levels, hydraulic conditions, pollutant characteristics (such as particle size, shape and density distribution), and operational variables (such as detention time and release rate).

Because of the above factors, it is inevitable in the design of such facilities that a variety of assumptions must be invoked. Therefore, it is important to improve the engineering understanding of such complex systems by monitoring the performance of existing systems.

## 1.1 Monitoring Program

One such monitoring program was undertaken under the auspices of the Storm Water Monitoring and Assessment Program (SWAMP) on the Maclean Avenue Tank in the Eastern Beaches. Over a period of approximately 2 years (from 1995-1996), City of Toronto staff assumed responsibility for flow monitoring while SWAMP staff assumed responsibility for water quality monitoring.

In addition to the SWAMP monitoring program, staff at the City of Toronto have maintained a variety of monitoring records on the Maclean Avenue tank. Advantage has been taken of this data wherever possible. Mr. Carmelo Pompeo of the City of Toronto was instrumental in providing and interpreting this data.

## 1.2 Objectives of the Proposed Work

In order to bring the Eastern Beaches Detention Tank study to a conclusion, the proposed work has the following objectives:

1. Based on the data available, conduct an assessment of the pollution control performance of the Eastern Beaches Detention Tank, both on an event-by-event basis as well as on a continuous basis.
2. Ascertain whether the facility is sized appropriately in relation to its control frequency requirements.

## 1.3 Study Methodology

The study methodology involves the following components:

1. Assemblage of a dossier of information pertaining to the Eastern Beaches Detention Tanks including SWAMP documentation, documentation/records from the City of Toronto, and relevant reports from consultants.
2. Undertaking of a quality control check of available data.
3. Assemblage of an appropriate data base on rainfall records, runoff flows, runoff volumes, sewage flows, inflow and outflow pollutant concentrations, storage levels, overflow volumes, operations histories, etc.
4. Undertaking of mass balance calculations on runoff volumes and pollutant masses as a further check on data integrity.
5. Performing an event-by-event analysis on inflow, outflow, overflow and pollutant removal to establish event performance.
6. Performing a statistical analysis on the collection of event data to establish long term performance.
7. Establishment of current performance characteristics of the Eastern Beaches Detention Tank and comparison with the original design objectives. Establishment of appropriateness of tank sizing and operation.
8. On the basis of above study results, if possible, recommendation of revised input data to rerun the Dorsch HVM-QQS model originally used in the facility design.

# 2.0 STUDY SITE

The Maclean Avenue Detention Tank is located at the south end of Maclean Avenue in the Eastern Beaches area between Glen Manor Drive and Balsam Avenue with a total storage volume of 8000 $m^3$. The tank was originally designed to operate in two stages: the interim stage and the ultimate stage.

In the interim stage, which is the current operating condition, the tank is equally divided into two compartments: a CSO compartment and a storm compartment. The CSO compartment receives the combined sewage overflows (CSOs) collected by sewers on Maclean Avenue from upstream overflow structures in the catchment during wet weather periods. The storm compartment receives urban runoff collected by the storm sewers on Glen Manor Drive and Balsam Avenue. A pump is installed in each compartment.

Depending on flow levels in the Lakefront Interceptor (LFI), the CSOs captured during wet weather periods are either pumped directly to the interceptor for conveyance to the Main Sewage Treatment Plant (MSTP) or detained within the compartment until interceptor capacity is available to accept them without overloading the sewer or treatment systems. The operation of the CSO pump is controlled by the water level in the Lakefront Interceptor. It can be started whenever the water depth in LFI does not exceed 0.488m. Once the water depth in LFI rises above 0.488m, the CSO pump is shut down until the water depth drops back down to 0.225m. After that, the pump is reactivated to continue pumping. When the CSO compartment is full, dewatering requires 4 to 6 hours. If a severe rainfall event occurs within the tank drainage area, the volume of the CSOs collected by the Maclean Avenue combined sewer could exceed the CSO tank storage volume, resulting in overflow from the CSO compartment to the storm compartment through the weir between the two chambers.

The runoff captured in the storm compartment is detained for an 8 hour period which allows the suspended solids to settle to the bottom of the tank. This sedimentation process allows the contaminants associated with storm runoff (e.g., bacteria, nutrients and metals) to settle together with the solids. After the 8 hour detention period, the supernatant is pumped 400m offshore to the Lake while the sediments are drained to the CSO compartment and then pumped to the LFI. If the rainfall event is severe enough and the water level within the storm compartment rises to a certain level, the storm pump is initiated to pump out the stormwater 400m offshore without any detention. If a more severe event occurs with an inflow rate greater than the pump capacity, a near-shore overflow occurs through the weir in the storm compartment to the Lake. Thus, the overflow from the storm compartment to the Lake consists of two components: a 400m offshore overflow by pumping and a near shore overflow over the weir. Near shore overflows are of greater concerned since they directly degrade the water quality in the Eastern Beaches recreation area. Figure 2.1 shows a schematic of the tank operation during the interim stage.

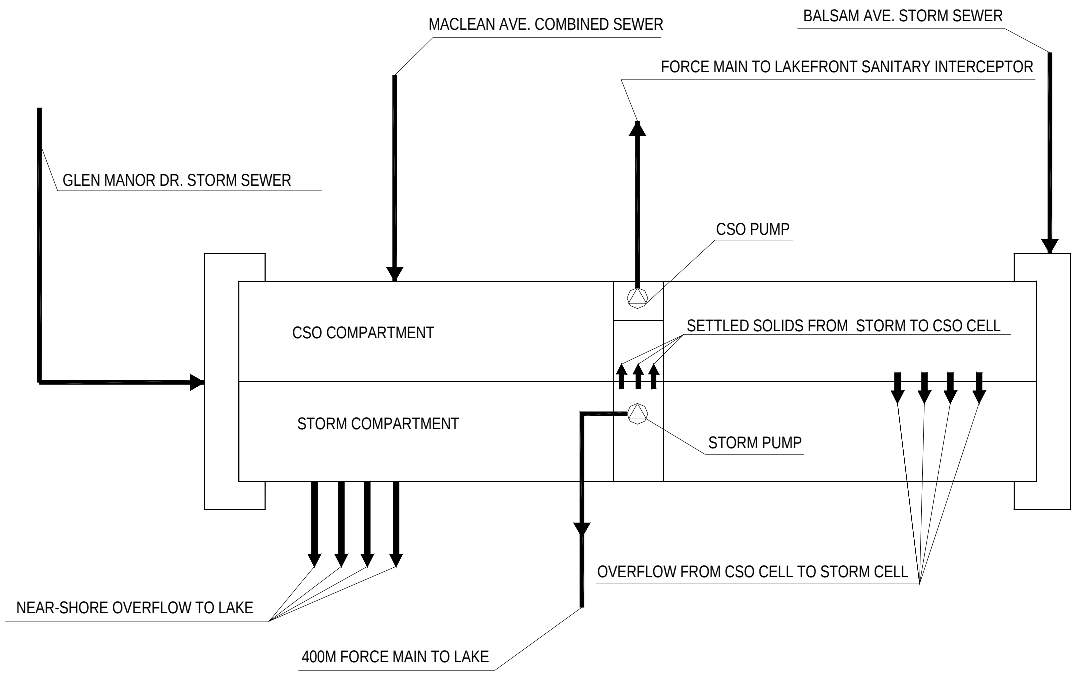


***Figure 2.1*:** System Operation Schematic

The Kingswood Trunk Relief Sewer (KTRS) along Queen Street East has been proposed to be built by the City in the future. The proposed KTRS is oversized in diameter from 1980 mm to 2500 mm to provide in-line storage for the CSOs currently discharged to the tank (Gore & Storrie and MacViro, 1993 (a)). As a result, the Maclean Avenue detention tank would ultimately receive stormwater only. The two compartments would be interconnected, and the settled sludge after the detention would be pumped to the LFI for further treatment at the MSTP.

The majority of the tank drainage area consists of residential housing ranging from small townhouse lots to estate residential areas. There are also numerous commercial and small industrial buildings. The drainage area of the storm compartment and the CSO compartment overlap, because the City's old combined sewer in this area could not be totally separated. Thus, the storm sewers collect runoff generated from roads, driveways, parking lots, and parks, and convey this part of the runoff to the storm compartment. The drainage area of the storm sewershed is 114 ha. The combined sewers in this area receive sanitary sewage plus runoff from some roofs and foundation drainage with a drainage area of 93 ha. A boardwalk extends along the length of the beach, from the foot of Beach Avenue in the east to Tommy Thompson Park in the west. During the warmer seasons, the beach area is used extensively for recreational activities.

# 3.0 WATER QUANTITY ANALYSIS

The objective of the water quantity analysis is to determine the performance of the system in terms of the runoff volume captured. Further consideration is given to evaluate the proper tank sizing. The pollutant removal efficiency of the system is then determined on the basis of the water quantity analysis.

## 3.1 System Description

The data analyzed for this study are the water depths recorded every five minutes during each runoff event in 1996, as provided by the City of Toronto staff. In order to calculate the runoff quantity control system performance, such as the runoff volume captured by the system and overflow volume from the tank to the Lake, the system geometry must be clearly understood.

Figure 3.1 shows the geometry of the tank. The 8000 $m^3$ tank is equally divided into two compartments: a CSO compartment and a storm compartment. The eastern channel and the western channel convey the stormwater from the Glen Manor Drive sewer and the Balsam Avenue sewer to the storm compartment, respectively. Thus, the volume of the two channels is included in the storm compartment volume. A concrete wall extending the full length of the tank separates the compartments. A trough oriented along the centreline extends the full width of the tank. Both compartments are sloped towards the trough at a 2% grade. A CSO pump is located in the sump to drain the captured CSOs in the tank and the settled sludge in the storm compartment. A sluice gate controls flow in the trough from the storm compartment to the CSO compartment. During normal operation, the sluice gate is shut. The pump in the storm compartment pumps out the excess inflow and supernatant after detention, 400 m off-shore to the Lake.

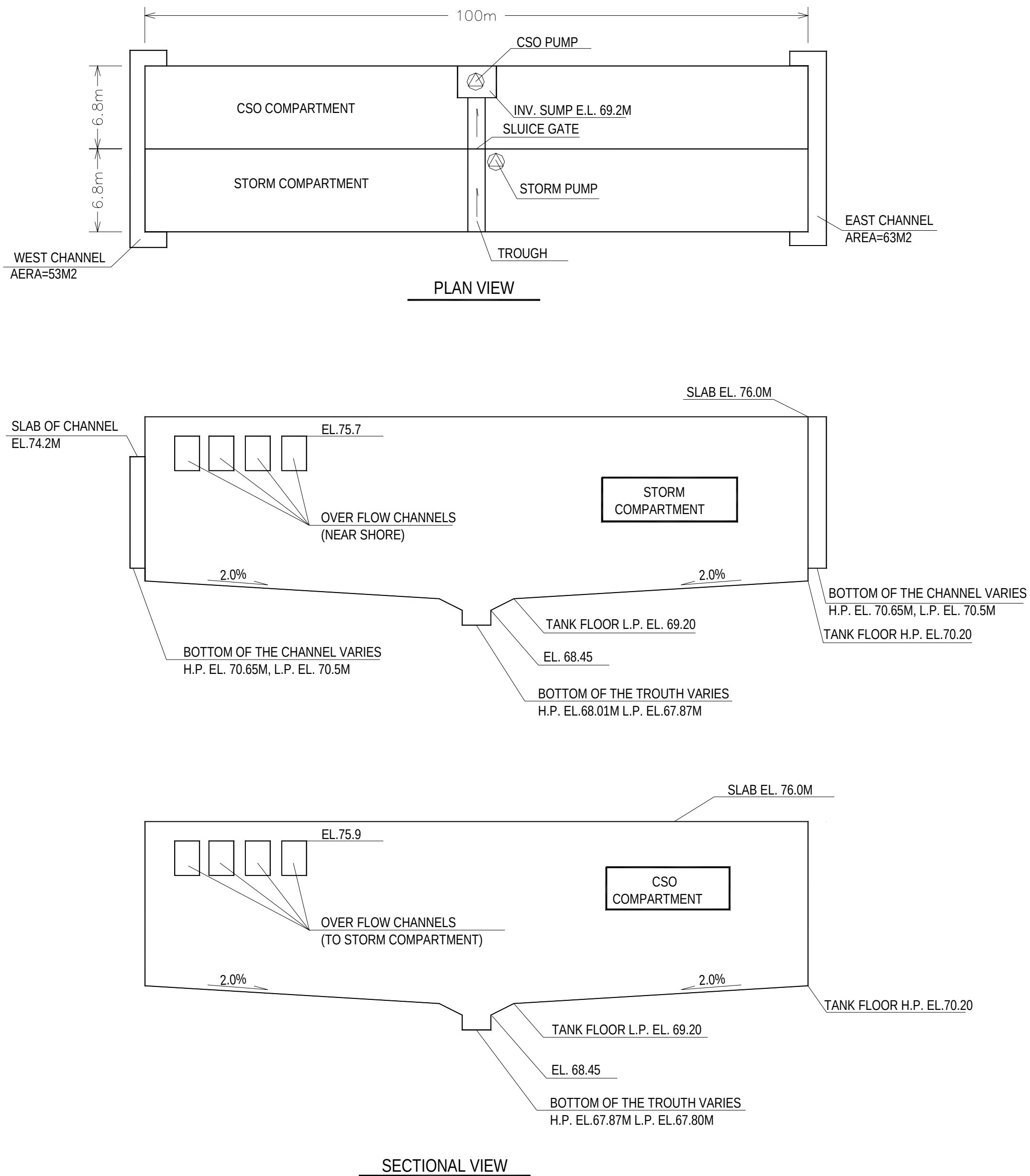


***Figure 3.1:*** Tank Dimension Schematic (Gore & Storrie and MacViro,1993 (b))

## 3.2 Storm Compartment Quantity Control Analysis

The following parameters are calculated, event by event, to evaluate the storm compartment performance: the near-shore overflow volume to the Lake ($V_o$); the 400m off-shore pump-out overflow volume ($V_p$); the runoff volume detained by the tank ($V_{detained}$); the total inflow runoff volume ($V_{in\text{-}total}$); the pumped out supernatant volume after the 8-hour detention period ($V_{out}$); and the percentage of runoff volume detained by the tank. Before the calculation, several key parameters of the system must be determined:

1. dry weather flow rate
2. pump capacity (used to calculate $V_p$)
3. overflow weir equation

To further understand the quantity calculation procedure, the event that occurred on January 26-27 is used as an example and is illustrated in Figure 3.2.

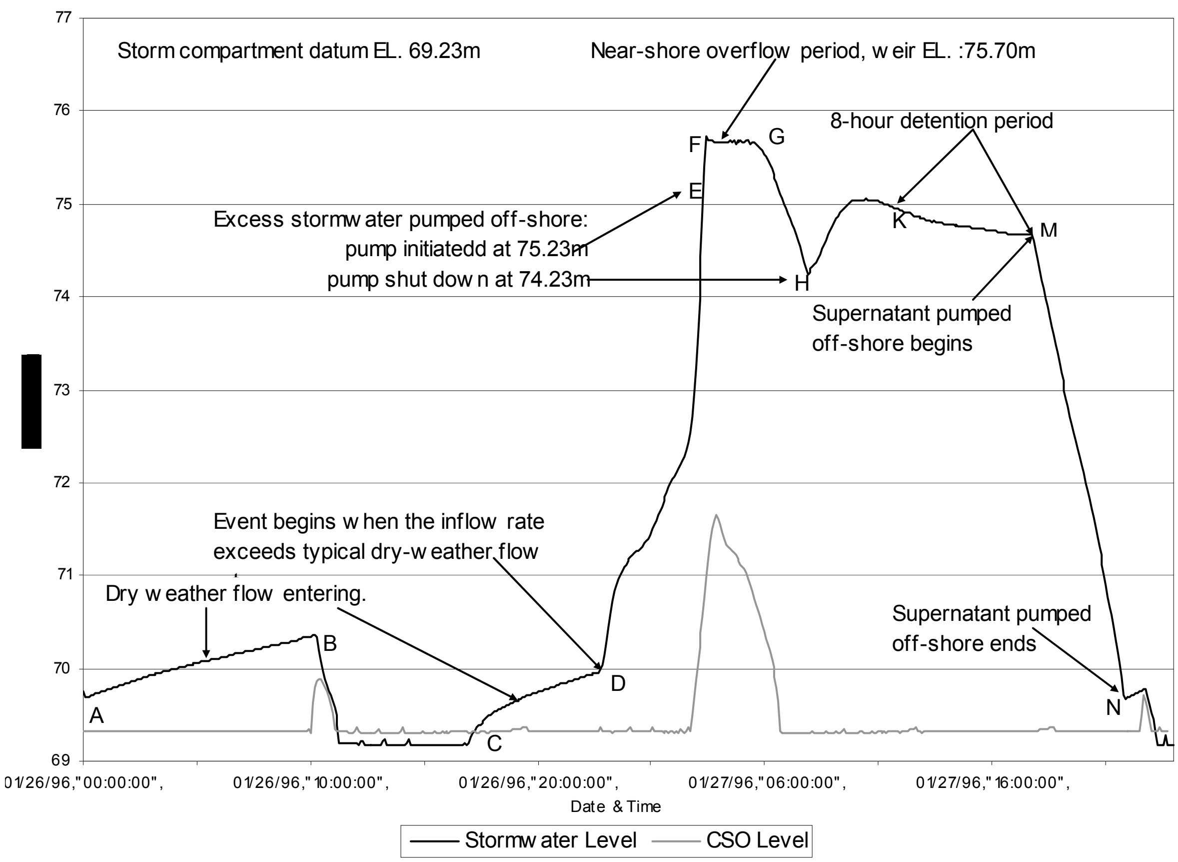


***Figure 3.2*:** Stormwater Compartment Operation Cycle Illustration

1. Dry weather flow rate calculation

A continuous base flow rate was found to drain into the storm compartment during the dry weather period. When the water level reaches a specific mark during a dry weather period, the storm compartment pump is triggered to pump the accumulated dry weather flow to the Lake. The pump is initiated at a water level of 70.43m and stopped at 69.68m.

As shown in Figure 3.2, the A-B and C-D sections of the curve are representative of the dry weather flow period. The dry weather flow rate can be obtained from the volume change divided by the time period. The flow rates for events with such dry weather flow sections available are calculated for the entire year. The calculated dry weather flow rate varies from $30m^3/h$ to $41m^3/h$. Since the change is quite moderate, an average rate of $36m^3/h$ is used in the following calculations for all the events in 1996.

2. Pump capacity evaluation

When heavy runoff events occur, overflows from the system occur with higher probabilities. Overflow of the storm compartment has two components: a near-shore overflow over the weir and a 400m off-shore overflow through the pump-forcemain system to the Lake. As shown in Figure 3.2, when the water level in the tank rises to point E at elevation 75.23m, pumping is initiated to pump out the excess inflow. After the pump starts, the water level in the tank might either rise or drop depending on whether the pumping rate greater or less than the inflow intensity, respectively. When the water level continues to rise and reach the weir elevation, 75.70m, a near-shore overflow occurs which is illustrated by the F-G section of the curve. When the inflow intensity decreases and is less than the pumping rate, the water level drops and the pump is shut down at point H at elevation of 74.23m. After point H, the water level may continue to rise if more runoff enters. It is possible that the water level reaches 75.23m again, and the pump starts to pump out runoff again. Thus, the pumped overflow (Vp) is the product of the pumping rate multiplied by the pumping time. As both the water level within the tank and the water level of the Lake change, the pumping rate varies depending on these variables. In order to obtain a reasonable estimate of the pumping rate to calculate the volumes of pumped-out overflows, empirical hydraulic equations are adopted at first; then, the observed data are used to verify the calculation.

i) Pump capacity calculation with hydraulic equation

The pumping head vs. flow rate relationship is derived from the pump performance curve as follows:

$$Hp = -7.333 \times 10^{-6} Q^2 - 0.03283335 Q + 22.06 \qquad (3.1)$$

where: Hp – pump head (m)

Q – pump rate (L/s)

A storm compartment pumping system schematic is shown in Figure 3.3.

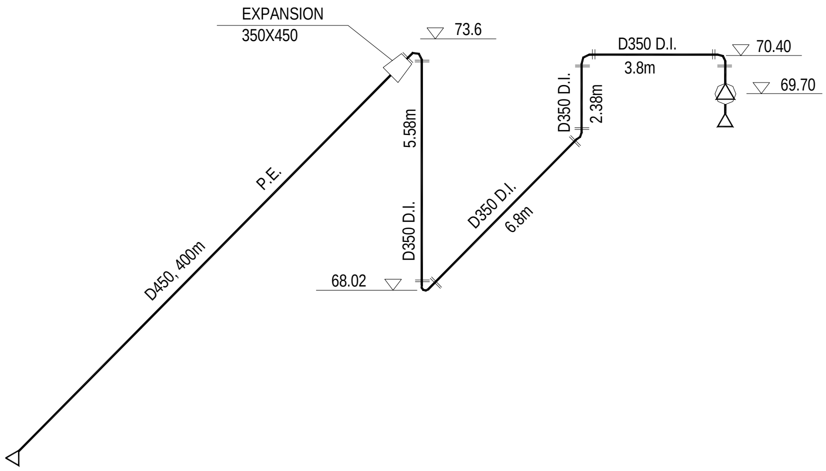


***Figure 3.3:*** Storm Compartment Pumping System Schematic

The Hazen-Williams equation for circular pipe sections flowing full is

$$Q = 0.28\ C\ D^{2.63}\ S^{0.54} = 0.28\ C\ D^{2.63}\ (h_f / L)^{0.54} \qquad (3.2)$$

or

$$h_f = L\ \left(\frac{Q}{0.28 \times C \times D^{2.63}}\right)^{1.852} \qquad (3.3)$$

where: Q = volumetric flow rate ($m^3/s$)
D = pipe diameter (m)
$h_f$ = head loss (m)
L = pipe length (m)
C = Hazen-Williams coefficient (dependant on pipe material, age, etc.)

Pipe fittings in the system include: 5 x $90^0$ standard elbows, 1 x gate valve, 1 x check valve, and 1 x expansion (350mm to 450mm). The friction loss in these fittings, in terms of equivalent length, is 70.7m of 350mm diameter pipe section.

The C value for D450 P.E. pipe is 140 and the actual diameter is 422mm, the C value for D350 D.I. pipe is 125, and the actual diameter is 297mm.

Substituting these values into Equation 3.3 yields

$$h_f = 2.0687 \times 10^{-4} \times Q^{1.852} \qquad (3.4)$$

where: Q = volumetric flow rate (L/s)

The head against which the pump must work when water is being pumped is

$$H_{pump} = (H_d - H_s) + \frac{V_s^2}{2g} + \frac{V_d^2}{2g} + h_f \qquad (3.5)$$

where: $H_d - H_s$ = total static head (m)

$V_s$ = suction side velocity (m/s) = $\dfrac{Q \times 10^{-3}}{\pi \times 0.149^2}$ (m/s)

$V_d$ = discharge side velocity (m/s) = $\dfrac{Q \times 10^{-3}}{\pi \times 0.211^2}$ (m/s)

Substituting Equation 3.4 and the suction and discharge velocity formulas into Equation 3.5 yields:

$$H_p = 2.0687\text{x}10^{-4}\text{x}Q^{1.852} + 1.31\text{x}10^{-5}\text{x}Q^2 + (H_d - H_s) \quad (3.6)$$

Setting Equation 3.6 equal to Equation 3.1 yields:

$$2.0687\text{x}10^{-4}\text{x}Q^{1.852} + 2.043\text{x}10^{-5}\text{x}Q^2 + 0.0328335\text{x}Q + (H_d - H_s) - 22.06 = 0 \quad (3.7)$$

The pump capacity can be obtained by solving Equation 3.7 if the total static head ($H_d$ -$H_s$) is known. The total static head is an instantaneous value responding to the variations of both the tank water level and the Lake water level. The tank water level varies only within a 1 meter range from 75.23m to 74.23m during the overflow pumped out period. The monthly average water levels (m above MSL) for Lake Ontario in 1996 recorded in Toronto Harbour are shown below:

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 74.62 | 74.75 | 74.77 | 74.83 | 75.14 | 75.25 | 74.15 | 75.0 | 74.85 | 74.75 | 74.72 | 74.75 |

In 1996, the highest Lake water level recorded in June was 75.25m, and the lowest lake water level recorded in January was 74.62m, with a difference of 0.63m. Since both the tank water level and the Lake water level change within a moderate range, the extreme values of the pump capacity are calculated at first. In January 1996, the pump capacity during the overflow pump out period varied from a minimum value of 1154m$^3$/h to a maximum value of 1190m$^3$/h, with an average of 1172m$^3$/h. In June 1996, the pump capacity changed from 1131m$^3$/h to 1168m$^3$/h, with an average of 1147m$^3$/h. Since the range of pump capacity during the overflow pump out period in the entire year was moderate, an average rate of 1161m$^3$/h was chosen to reasonably represent the pumping rate in order to simplify calculations.

ii) Pump capacity calculation verification with observed data

When overflow is pumped out, the pump basically works between 75.23m to 74.23m on the water depth variation curve. There are some events in 1996 with water levels from 75.23m to 74.23m after the 8-hour detention period. During this period, the rainfall event stops and only dry weather flow enters the system. Thus, the volume change during this period divided by the duration, plus the dry weather flow rate might represent the pumping rate during the overflow pump-out period. As shown in Figure 3.2, the change of the system volume from point M (6:10 am, 74.74m) down to the point (6:30 am, 74.32m) at which the pump is shut down by the operating program is 400m$^3$, spanning a duration of 20 minutes. Thus, the pump capacity equals 400$m^3$ divided by 20 minutes, plus the dry weather flow rate, 36$m^3$/h, which yields 1236$m^3$/h. Twelve events in 1996 are viewed as qualifying for this pump capacity calculation protocol. They are the events that occurred on Jan. 16, Jan. 18, Jan. 23, Jan. 26, Feb. 10, Feb. 20, June 22, July 30, Sep. 11, Sep. 27, Oct. 18, and Dec. 12. The average pumping rate during these 12 events is found to be 1270$m^3$/h by the calculation procedure above. Compared with the result from the equation, 1161$m^3$/h, there is an 8.5% difference. The value of 1270$m^3$/h is used as the pump capacity for the calculation of the volume of the pumped out overflows.

There is another characteristic of the system that requires mention. The invert elevation of the storm sewer on Glen Manor Drive is only 71.05m at its connection to the tank, and the invert elevation of the sewer on Balsam Ave is 73.76m at its connection to the tank; thus, the captured runoff during the detention period within the tank extends back upstream in the sewer system during most events. The maximum distance of the backup is 300m on Glen Manor Dr. Thus, the sewers should be considered as an integral part of the storage volume of the tank system. Figure 3.4 shows the system geometry.

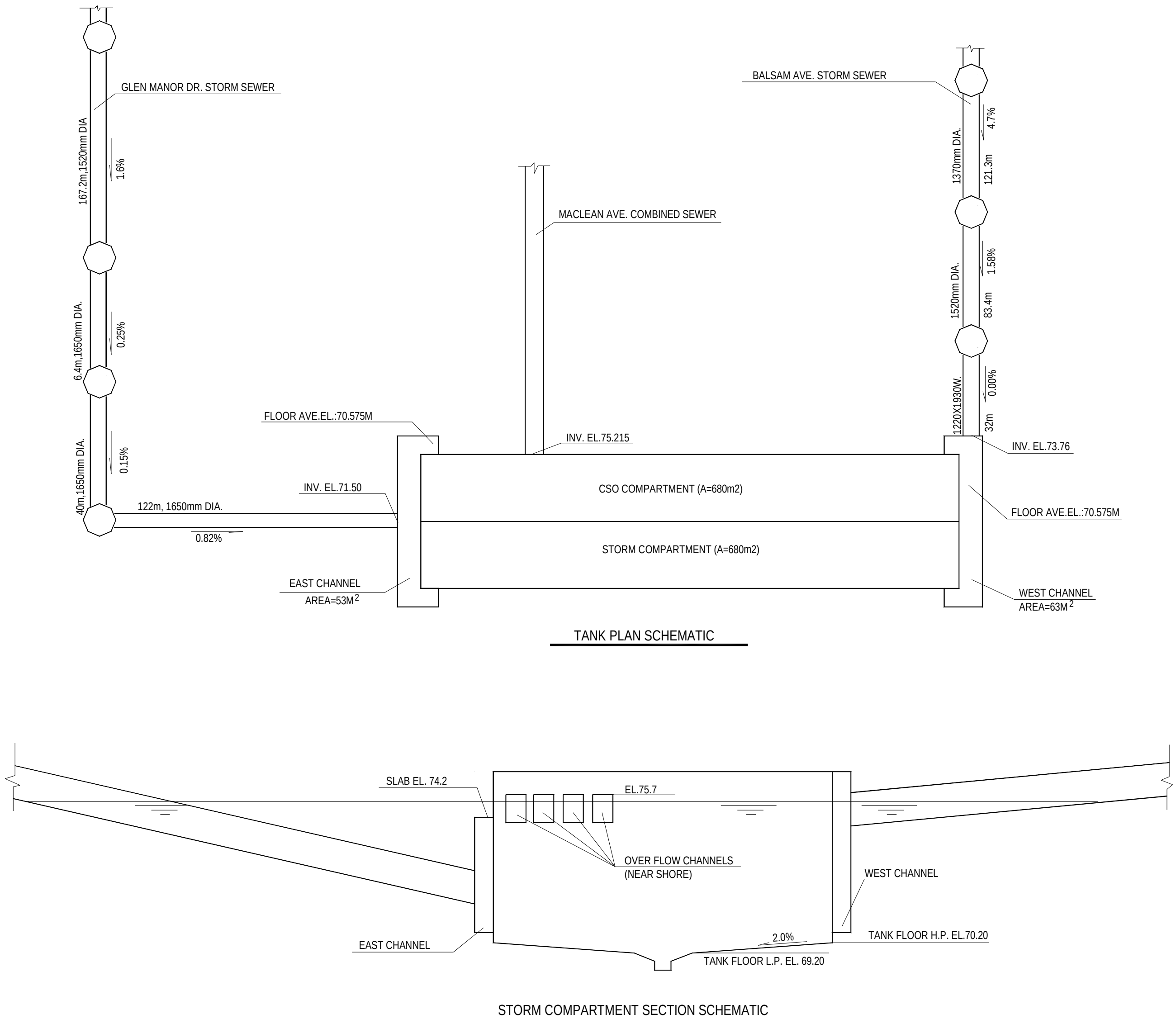


***Figure 3.4:*** System Geometry Schematic

3. Overflow weir equation selection

Because the length of the weir in the storm compartment is 54.4m, for most overflow events, the head on the weir crest is very small. Since aerated nappe conditions cannot be guaranteed under these circumstances, traditional weir equations for this situation have reduced reliability. Although the error introduced by a non-aerated nappe condition is not known with certainty, it is generally assumed that the traditional weir equation would underestimate flows to some extent. Thus, the weir equation is still used with this caveat for this case when calculating the near-shore overflow. In reality, there are only five events in 1996 with weir overflow.

Another important parameter of the system operation should be clear before the quantity calculation can be continued, that is the time when the runoff event is recognized to have ended. According to the information provided by City staff, an 8-hour detention time is set, and 8 hours before the supernatant pump-out point (point M on Figure 3.2) is recognized as the time that the runoff event ended (point K on the curve in Figure 3.2).

The M-N section in Figure 3.2 represents the volume pumped out 400m off-shore to the Lake after the 8 hour detention period. On the January 26 event curve, M is lower than K which is the point when the runoff event ended. This might be due to the leakage of the sluice gate which is caused by the water level difference between two compartments during the detention period. In most of the events, the CSO compartment is empty, while the storm compartment is detaining the stormwater.

There are more events with point M higher than K. That is most probably because the dry weather flow continues entering the tank during the detention period. Thus, the curve's shape during the detention period is affected by both dry weather flow entering and the leakage to the CSO compartment. This situation is illustrated in Figure 3.5.

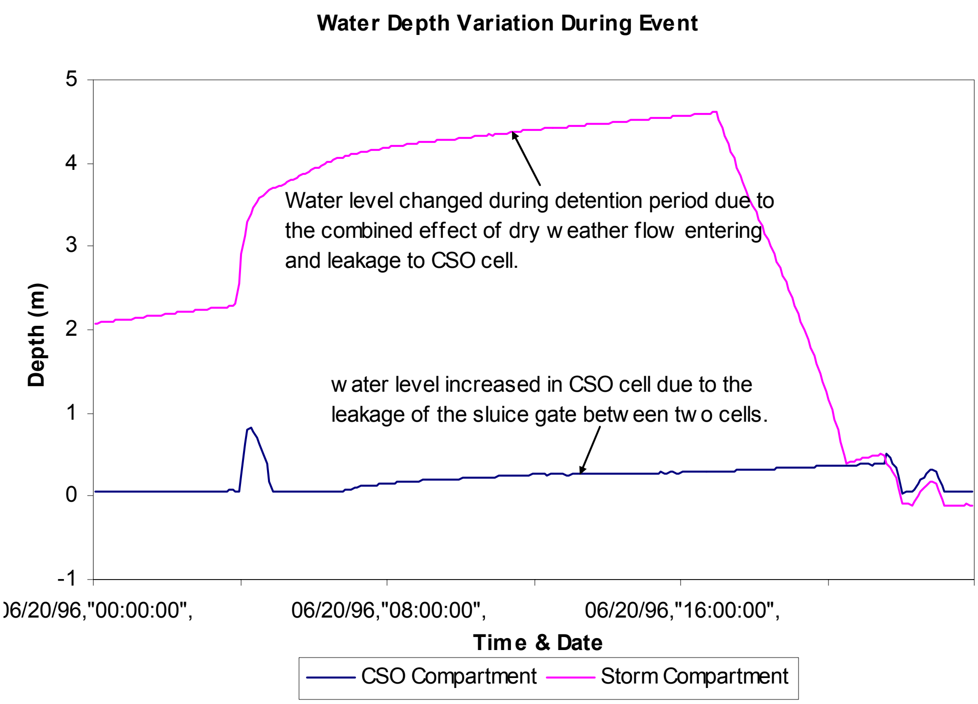


***Figure 3.5***: Water Level Variations during the Detention Period in the Two Cells

When performing the runoff quantity control calculations, the volume between point D and point K in Figure 3.2 represents the volume captured and detained by the system (Vdetained), while the volume between point M and point N represents the supernatant volume pumped out after the detention period (Vout). Both of the two volumes take into account the dry weather flow and sluice gate leakage influences and are used to calculate the influent and effluent loads, as both the dry weather flow and the leakage between the two cells influence both the influent and effluent contaminant concentrations.

Unfortunately, the water depth records for the tank in this study provided by City staff have some incomplete files with missing data, as illustrated in Figure 3.6. Every effort was made to complete the files, but more data could not be found due to a variety of reasons, such as equipment malfunction at that time or human error during the data archiving process. After the investigation of all of the events with missing data, two groups of events can be categorized: one is similar to the event on March 20 shown on the right in Figure 3.6. The inflow rate at the point where the curve ceases is almost the same with the dry weather flow rate; thus, it suggests that the runoff event ended at the point where runoff inflow rate approaches the dry weather flow rate. Also, there is another factor which could be involved to support this conclusion, that of rainfall duration. On Mar 20, 1996, the rainfall event ended at 18:00h, thus suggesting that the runoff event ceased around 19:00h. This interpretation of the curve might be acceptable and the volumes calculated according these curves might represent the actual situation with a certain degree of confidence. Thus, the runoff quantity control values calculated according to these types of events may be considered satisfactory for the system performance evaluation.

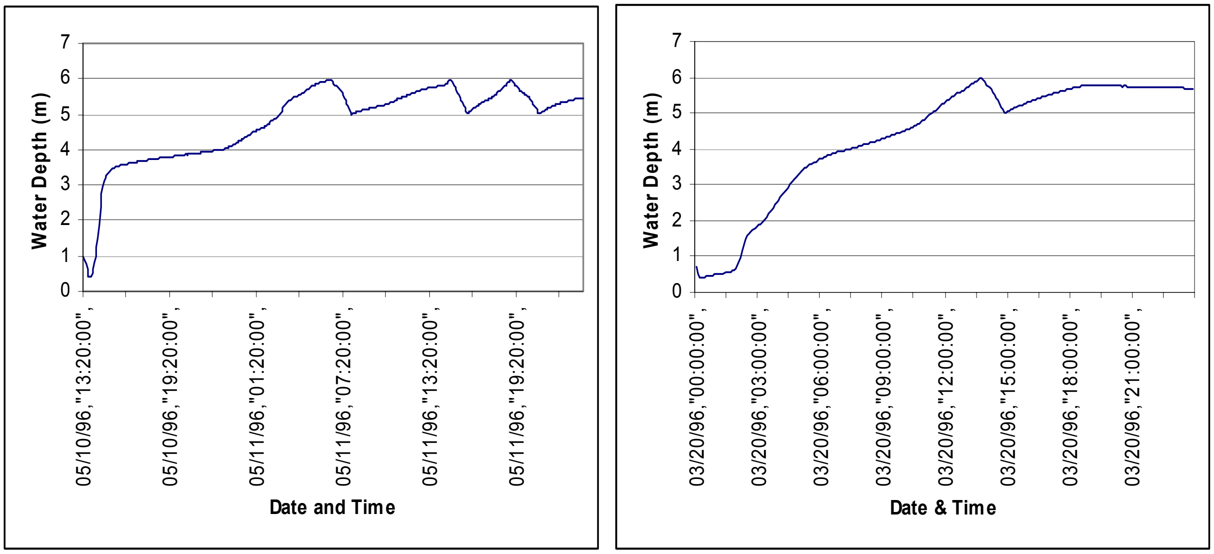


***Figure 3.6:*** Examples of Events with Missing Data

However, there are more difficult problems associated with analyzing events similar to the event on May 10 shown on the left of Figure 3.6. The curve terminates on the rising section and the rainfall event still continues according to the Kew Beach rain gauge. Thus, the best that could be done here is to calculate the detained volume or overflow volume by the time the curve ended. The overflow volume calculated by that point would be underestimated, but including this event into the number of overflows that occurred in 1996 is definitely not problematic. This information is important for the further evaluation of the tank sizing. There are a total of 10 events in this situation and 4 events with overflows having occurred. These 10 events are marked with an asterisk in the volume calculation results in Table 3.1.

## 3.3 CSO Compartment Quantity Control Analysis

The event that occurred on January 26, 1996 is used to illustrate the CSO compartment operation process as shown in Figure 3.7.

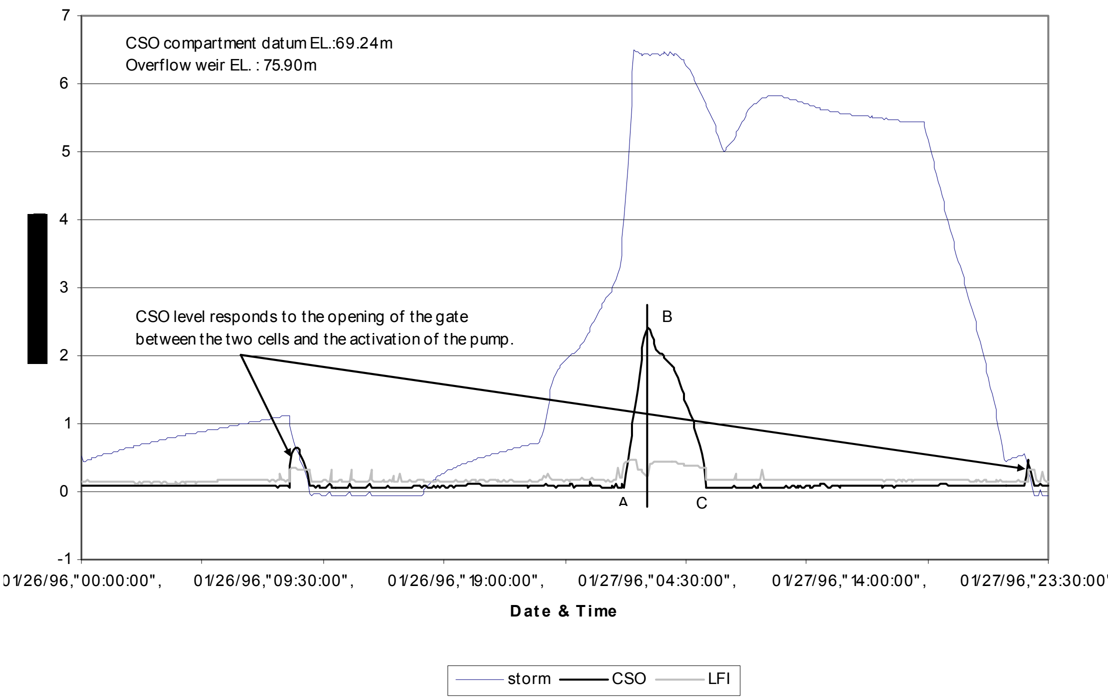


***Figure 3.7:*** Water Level Correspondences during a Runoff Event in the CSO Tank, Storm Tank and LFI

The role of the CSO compartment is to attenuate the peak charge rate to the Lakefront Interceptor (LFI) and Main Sewage Treatment Plant (MSTP); no treatment is provided for the captured CSOs in the tank. Thus, the volume captured by the tank is pumped back to the LFI whenever capacity in the LFI is available. The CSO compartment pump is controlled by the water level in the LFI. It can be started whenever the water depth in the LFI does not exceed 0.488m. Once the water depth in the LFI rises above 0.488m, the CSO pump is shut down. When the water depth in the LFI drops back down to 0.225m, the CSO pump is reactivated to continue pumping again. Because the CSO pump can be started whenever the water level in the LFI is lower than 0.488m, the point when the pump is activated is difficult to determine with certainty. For example, the pump is definitely operating in the B-C section of the curve in Figure 3.7, but it is also possible that the pump is operating in the A-B section, since the water level in the LFI is lower than 0.488m in the A-B section. From the curve of the January 26 event shown in Figure 3.7, it appears that the pump stated at point B, because the CSO curve is very steeply increasing in the A-B section. At the same time, the CSO curve decreases after point B and the LFI curve also increases after point B. But it is difficult to determine the pump start point in most of the other events in the CSO compartment. By analyzing all of the events with any volume captured in the CSO compartment (all the curves in 1996 are available in Appendix B), both the event numbers and the volumes are found to be relatively small compared to the storm compartment. There were only two events with overflows to the storm compartment while a total of 18 events occurred in the CSO compartment in 1996. These numbers can be used to qualitatively evaluate the performance of the system; however, a quantitative assessment is not possible with the available data.

Once the parameters of the system are clearly understood, the runoff quantity control analysis can be conducted. The results are shown in Table 3.1 and discussed below.

***Table 3.1:*** Runoff Volume Captured by the Maclean Avenue Detention Tank (1996)

| | | Storm Compartment | | | | | | | | CSO Compartment | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Overflow | | | | | | % of | % of | | |
| | Rainfall | Vp | Vo | Vdetained | Vin-total | Vout | DWF | Vdetained | Voverflow | Vin | Voo |
| Date | (mm) | m3 | m3 | m3 | m3 | m3 | m3/h | % | % | m3 | m3 |
| Jan 16-17 | 16.5 | 7408 | 0 | 4635 | 12043 | 4420 | 34 | 38 | 62 | Yes | |
| Jan 18-19 | 18.8 | 4657 | 0 | 4061 | 8718 | 4216 | 35 | 47 | 53 | | |
| Jan 23-24 | 12 | 0 | 0 | 4565 | 4565 | 4525 | 35 | 100 | 0 | | |
| Jan 26-27 | 21 | 5080 | 137 | 4568 | 9785 | 4333 | 36 | 47 | 53 | Yes | |
| Feb. 8 | 13.25 | 5296 | 0 | 4650 | 9946 | 4656 | 36 | 47 | 53 | | |
| Feb.10-11 | 8.5 | 0 | 0 | 4517 | 4517 | 4438 | 36 | 100 | 0 | | |
| Feb. 14 | 0.25 | 532 | 0 | 0 | 532 | 0 | 36 | 0 | 100 | | |
| Feb. 20* | 5.25 | 0 | 0 | 4518 | 4518 | 4593 | 36 | 100 | 0 | | |
| Feb. 23-24 | 5.25 | 0 | 0 | 2989 | 2989 | 3898 | 36 | 100 | 0 | | |
| Feb. 27-28 | 4 | 0 | 0 | 1019 | 1019 | 1374 | 36 | 100 | 0 | | |
| Mar.20 | 18.75 | 1270 | 0 | 4594 | 5864 | 4697 | 36 | 78 | 22 | | |
| Apr. 1 | 6.5 | 0 | 0 | 1557 | 1557 | 2063 | 36 | 100 | 0 | | |
| Apr.3 | 1.5 | 967 | | 0 | 967 | 967 | 36 | 0 | 100 | | |
| Apr. 5 | 5.75 | 1554 | 0 | 0 | 1554 | 0 | 36 | 0 | 100 | | |
| Apr.7* | 1.75 | 849 | 0 | 0 | 849 | 0 | 36 | 0 | 100 | | |
| Apr. 12-13 | 29 | 7620 | 0 | 4569 | 12189 | 4609 | 36 | 37 | 63 | Yes | |
| Apr. 15* | 10.25 | 0 | 0 | 3089 | 3089 | | 39 | 100 | 0 | | |
| Apr. 19 | 3 | 0 | 0 | 1023 | 1023 | 1530 | 38 | 100 | 0 | | |
| Apr.20 | 8.2 | 0 | 0 | 2781 | 2781 | 3734 | 37 | 100 | 0 | | |
| Apr.22* | 7 | 0 | 0 | 3082 | 3082 | | 33 | 100 | 0 | Yes | |
| Apr.25 | 2.2 | 743 | 0 | 0 | 743 | 750 | 41 | 0 | 100 | | |
| May 9-10 | 8.75 | 0 | 0 | 2352 | 2352 | 2738 | 35 | 100 | 0 | | |
| May 10-11* | 24.25 | 6033 | 0 | 4323 | 10356 | | 35 | 42 | 58 | | |
| May 20-21 | 32.8 | 9631 | 369 | 3829 | 13829 | 4350 | 36 | 28 | 72 | Yes | |
| May.23 | 2 | 810 | | 0 | 810 | 810 | 41 | 0 | 100 | | |
| June 7 | 13.6 | 2222 | 0 | 4723 | 6945 | 4760 | 36 | 68 | 32 | Yes | |
| June 9 | 0.8 | 672 | 0 | 0 | 672 | 0 | 38 | 0 | 100 | | |
| June 10-11 | 5.6 | 0 | 0 | 2513 | 2513 | 2623 | 36 | 100 | 0 | | |
| June 13* | 19.8 | 4191 | 2796 | 4268 | 11255 | | 40 | 38 | 62 | Yes | Yes |
| June 18 | 2.6 | 798 | 0 | 0 | 798 | 0 | 36 | 0 | 100 | | |
| June19 | 4.2 | 774 | 0 | 0 | 774 | 0 | 36 | 0 | 100 | | |
| June 20 | 2 | 0 | 0 | 3015 | 3015 | 3479 | 36 | 100 | 0 | Yes | |
| June 22 | 17 | 2857.5 | 205 | 3826 | 6888.5 | 4485 | 36 | 56 | 44 | Yes | |
| June 24 | 3.4 | 0 | 0 | 1363 | 1363 | | 36 | 100 | 0 | | |
| June 29 | 25.8 | 741 | 0 | 3982 | 4723 | | 34 | 84 | 16 | Yes | |
| July 2* | 27.75 | 3810 | | 4032 | 7842 | | 35 | 51 | 49 | Yes | |
| July 7 | 3 | 0 | 0 | 1607 | 1607 | 2129 | 36 | 100 | 0 | | |
| July 8* | 10.8 | 0 | 0 | 3686 | 3686 | | 36 | 100 | 0 | | |
| July 15 | 40.4 | 4551 | 212 | 3949 | 8712 | 3817 | 36 | 45 | 55 | Yes | Yes |
| July 19 | 10.2 | 0 | 0 | 3120 | 3120 | 3874 | 36 | 100 | 0 | | |
| July 25 | 5.2 | 0 | 0 | 1426 | 1426 | 1383 | 36 | 100 | 0 | | |
| July 30 | 16 | 0 | 0 | 4496 | 4496 | 4846 | 36 | 100 | 0 | Yes | |
| Aug 08 | 12.8 | 2858 | 97 | 4044 | 6999 | | 31 | 58 | 42 | Yes | |
| Aug 15 | 0.8 | 396 | 0 | 0 | 396 | 396 | 36 | 0 | 100 | | |
| Aug 20 | 4.4 | 0 | 0 | 1326 | 1326 | 1907 | 30 | 100 | 0 | | |
| Aug 26 | 1.2 | 840 | 0 | 0 | 840 | 0 | 36 | 0 | 100 | | |
| Aug 27 | 3.2 | 790 | 0 | 0 | 790 | 0 | 36 | 0 | 100 | | |
| Sep 7-8* | 57.8 | 5461 | 123 | 3985 | 9569 | | 36 | 42 | 58 | Yes | |
| Sep 11-12 | 14.8 | 1803 | 0 | 3918 | 5721 | 4432 | 36 | 68 | 32 | | |
| Sep 13 | 22.2 | 5080 | 0 | 3793 | 8873 | 4551 | 36 | 43 | 57 | | |
| Sep 14-15 | 4.8 | 1043 | 0 | 0 | 1043 | 0 | 36 | 0 | 100 | | |
| Sep 27-28 | 20.8 | 3493 | 0 | 4488 | 7981 | 4536 | 36 | 56 | 44 | | |
| Oct.2 | 2 | 718 | 0 | 0 | 718 | 7180 | 36 | 0 | 100 | | |
| Oct.13 | 1.2 | 698 | | 0 | 364 | 0 | 36 | 0 | 100 | | |
| Oct.16 | 5.8 | 0 | 0 | 2091 | 2091 | | 36 | 100 | 0 | | |

***Table 3.1:*** Runoff Volume Captured by the Maclean Avenue Detention Tank (1996) (cont'd)

| | | Storm Compartment | | | | | | | | CSO Compartment | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Overflow | | | | | | | | | |
| | Rainfall | Vp | Vo | Vdetained | Vin-total | Vout | DWF | % of Vdetained | % of Voverflow | Vin | Voo |
| Date | (mm) | m3 | m3 | m3 | m3 | m3 | m3/h | % | % | m3 | m3 |
| Oct 18-19 | 14.6 | | | 4783 | 4783 | 4459 | 36 | 100 | 0 | Yes | |
| Oct 20-21 | 4 | 1939 | | 0 | 1937 | 0 | 36 | 0 | 100 | | |
| Oct 23 | 1 | 567 | | 0 | 567 | 0 | 36 | 0 | 100 | | |
| Oct 24 | 1.2 | 566 | 0 | 0 | 566 | 0 | 36 | 0 | 100 | | |
| Oct 30 | 7 | 0 | 0 | 2202 | 2202 | 2854 | 38 | 100 | 0 | | |
| Nov 7-8 | 8.2 | 0 | 0 | 2704 | 2704 | 2794 | 36 | 100 | 0 | | |
| Nov17-18 | 1.6 | 576 | 0 | 0 | 576 | 0 | 36 | 0 | 100 | | |
| Nov 23 | 2.2 | 788 | 0 | 0 | 788 | 0 | 36 | 0 | 100 | | |
| Nov 30 | 2.8 | 727 | 0 | 0 | 727 | 0 | 36 | 0 | 100 | | |
| Dec 01 | 8.4 | 0 | 0 | 3005 | 3005 | 3074 | 36 | 100 | 0 | | |
| Dec 3-4 | 4.4 | 1836 | 0 | 0 | 1836 | 0 | 36 | 0 | 100 | | |
| Dec 5-6 | 2.8 | 913 | 0 | 0 | 913 | 0 | 36 | 0 | 100 | | |
| Dec.12-13 | 13.8 | 1586 | 0 | 3866 | 5452 | 4436 | 36 | 71 | 29 | | |
| Dec 16-17 | 27.6 | 5715 | 0 | 4322 | 10037 | 4403 | 36 | 43 | 57 | | |
| Dec 22 | 1.6 | 858 | 0 | 0 | 513 | 0 | 36 | 0 | 100 | | |
| Dec 23-24 | 25.6 | 5080 | 0 | 3873 | 8953 | 4181 | 36 | 43 | 57 | Yes | |
| Dec 28-29 | 3.8 | 0 | 0 | 3688 | 3688 | | 36 | 100 | 0 | | |
| Sum | 757 | 117398 | 3939 | 164815 | 285471 | 143300 | | | | | |

Legend: storm compartment:
Vp: pumped out overflow (400m off-shore)
Vo: near-shore overflow through weir
Vdetained: volume captured by tank before detention started
Vin-total: total inflow runoff volume
V out: supernatant volume pumped out after detention
% of Vdetained = (Vdetained/Vin-total)x100
% of Voverflow = 100 - % of Vdetained
The events marked with * mean that the volume calculated by estimation and the volumes are underestimated.

CSO compartment:
Vin: total inflow volume = Vout + Vo
Voo: overflow to storm compartment
The events notated by "Yes" mean that the CSO compartment was utilized

Rainfall volumes are calculated based on the Kew Beach and Kimberly rain gauges of the City.

## 3.4 Quantity Analysis Results

As presented in Table 3.1, a total of 73 rainfall-runoff events were detected in 1996. In the storm compartment, 22 events generated both near-shore and off-shore overflow to the Lake, representing 30% of the total events. There is a phenomenon in Table 3.1 that requires clarification: the 24 events with 100% overflow. The overflows generated from these 24 events did not result from insufficient tank storage but from the design of the operational program of the system. When the runoff generated from “minor” rainfalls (volume less than 4mm) is captured by the tank, it is pumped out without any detention, because the “minor” rainfall event is not considered to be worth detaining in relation to the energy and labour involved. The maximum individual event volume of these 24 events in 1996 was 1939m$^3$. The total volume was 19,083m$^3$, representing 7% of the total 1996 inflow volume into the tank (285,471m$^3$). Since these “overflows” were not caused by a shortage of tank storage, and they could have been captured by the system if desired, the following tank performance analysis does not consider them as overflows.

There were 7 events that resulted in near-shore overflows. The near shore overflows are of greater concern to the City, as they might directly cause beach posting, and decreasing the beach closing frequency is one of the main purposes of the tank. The total near-shore overflow volume was 3939m$^3$ which represents 1.38% of the 1996 total inflow volume to the tank. The 400m off-shore overflow volume was 117,397m$^3$, which represents 41% of the total inflow volume. The system pumped out almost half of the total inflow of urban runoff without any treatment to the Lake 400m off-shore in 1996. If only the near shore overflow is of concern, the construction of the tank definitely contributed to decreasing the beach closing frequency. Also, even these 7 near-shore overflow events could have be eliminated if the storm pump capacity was slightly enlarged. However, when considering the environmental improvement to the Lake by the Maclean tank, the performance of the system seems to be less than what was expected.

A review of the design drawings of the Maclean Avenue tank revealed that the elevation of the intake of the storm pump should be reconsidered. The tank floor slopes from 70.2m at the highest point to 69.2m at the lowest point with a trough in the center of the tank. The storm pump intake is installed beside the trough with an elevation of 69.7m (this value was provided by City staff and was not detailed in the design drawings by Gore & Storrie and MacViro, 1993 (b)). The pump was designed to pump out the supernatant after an 8 hour detention period, but it might also pump out at least a part of the settled sludge to the Lake if the pump’s intake is truly installed at the low elevation of 69.7m.

One approach to evaluate the severity of the overflow volume is to express the overflow volume as a fraction of the total inflow volume for each storm event. Table 3.1 also illustrates the computed results of this analysis and shows that the highest recorded percentage in overflow volume is 72% of the total inflow volume. This event occurred on May 20-21, 1996 when the recorded rainfall volume was 32.8 mm. The percentages of runoff overflowed range from 16% to 72% with an average of 49.1% for those 22 overflow events. In the event of May 20, the total overflow volume (Vp + Vo) was 10,000m$^3$, almost triple the detained volume of 3892m$^3$. The storm tank volume is not sufficient in this case. The future consideration of converting the CSO compartment to collect storm water would definitely help decrease the numbers and volumes of overflows. An evaluation of the tank sizing is conducted in Chapter 6.

The rainfall volumes in Table 3.1 are calculated from the Kew Beach and Kimberly rain gauges. The Kew Beach rain gauge is located in the tank drainage area, and it is used for most of the events. In some events, there is a runoff event in the tank but no rainfall is event recorded by the Kew Beach rain gauge, in which case, the Kimberly rain gauge data is adopted.

In the CSO compartment, a total of 18 events occurred and only 2 events triggered overflows to the storm compartment. All of these 18 events were generated by severe rainfall events with volumes greater than 13.6mm except for the events on April 22 (7mm) and June 20 (2mm). The recorded rainfall volume of the event that occurred on June 20 suggests that the rain gauge did not work properly by checking the water depth curve in both the storm tank and the CSO tank. As mentioned before, it is difficult to accurately quantify the volume captured by the CSO tank, but by observation of the curve of water depth variation in the tank, the volumes were not large for most of these events. It could be possible to store this part of the runoff volume in-line by oversizing the proposed Kingswood Trunk Relief Sewer along Queen Street in the future.

# 4.0 WATER QUALITY ANALYSIS

## 4.1 Field Program Summary

Monitoring of both water quantity and quality was conducted by the City of Toronto after the tank was constructed to evaluate the effectiveness of the facility in reducing bacterial counts in the Eastern Beaches area. The quantity data used in Chapter 3 was provided by City staff. The quality data included in this chapter were collected by SWAMP staff from July 1995 to December 1996.

An automatic wastewater sampler was set up within one of the maintenance holes along the Balsam Avenue storm sewer to collect flow composite samples from which the event mean concentrations of the various contaminants could be determined. An automatic sampler with a delay mechanism was set up at the top of the storm compartment to collect the outflow samples. The intake point for the sampler was located approximately 2.3 m above the invert level of the trough which is at elevation 67.8 m. The level was taken to be the intake level of the pump that discharges the supernatant 400 m off shore. Thus, the pollutant concentrations at that point were assumed to be representative of the supernatant concentration after the 8 hour detention period. However, a review of the tank drawings in this study indicated that the pump intake is near the lowest point of the tank floor. Most of the graphs of the storm compartment operation cycle show that the pump stops pumping the supernatant around 69.6 m. The tank operation program sets an 8 hour detention period after the program detects the end of the runoff event. The sampler was set to start collecting composite samples 7.5 hours after the runoff event ended, allowing one half hour to collect the samples.

As the monitoring work was already completed at the time of the present study, some assumptions have to be made in the data analysis based on the data collected, as follows:

1. The inflow event mean concentration of the unmonitored Glen Manor Drive storm sewer is equal to that of the Balsam Avenue storm sewer. Thus, the event mean concentration data collected at the Balsam Avenue storm sewer is used to represent the total inflow concentration of the storm compartment.
2. The outflow concentration data collected at 2.3 m above the invert level of the trough 7.5 hours after the detention period started is used to represent the supernatant concentration.

Table 4.1 describes the monitoring equipment and monitoring station locations.

***Table 4.1:*** Monitoring Station Location and Description

| Station | Location | Type of Samples | Equipment Installed |
|---|---|---|---|
| Inlet | Balsam Avenue storm sewer, 30 m upstream of the stormwater compartment | Flow Composite Samples | 1 Automatic Sampler & 1 Flow Logger |
| | | Grab Samples (Dry Weather Events, Winter/Spring Samples) | Manually Operated |
| Outlet | Stormwater compartment, 2.3 m above the bottom of the trough | Time Composite Samples | 1 Automatic Sampler |
| | | Grab Samples (Dry Weather Events) | As Appropriate |
| CSO | CSO compartment, 3 m above the tank bottom | Time Composite Samples | 1 Automatic Sampler |
| | | Grab Samples (Dry Weather Events) | Manually Operated |

In summary, the water quality monitoring program includes the following components:

- influent and effluent water chemistry,
- influent and effluent toxicity,
- influent and effluent particle size distribution,
- sediment chemistry.

This chapter focuses on the influent and effluent water chemistry, as the removal efficiency of the system is obtained from the pollutant concentration difference between the inlet and outlet, and as one of main purposes of this study is to evaluate the system performance based on pollutant removal.

Although the field monitoring was conducted from July 1995 to December 1996, only the 1996 data were applicable because the inflow samples collected in 1995 were affected by either dry weather flow or backwater from the tank. In addition, the supernatant samples collected in the stormwater tank did not take the quiescent settling period into consideration. These deficiencies were corrected in 1996 after both the inlet and outlet samplers were reinstalled at new locations in the system. Thus, the 1995 water chemistry data were disregarded. A total of 46 water samples were obtained in the 1996 monitoring period, and 24 influent samples were collected from the Balsam Avenue storm sewer that discharges runoff to the storm compartment. A total of 19 samples were obtained from the storm compartment, using the location and time considered to provide a residual suspension representative of the supernatant that is pumped offshore. Three influent samples were also collected from the CSO compartment.

Samples were divided into different groups by location (inlet and supernatant) and by season (winter/spring and summer/fall). The winter/spring season was defined as the period from December 1 to April 30, and the summer/autumn season was defined as the period between May 1 and November 30. Water samples were analyzed for the following contaminants at the MOE Resources Road Laboratory in Toronto:

- heavy metals (aluminum, arsenic barium, beryllium, cadmium, cobalt, copper, iron, mercury manganese, molybdenum, nickel, lead, strontium, titanium, vanadium, zinc, calcium and magnesium);
- nutrients (ammonia, nitrate, nitrite, TKN, phosphate and phosphorus);
- total suspended solids (TSS);
- alkalinity, conductivity and pH;
- bacteria (E. coli, Fecal Streptococci, Pseudomonas aeruginosa);
- solvent extractables;
- dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC);
- particle size distribution
- polyaromatic hydrocarbons (PAH);
- polychlorinated biphenyls (PCB).

## 4.2 Combined Sewage and Stormwater Characterization Results

Table 4.2 shows the inlet and outlet pollutant concentrations of all observations with the sample dates. Table 4.3 summaries the average contaminant concentrations; MDL concentrations are included in the table to simplify comparisons. Tables 4.4 and 4.5 show the statistical analysis for stormwater samples in the summer/autumn season and the winter/spring season, respectively. Table 4.6 shows the statistical summaries for combined sewage contaminant concentrations, while Table 4.7 presents comparisons between monitoring results and other studies and regulation standards.

In Table 4.1, 23 samples are for the inlet and 19 samples are for the outlet of the storm compartment; thus, a total of 19 events have both inlet and outlet contaminant concentrations. These events are used to calculate pollutant loads and pollutant removals in the system in Chapter 5.

The combined sewage samples were collected from the CSO compartment. The sampler in CSO tank was installed at a specific elevation. When the captured water level reached this elevation, the program recognized that an event occurred and the sampler was triggered to collect samples. Because the CSO compartment does not provide any treatment of the captured combined sewage, its water chemistry analysis was conducted to compare the concentration differences with that of urban runoff as a reference for the risk analysis of CSOs.

Only three events were sampled in the CSO compartment in 1996 with rainfall volumes of 40.4mm, 12.8mm and 32.8mm. Actually there were 18 events that occurred in the CSO compartment in that year. The combined sewage appears to have been significantly diluted. It is interesting to note that the combined sewage overflows are less polluted than the stormwater when comparing the pollutant concentrations between the samples from the two compartments. Some pollutants have higher concentrations in the combined sewage samples, but they are in the same order of magnitude. The average TSS concentration is only 48 mg/L for combined sewage, while the average concentration for the storm influent is 106 mg/L and 55 mg/L for the supernatant. Although the average E. coli colony count is one order of magnitude greater than that of the stormwater, the average Fecal Streptococci count is less than that observed in the stormwater. The observed phenomenon, that the combined sewage is less polluted than the stormwater, might be explained by the combined sewage overflowed to the CSO compartment usually occurring in the latter period of the runoff event. The sanitary sewage is significantly diluted, and the urban runoff that is collected by the combined sewer in this area is generated from roof and foundation drainage, thus it is cleaner than the runoff generated from the ground surface that enters the storm sewer. If the collected samples in the CSO compartment really represent the combined sewage overflow concentrations in this area during the wet weather period, the environmental risk of CSOs to the Lake is lower than discharging the urban runoff directly to the Lake. This situation should be taken into account in the future in converting the CSO compartment for the detention of stormwater.

The pollutant removal mechanism in the detention tank is primarily by sedimentation; thus, the suspended solid concentration is a key factor in the evaluation of the performance of the tank. The inlet TSS concentration in the summer/fall season is much larger than that in winter season; also the difference between inlet and outlet concentration is larger in the summer season. This suggests that the removal efficiency of the detention tank is higher in the summer season than in winter. However, the system performance over the entire year must be considered, since in the summer there are more overflows. The issue of removal efficiency is addressed in the next chapter. One dramatic difference between the seasons was the increased salt concentration in winter, as seen in the chloride concentrations and the conductivity data. This is due to the use of salt as a road de-icer in the winter. The E. coli count per 100mL in the stormwater supernatant was 38,633 on average. This value is dramatically higher than the PWQO which is 100/100mL. Thus, the reduction of E.coli in the tank is far from achieving the objective. The detention time might need to be re-evaluated. The E.coli count is a key factor in the beach closure issue; thus, the decreasing frequency of beach closings after the tank construction seems to be not due to the treatment efficiency of the facility, but because of the 400m offshore pumping of both the urban runoff and its supernatant after the 8 hour detention period.

Figure 4.1 is a graphical presentation of the statistical analysis of the water quality parameters. For the stormwater inflow and supernatant, the average event mean concentrations (AEMCs) for each contaminant are shown with their respective 95% confidence intervals. The data are presented on a logarithmic scale. For a specific contaminant, if the range of the upper and lower 95% confidence intervals of the AEMC overlapped for samples taken at the different locations (i.e., inlet, supernatant, CSO), then the AEMCs for the samples could be classified as being similar (i.e., in the same order of magnitude). A comparison of the 95% confidence intervals indicated that, for all of the variables analyzed in both warm and cold seasons, similar concentrations were observed between the inlet and supernatant locations. Although the pollutant concentrations were of a similar order of magnitude at the inlet and supernatant locations, the average event mean concentrations for many of the variables were found to be relatively smaller for the supernatant compared to those for the inlet location. This observation indicates that the storm compartment was retaining a portion of these pollutants.

The retained materials had settled below the sampling point over the 8 hour quiescent detention period provided after the storm had ended. For example, the influent and effluent mean concentration for TSS was 163 mg/L and 56 mg/L, respectively, for the summer/fall season indicating a reduction in concentration by about 65%. This result shows that the stormwater compartment was effective in removing some suspended solids and was expected to have removed a portion of the other insoluble pollutants known to attach to suspended particles. Incidentally, some of the variables were found to have lower AEMCs at the inlet than those of the outlet. For the summer/autumn season, marginally lower AEMCs were found for alkalinity, chloride, molybdenum, nitrate, strontium and titanium at the inlet as compared to the outlet station. For the winter/spring season, a longer list of variables was found to demonstrate lower inlet AEMCs than the outlet AEMC's. These variables include alkalinity, ammonia, barium, dissolved inorganic carbon, nickel, nitrate, nitrite, silicates and vanadium. It should also be noted that the concentrations of some of the mentioned variables were at the detection limit for the majority of the events. These variables, which include nickel, molybdenum, and vanadium, were present in insignificant amount and, therefore, the performance of the tank on these variables should be assessed with care and proper judgment. In addition, since most of these variables were in soluble form, any observation, which indicated marginal reduction or increase in concentration, may simply suggest that there was no removal of the particular variables. The slight difference in concentration could be due to error arising from the difficulty in collecting homogenous samples at the inlet and supernatant locations. While the other variables for which the supernatant concentrations were obviously found higher than the inlet concentrations, the observation might have resulted from chemical transformations or leaching from the materials stuck on the walls of tank.

***Table 4.2:*** Summary of Contaminant Concentration by Event (cont'd)

| Location | DATE | Aluminum mg/L | Arsenic mg/L | Barium mg/L | Beryllium mg/L | Cadmium mg/L | Cobalt mg/L | Chromium mg/L | Copper mg/L | Iron mg/L | Mercury υg/L | Manganese mg/L | Molybdenum mg/L | Nickel mg/L | Lead mg/L | St mg/L | Ti mg/L | Va mg/L | Zn mg/L | Alkalinity mg/L as CaCO3 | Chloride mg/L | Conductivity µS/cm | DIC mg/L | DOC mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RMDL | | 0.050 | 0.001 | 0.005 | 0.0010 | 0.0005 | 0.0010 | 0.0010 | 0.0010 | 0.10 | 0.02 | 0.005 | 0.0020 | 0.00500 | 0.005 | 0.02 | 0.010 | 0.0020 | 0.0025 | 0.2 | 0.2 | 1 | 0.2 | 0.1 |
| CSO | May 21 | 0.180 | 0.002 | 0.022 | 0.0001 | 0.0001 | 0.0002 | 0.0014 | 0.0088 | 0.36 | 0.02 | 0.050 | 0.0002 | 0.00100 | 0.010 | 0.09 | 0.002 | 0.0014 | 0.0380 | 85.6 | 65.4 | 422 | 20.6 | 2.3 |
| CSO | Jul 16 | 0.370 | 0.002 | 0.019 | 0.0001 | 0.0006 | 0.0006 | 0.0052 | 0.0180 | 0.46 | 0.03 | 0.044 | 0.0006 | 0.00200 | 0.020 | 0.05 | 0.002 | 0.0012 | 0.0980 | 34.6 | 26.4 | 207 | 7.8 | 2.0 |
| CSO | Aug 9 | 1.600 | 0.003 | 0.074 | 0.0004 | 0.0012 | 0.0010 | 0.0030 | 0.0530 | 1.20 | 0.16 | 0.096 | 0.0008 | 0.00550 | 0.040 | 0.07 | 0.001 | 0.0036 | 0.2000 | 55.8 | 14.8 | 194 | 12.8 | 11.8 |
| Inlet | Jan 19 | 0.330 | 0.001 | 0.014 | 0.0001 | 0.0003 | 0.0008 | 0.0036 | 0.0200 | 0.60 | 0.03 | 0.044 | 0.0002 | 0.00200 | 0.035 | 0.09 | 0.006 | 0.0016 | 0.0860 | 42.4 | 70.8 | 364 | 9.6 | 3.8 |
| Inlet | Jan 19 | 0.250 | 0.002 | 0.027 | 0.0025 | 0.0025 | 0.0056 | 0.0050 | 0.0510 | 0.68 | 0.05 | 0.120 | 0.0050 | 0.01250 | 0.125 | 0.35 | 0.025 | 0.0080 | 0.1800 | 91.2 | 1230.0 | 3880 | 19.6 | 6.3 |
| Inlet | Jan 24 | 0.520 | 0.001 | 0.019 | 0.0001 | 0.0010 | 0.0008 | 0.0070 | 0.0350 | 1.20 | 0.04 | 0.094 | 0.0010 | 0.00400 | 0.040 | 0.18 | 0.009 | 0.0036 | 0.1700 | 59.6 | 236.0 | 970 | 12.6 | 5.1 |
| Inlet | Feb 8 | 1.000 | 0.002 | 0.047 | 0.0030 | 0.0068 | 0.0002 | 0.0170 | 0.0900 | 2.10 | 0.07 | 0.230 | 0.0086 | 0.00400 | 0.180 | 0.26 | 0.032 | 0.0130 | 0.4200 | 67.6 | 800.0 | 2660 | 13.6 | 5.2 |
| Inlet | Feb 20 | 0.850 | 0.001 | 0.052 | 0.0001 | 0.0001 | 0.0002 | 0.0068 | 0.0550 | 3.00 | 0.06 | 0.250 | 0.0002 | 0.00750 | 0.070 | 0.52 | 0.014 | 0.0098 | 0.3500 | | 3570.0 | | 21.6 | 20.2 |
| Inlet | Feb 21 | 0.120 | 0.003 | 0.016 | 0.0001 | 0.0011 | 0.0002 | 0.0078 | 0.0310 | 0.38 | 0.03 | 0.067 | 0.0024 | 0.00150 | 0.005 | 0.25 | 0.002 | 0.0010 | 0.1200 | | 630.0 | | 24.0 | 11.3 |
| Inlet | Mar 13 | 0.020 | 0.001 | 0.021 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0160 | 0.10 | | 0.071 | 0.0018 | 0.00250 | 0.025 | 0.34 | 0.001 | 0.0030 | 0.0540 | 74.8 | 1810.0 | 5360 | 18.2 | 6.5 |
| Inlet | Mar 25 | 0.030 | 0.001 | 0.100 | 0.0001 | 0.0001 | 0.0002 | 0.0880 | 0.0024 | 0.16 | 0.02 | 0.084 | 0.0006 | 0.00150 | 0.010 | 0.43 | 0.001 | 0.0028 | 0.0180 | 349.0 | 659.0 | 2730 | 83.4 | 1.3 |
| Inlet | Apr 12 | 0.170 | 0.001 | 0.052 | 0.0001 | 0.0005 | 0.0004 | 0.0034 | 0.0760 | 0.34 | 0.02 | 0.066 | 0.0010 | 0.00300 | 0.015 | 0.30 | 0.004 | 0.0010 | 0.0490 | 170.0 | 490.0 | 1950 | 40.0 | 4.8 |
| Inlet | Apr 25 | 0.390 | 0.001 | 0.018 | 0.0001 | 0.0004 | 0.0004 | 0.0044 | 0.0300 | 0.82 | 0.03 | 0.066 | 0.0014 | 0.00250 | 0.020 | 0.18 | 0.007 | 0.0036 | 0.1200 | 52.0 | 31.2 | 281 | 12.0 | 6.3 |
| Inlet | Apr 30 | 0.220 | 0.001 | 0.009 | 0.0001 | 0.0001 | 0.0004 | 0.0036 | 0.0150 | 0.44 | 0.02 | 0.038 | 0.0002 | 0.00150 | 0.025 | 0.06 | 0.003 | 0.0018 | 0.0600 | | 12.8 | | 7.0 | 3.0 |
| Inlet | May 21 | 0.800 | 0.002 | 0.040 | 0.0001 | 0.0022 | 0.0010 | 0.0048 | 0.0430 | 1.50 | 0.03 | 0.200 | 0.0006 | 0.00450 | 0.050 | 0.16 | 0.006 | 0.0050 | 0.2500 | 87.6 | 57.2 | 397 | 23.6 | 13.1 |
| Inlet | Jun 7 | 0.120 | 0.001 | 0.019 | 0.0001 | 0.0001 | 0.0004 | 0.0014 | 0.0190 | 0.42 | 0.02 | 0.100 | 0.0004 | 0.00250 | 0.010 | 0.11 | 0.002 | 0.0018 | 0.0610 | 78.8 | 49.2 | 371 | 58.2 | 1.7 |
| Inlet | Jun 21 | 0.440 | 0.001 | 0.037 | 0.0001 | 0.0016 | 0.0004 | 0.0032 | 0.0310 | 1.00 | 0.02 | 0.110 | 0.0006 | 0.00350 | 0.030 | 0.15 | 0.004 | 0.0028 | 0.2500 | 108.0 | 84.4 | 562 | 26.6 | 5.6 |
| Inlet | Jul 10 | 0.070 | 0.001 | 0.038 | 0.0001 | 0.0005 | 0.0008 | 0.0046 | 0.0440 | 1.20 | 0.04 | 0.140 | 0.0002 | 0.00350 | 0.060 | 0.09 | 0.006 | 0.0034 | 0.1500 | 57.2 | 29.2 | 246 | 13.0 | 5.0 |
| Inlet | Jul 12 | 0.190 | 0.001 | 0.077 | 0.0001 | 0.0001 | 0.0002 | 0.0006 | 0.0042 | 0.30 | 0.02 | 0.140 | 0.0006 | 0.00100 | 0.005 | 0.33 | 0.001 | 0.0006 | 0.0220 | 333.0 | 408.0 | 1810 | 76.8 | 1.8 |
| Inlet | Jul 16 | 1.400 | 0.002 | 0.057 | 0.0001 | 0.0019 | 0.0012 | 0.0100 | 0.0650 | 3.40 | 0.09 | 0.250 | 0.0004 | 0.00750 | 0.090 | 0.19 | 0.009 | 0.0066 | 0.2700 | 121.0 | 92.8 | 606 | 29.6 | 8.4 |
| Inlet | Jul 22 | 0.400 | 0.001 | 0.037 | 0.0001 | 0.0007 | 0.0008 | 0.0024 | 0.0280 | 0.66 | 0.04 | 0.120 | 0.0008 | 0.00450 | 0.025 | 0.13 | 0.005 | 0.0032 | 0.1000 | 98.8 | 75.6 | 487 | 24.6 | 6.8 |
| Inlet | Aug 8 | 4.800 | 0.004 | 0.150 | 0.0001 | 0.0014 | 0.0014 | 0.0058 | 0.1500 | 4.00 | 0.34 | 0.240 | 0.0002 | 0.01000 | 0.110 | 0.15 | 0.001 | 0.0058 | 0.4500 | 88.0 | 28.8 | 297 | 22.0 | 12.8 |
| Inlet | Sep 9 | 0.197 | 0.001 | 0.011 | 0.0068 | 0.0003 | 0.0000 | 0.0016 | 0.0113 | 0.40 | 0.02 | 0.031 | 0.0010 | 0.00101 | 0.011 | 0.03 | 0.003 | 0.0018 | 0.0494 | 26.6 | 3.4 | 80 | 5.4 | 3.6 |
| Inlet | Sep 13 | 1.490 | 0.001 | 0.074 | 0.1040 | 0.0018 | 0.0014 | 0.0065 | 0.0418 | 3.38 | 0.07 | 0.235 | 0.0021 | 0.00504 | 0.110 | 0.08 | 0.007 | 0.0058 | 0.3010 | 52.4 | 3.0 | 118 | 10.2 | 3.1 |
| Inlet | Sep 30 | 0.899 | 0.001 | 0.038 | 0.0494 | 0.0021 | 0.0007 | 0.0046 | 0.0298 | 2.15 | 0.02 | 0.158 | 0.0011 | 0.00337 | 0.039 | 0.06 | 0.002 | 0.0035 | 0.2480 | 40.8 | 2.0 | 98 | 8.0 | 4.2 |
| Inlet | Oct 21 | 0.189 | 0.001 | 0.025 | 0.0000 | 0.0005 | 0.0002 | 0.0019 | 0.0212 | 0.48 | 0.02 | 0.005 | 0.0000 | 0.00005 | 0.010 | 0.09 | 0.003 | 0.0014 | 0.0637 | 36.8 | 4.8 | 112 | 8.8 | 4.0 |
| Inlet | Nov 4 | 1.220 | 0.001 | 0.045 | 0.0001 | 0.0011 | 0.0017 | 0.0060 | 0.0747 | 2.96 | 0.04 | 0.294 | 0.0005 | 0.00708 | 0.080 | 0.08 | 0.006 | 0.0055 | 0.2610 | 66.0 | 10.4 | 185 | 17.4 | 11.2 |
| Outlet | Jan 19 | 0.380 | 0.001 | 0.015 | 0.0001 | 0.0003 | 0.0006 | 0.0020 | 0.0200 | 0.70 | 0.04 | 0.059 | 0.0002 | 0.00100 | 0.030 | 0.08 | 0.006 | 0.0022 | 0.0940 | 56.4 | 85.8 | 447 | 12.0 | 3.5 |
| Outlet | Jan 24 | 0.360 | 0.001 | 0.013 | 0.0001 | 0.0004 | 0.0004 | 0.0032 | 0.0220 | 0.78 | 0.03 | 0.058 | 0.0006 | 0.00250 | 0.025 | 0.08 | 0.007 | 0.0026 | 0.0880 | 45.8 | 135.0 | 604 | 10.0 | 3.8 |
| Outlet | Feb 8 | 1.200 | 0.002 | 0.059 | 0.0029 | 0.0025 | 0.0002 | 0.0230 | 0.0810 | 2.30 | 0.08 | 0.280 | 0.0002 | 0.01300 | 0.075 | 0.38 | 0.034 | 0.0150 | 0.3700 | 105.0 | 1500.0 | 4680 | 24.2 | 6.7 |
| Outlet | Feb 20 | 0.750 | 0.001 | 0.060 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0410 | 2.50 | 0.05 | 0.240 | 0.0002 | 0.00750 | 0.020 | 0.59 | 0.014 | 0.0078 | 0.2400 | | 4230.0 | | 33.6 | 19.5 |
| Outlet | Feb 21 | 0.290 | 0.002 | 0.025 | 0.0001 | 0.0005 | 0.0002 | 0.0040 | 0.0230 | 0.92 | 0.03 | 0.086 | 0.0020 | 0.00050 | 0.025 | 0.20 | 0.004 | 0.0002 | 0.1300 | | 682.0 | | 22.6 | 7.7 |
| Outlet | Mar 25 | 0.030 | 0.001 | 0.074 | 0.0001 | 0.0001 | 0.0002 | 0.0066 | 0.0028 | 0.30 | 0.02 | 0.094 | 0.0002 | 0.00050 | 0.020 | 0.33 | 0.001 | 0.0010 | 0.0140 | 345.0 | 416.0 | 2060 | 80.2 | 1.7 |
| Outlet | Apr 12 | 0.080 | 0.001 | 0.074 | 0.0001 | 0.0001 | 0.0002 | 0.0014 | 0.0082 | 0.36 | 0.02 | 0.100 | 0.0002 | 0.00100 | 0.010 | 0.35 | 0.001 | 0.0004 | 0.0280 | 308.0 | 443.0 | 2090 | 70.8 | 2.9 |
| Outlet | Apr 25 | 0.210 | 0.001 | 0.052 | 0.0001 | 0.0005 | 0.0004 | 0.0032 | 0.0130 | 0.54 | 0.02 | 0.089 | 0.0008 | 0.00100 | 0.010 | 0.30 | 0.003 | 0.0020 | 0.0600 | 225.0 | 240.0 | 1350 | 51.8 | 4.0 |
| Outlet | Apr 30 | 0.250 | 0.001 | 0.012 | 0.0001 | 0.0002 | 0.0004 | 0.0032 | 0.0150 | 0.50 | 0.02 | 0.048 | 0.0002 | 0.00100 | 0.020 | 0.12 | 0.002 | 0.0018 | 0.0740 | | 30.0 | | 10.0 | 2.9 |
| Outlet | May 21 | 0.170 | 0.001 | 0.013 | 0.0001 | 0.0004 | 0.0004 | 0.0018 | 0.0140 | 0.34 | 0.02 | 0.050 | 0.0002 | 0.00150 | 0.015 | 0.06 | 0.002 | 0.0020 | 0.0820 | 40.4 | 18.8 | 163 | 10.4 | 4.0 |
| Outlet | Jun 21 | 0.300 | 0.001 | 0.020 | 0.0001 | 0.0004 | 0.0002 | 0.0020 | 0.0170 | 0.72 | 0.03 | 0.081 | 0.0004 | 0.00250 | 0.020 | 0.07 | 0.002 | 0.0018 | 0.0760 | 47.0 | 29.6 | 237 | 10.8 | 5.1 |
| Outlet | Jul 10 | 0.450 | 0.001 | 0.026 | 0.0001 | 0.0004 | 0.0004 | 0.0038 | 0.0320 | 0.74 | 0.03 | 0.088 | 0.0002 | 0.03200 | 0.040 | 0.08 | 0.050 | 0.0034 | 0.0980 | 53.4 | 26.8 | 229 | 12.2 | 5.0 |
| Outlet | Jul 12 | 0.170 | 0.001 | 0.069 | 0.0001 | 0.0004 | 0.0002 | 0.0022 | 0.0030 | 0.32 | 0.02 | 0.100 | 0.0006 | 0.00100 | 0.005 | 0.30 | 0.001 | 0.0014 | 0.0260 | 326.0 | 367.0 | 1760 | 74.8 | 2.1 |
| Outlet | Jul 16 | 1.200 | 0.002 | 0.048 | 0.0001 | 0.0014 | 0.0018 | 0.0100 | 0.0510 | 3.20 | 0.06 | 0.220 | 0.0004 | 0.00700 | 0.090 | 0.15 | 0.009 | 0.0062 | 0.2500 | 96.4 | 62.8 | 455 | 22.6 | 7.1 |
| Outlet | Sep 9 | 0.093 | 0.001 | 0.005 | 0.0014 | 0.0000 | 0.0004 | 0.0013 | 0.0068 | 0.15 | 0.02 | 0.012 | 0.0009 | 0.00124 | 0.007 | 0.02 | 0.002 | 0.0008 | 0.0287 | 19.8 | 1.6 | 54 | 3.8 | 1.7 |
| Outlet | Sep 13 | 0.259 | 0.001 | 0.033 | 0.0162 | 0.0006 | 0.0003 | 0.0018 | 0.0145 | 0.63 | 0.02 | 0.074 | 0.0000 | 0.00124 | 0.013 | 0.13 | 0.003 | 0.0023 | 0.0619 | 110.0 | 95.4 | 564 | 23.8 | 4.4 |
| Outlet | Sep 30 | 0.394 | 0.001 | 0.037 | 0.0000 | 0.0012 | 0.0005 | 0.0028 | 0.0144 | 0.88 | 0.03 | 0.122 | 0.0005 | 0.00162 | 0.027 | 0.13 | 0.006 | 0.0031 | 0.0841 | 114.0 | 99.4 | 595 | 23.0 | 2.9 |
| Outlet | Oct 21 | 0.032 | 0.001 | 0.010 | 0.0000 | 0.0001 | 0.0004 | 0.0014 | 0.0095 | 0.05 | 0.02 | 0.060 | 0.0003 | 0.00058 | 0.000 | 0.04 | 0.001 | 0.0008 | 0.0143 | 82.8 | 69.0 | 422 | 21.0 | 4.6 |
| Outlet | Nov 4 | 0.117 | 0.001 | 0.041 | 0.0000 | 0.0001 | 0.0003 | 0.0003 | 0.0185 | 0.59 | 0.02 | 0.120 | 0.0002 | 0.00141 | 0.006 | 0.16 | 0.001 | 0.0011 | 0.1050 | 164.0 | 141.0 | 808 | 44.0 | 11.0 |

***Table 4.2:*** Summary of Contaminant Concentration by Event (cont'd)

| Location | DATE | Anthracene mg/L | Benzo(a)pyrene µg/L | Chrysene µg/L | Ammonia + Ammonium mg/L | Nitrate + Nitrite mg/L | Nitrite mg/L | TKN mg/L | pH | Phosphate mg/L | Phosphorus mg/L | Suspended Solids mg/L | Silicon mg/L | Solvent Extractables mg/L | Turbidity FTU | E. Coli c/100mL | Fecal Streptococci c/100mL | Pseudomonas Aeruginosa c/100mL | Benzo (a) Anthracene µg/L | Benzo (A) Pyrene µg/L | Benzo (a) Fluoranthene µg/L | Biphenyl µg/L | Benzo (k) Fluoranthene µg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RMDL | | 0.2 | 0.2 | 0.2 | 0.002 | 0.005 | 0.001 | 0.02 | | 0.0005 | 0.002 | 2 | 0.1 | 0.5 | 0.01 | 3 | 3 | | 0.2 | | 0.2 | | 0.2 |
| CSO | May 21 | 0.2 | 0.2 | 0.2 | 0.156 | 0.945 | 0.117 | 1.06 | 7.95 | 0.0565 | 0.220 | 13 | 1.5 | 2.0 | 5.46 | | | | 0.2 | | 0.2 | | 0.2 |
| CSO | Jul 16 | | | | 0.558 | 2.300 | 1.650 | 3.30 | 7.25 | 0.3200 | 0.550 | 33 | 0.6 | 0.5 | 2.1 | 380,000 | 20,000 | 4,500 | | | | | |
| CSO | Aug 9 | | | | 2.360 | 0.295 | 0.193 | 7.00 | 7.39 | 0.4500 | 2.000 | 97 | 0.8 | 10.0 | 55.1 | | | | | | | | |
| Inlet | Jan 19 | 0.2 | 0.2 | 0.2 | 0.322 | 0.320 | 0.036 | 1.56 | 7.44 | 0.1400 | 0.304 | 37 | 0.6 | 1.5 | 17.8 | | | | 0.2 | | 0.2 | | 0.2 |
| Inlet | Jan 19 | 0.2 | 0.8 | 0.6 | 4.900 | 0.915 | 0.215 | 9.20 | 7.42 | 0.3300 | 0.890 | 131 | 1.3 | 6.0 | 26.3 | | | | 0.4 | | 1.2 | | 0.2 |
| Inlet | Jan 24 | 0.2 | 0.6 | 0.8 | 0.710 | 1.450 | 0.107 | 2.50 | 7.63 | 0.2350 | 0.420 | 64 | 1.2 | 6.0 | 53.5 | | | | 0.4 | 0.6 | 0.8 | 0.2 | 0.8 |
| Inlet | Feb 8 | 0.2 | 1.2 | 2.2 | 6.350 | 1.390 | 0.172 | 10.30 | 7.43 | 0.1600 | 0.890 | 199 | 0.8 | 16.5 | 115 | | | | 1 | | 1.6 | | 1.6 |
| Inlet | Feb 20 | | | | | 1.490 | 0.330 | | | 0.0055 | | | 1.1 | 12.5 | 41.7 | | | | 0.4 | 0.6 | 1 | 0.2 | 0.8 |
| Inlet | Feb 21 | | | | 6.260 | 1.860 | 0.060 | | | 0.2250 | | | 1.4 | 2.0 | 2.07 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Inlet | Mar 13 | | | | 2.040 | 1.260 | 0.055 | 4.80 | 7.49 | 0.1480 | 0.364 | 58 | 1.5 | | 20.6 | | | | | | | | |
| Inlet | Mar 25 | | | | 0.106 | 1.770 | 0.024 | 0.56 | 8.06 | 0.0170 | 0.094 | 20 | 6.4 | 0.5 | 2.39 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Inlet | Apr 12 | | | | 0.118 | 1.860 | 0.020 | 1.00 | 7.78 | 0.0110 | 0.130 | 37 | 3.0 | 1.0 | 8.01 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Inlet | Apr 25 | | | | 0.040 | 2.440 | 0.045 | 2.00 | 7.66 | 0.1500 | 0.316 | 36 | 1.3 | 6.5 | 28.8 | | | | 0.2 | 0.4 | 0.2 | 0.2 | 0.4 |
| Inlet | Apr 30 | 0.2 | 0.2 | 0.2 | 0.022 | 0.635 | 0.014 | 0.34 | | 0.0815 | 0.086 | 24 | 0.5 | | | | | | 0.2 | | 0.2 | | 0.2 |
| Inlet | May 21 | 0.2 | 0.4 | 0.6 | 0.764 | 0.055 | 0.007 | 3.40 | 7.27 | 0.0810 | 0.520 | 117 | 1.0 | 7.5 | 51.4 | | | | 0.4 | | 0.6 | | 0.4 |
| Inlet | Jun 7 | 0.8 | 1.2 | 1.4 | 0.586 | 0.665 | 0.221 | 1.70 | 7.41 | 0.2400 | 0.344 | 17 | 3.0 | 6.5 | 6.84 | | | | 1.2 | | 1.2 | | 1.2 |
| Inlet | Jun 21 | 0.2 | 0.4 | 0.4 | 0.300 | 2.150 | 0.176 | 1.84 | 7.86 | 0.2700 | 0.424 | | 2.2 | 7.5 | 13.9 | 34,000 | 102,000 | 140 | 0.4 | | 0.4 | | 0.4 |
| Inlet | Jul 10 | | | | 0.400 | 0.900 | 0.105 | 1.80 | 7.87 | 0.2000 | 0.456 | 139 | 1.0 | 5.0 | | 6,800 | 600 | 120 | | | | | |
| Inlet | Jul 12 | | | | 0.172 | 3.110 | 0.064 | 0.46 | 8.25 | 0.0480 | 0.088 | 11 | 6.3 | 1.0 | 6.24 | | | | | | | | |
| Inlet | Jul 16 | | | | 1.200 | 1.410 | 0.460 | 4.50 | 7.71 | 0.0555 | 0.730 | 211 | 2.0 | 11.0 | 72.6 | 180,000 | 71,000 | 480 | | | | | |
| Inlet | Jul 22 | | | | 0.432 | 0.795 | 0.400 | 2.16 | 8.09 | 0.0810 | 0.310 | 57 | 1.8 | 5.0 | 13.9 | 18,000 | 2,300 | 690 | | | | | |
| Inlet | Aug 8 | | | | 2.570 | 0.050 | 0.012 | 24.00 | 7.41 | 0.6200 | 4.200 | 282 | 1.8 | 26.5 | 106 | 240,000 | 570,000 | 20,000 | | | | | |
| Inlet | Sep 9 | | | | 0.056 | 0.580 | 0.040 | 0.94 | 7.56 | 0.0715 | 0.186 | 143 | 0.3 | 1.0 | 7.85 | 6,100 | 1,380 | 32 | | | | | |
| Inlet | Sep 13 | | | | 0.034 | 0.240 | 0.017 | 0.64 | 7.92 | 0.0340 | 0.118 | 276 | 0.5 | | 42.1 | | | | | | | | |
| Inlet | Sep 30 | | | | 0.016 | 0.115 | 0.005 | 2.00 | 7.66 | 0.0180 | 0.270 | 126 | 0.5 | 5.0 | 12.9 | 5,400 | 1,880 | 90 | | | | | |
| Inlet | Oct 21 | | | | 0.148 | 0.855 | 0.046 | 1.88 | 7.24 | 0.0840 | 0.370 | 51 | 0.6 | 3.0 | 16.5 | 3,700 | 4,200 | 260 | | | | | |
| Inlet | Nov 4 | | | | 0.002 | 0.030 | 0.007 | 1.36 | 7.39 | 0.4100 | 0.530 | 187 | 1.1 | 11.5 | 63.7 | | | | | | | | |
| Outlet | Jan 19 | 0.2 | 0.4 | 0.4 | 0.380 | 0.600 | 0.036 | 2.10 | 7.64 | 0.1700 | 0.470 | 73 | 0.9 | 5.5 | 39.7 | | | | 0.2 | | 0.8 | | 0.2 |
| Outlet | Jan 24 | 0.2 | 0.2 | 0.2 | 0.614 | 1.160 | 0.059 | 2.10 | 7.53 | 0.2250 | 0.370 | 33 | 0.9 | 3.5 | 24.2 | | | | 0.2 | | 0.2 | | 0.2 |
| Outlet | Feb 8 | 0.2 | 1.2 | 2.0 | 6.550 | 2.210 | 0.055 | | 7.54 | 0.1200 | 0.850 | 198 | 1.9 | 13.5 | 146 | | | | 0.8 | | 1.8 | | 1.2 |
| Outlet | Feb 20 | | | | 6.360 | 3.310 | 0.370 | | | 0.0355 | | | 2.2 | 8.5 | 26.9 | | | | 0.2 | 0.2 | 0.4 | 0.2 | 0.4 |
| Outlet | Feb 21 | | | | 4.740 | 2.660 | 0.130 | | | 0.3000 | | | 1.5 | 1.0 | 12.1 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Outlet | Mar 25 | | | | 0.192 | 4.680 | 0.024 | 0.68 | 8.21 | 0.0180 | 0.078 | 13 | 6.2 | 0.5 | 2.67 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Outlet | Apr 12 | | | | 0.216 | 4.550 | 0.111 | 0.84 | 8.03 | 0.0340 | 0.090 | 18 | 5.5 | 0.5 | 3.49 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Outlet | Apr 25 | | | | 0.008 | 3.840 | 0.013 | 0.60 | 8.26 | 0.1600 | 0.230 | 28 | 4.2 | 3.0 | 15.4 | | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Outlet | Apr 30 | 0.2 | 0.2 | 0.4 | 0.002 | 0.915 | 0.001 | 0.28 | | 0.0930 | 0.092 | 31 | 0.7 | | | | | | 0.2 | | 0.4 | | 0.2 |
| Outlet | May 21 | 0.2 | 0.2 | 0.2 | 0.634 | 0.085 | 0.018 | 1.68 | 7.40 | 0.0810 | 0.210 | 21 | 0.5 | 1.0 | 13.1 | | | | 0.2 | | 0.2 | | 0.2 |
| Outlet | Jun 21 | 0.2 | 0.2 | 0.2 | 0.524 | 0.900 | 0.094 | 0.90 | 7.55 | 0.2500 | 0.220 | | 0.9 | 5.0 | 16.9 | 65,000 | 124,000 | 520 | 0.2 | | 0.2 | | 0.2 |
| Outlet | Jul 10 | | | | 0.388 | 1.060 | 0.092 | 1.60 | 7.82 | 0.2450 | 0.390 | 93 | 0.9 | 4.0 | | 5,800 | 2,500 | 20 | | | | | |
| Outlet | Jul 12 | | | | 0.218 | 3.050 | 0.057 | 0.46 | 8.28 | 0.0440 | 0.078 | 8 | 6.1 | 1.5 | 5.29 | | | | | | | | |
| Outlet | Jul 16 | | | | 0.874 | 1.490 | 0.560 | 3.84 | 7.71 | 0.0390 | 0.610 | 189 | 1.4 | 12.0 | 55.4 | 140,000 | 62,000 | 460 | | | | | |
| Outlet | Sep 9 | | | | 0.098 | 0.340 | 0.027 | 0.52 | 7.54 | 0.0575 | 0.098 | 28 | 0.2 | 0.5 | 3.49 | 7,100 | 5,400 | 124 | | | | | |
| Outlet | Sep 13 | | | | 0.096 | 1.450 | 0.055 | 1.22 | 8.09 | 0.0785 | 0.204 | 31 | 2.2 | 2.0 | 9.59 | | | | | | | | |
| Outlet | Sep 30 | | | | 0.118 | 1.510 | 0.065 | 1.16 | 8.03 | 0.0560 | 0.210 | 48 | 2.4 | 2.0 | 19.1 | 9,400 | 4,300 | 20 | | | | | |
| Outlet | Oct 21 | | | | 0.196 | 1.790 | 0.063 | 1.86 | 7.38 | 0.2400 | 0.330 | 39 | 1.6 | 2.0 | 19 | 4,500 | 2,900 | 20 | | | | | |
| Outlet | Nov 4 | | | | 0.204 | 0.025 | 0.010 | 0.20 | 7.50 | 0.5250 | 0.010 | 30 | 3.0 | 1.5 | 16.5 | | | | | | | | |

***Table 4.2:*** Summary of Contaminant Concentration by Event (cont'd)

| Location | DATE | Chrysene µg/L | Fluoranthene µg/L | Fluorin µg/L | Benzo (g,h,I,) Perylene µg/L | Indole µg/L | Indeno (1,2,3-c,d) Prene µg/L | Penanthrene µg/L | Pyrene µg/L | a-BHC µg/L | g-BHC µg/L | a-Chlordane µg/L | g-Chlordane µg/L | Dieldrin µg/L | pp-DDE µg/L | pp-DDT µg/L | Dicamba µg/L | 2,4-D µg/L | Pentachlorophenol µg/L | 2,4,6-trichlorophenol µg/L | Calcium mg/L | Calcium m m mg/L | Hardness mg/L | Potassium mg/L | Magnesium mg/L | Magnesium mg/L | Sodium mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RMDL | | | 0.2 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | | 1 | 5 | 50 | 100 | 100 | 100 | | 0.01 | | | | 0.01 | |
| CSO | May 21 | | 0.2 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 2 | 2 | 2 | 4 | 1 | 5 | 50 | 190 | 140 | 20 | | | | | | | |
| CSO | Jul 16 | | | | | | | | | | | | | | | | 50 | 280 | 60 | 20 | | | | | | | |
| CSO | Aug 9 | | | | | | | | | | | | | | | | 50 | 580 | 23 | 20 | | | | | | | |
| Inlet | Jan 19 | | 0.4 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.4 | 3 | 2 | 2 | 2 | 3 | 1 | 5 | | | | | | | | | | | |
| Inlet | Jan 19 | | 1.4 | | 0.8 | 0.2 | 0.5 | 0.8 | 1.2 | 1 | 1 | 2 | 2 | 30 | 1 | 5 | 50 | 1100 | 420 | 100 | | | | | | | |
| Inlet | Jan 24 | 0.8 | 1.6 | 0.2 | 0.4 | 0.2 | 0.5 | 0.6 | 1.2 | 2 | 1 | 2 | 2 | 10 | 1 | 5 | 50 | 300 | 270 | 44 | | | | | | | |
| Inlet | Feb 8 | | 4.4 | | 1.6 | 0.2 | 0.5 | 3.2 | 3.6 | 4 | 2 | 7 | 7 | 41 | 8 | 14 | 50 | 100 | 200 | 20 | | | | | | | |
| Inlet | Feb 20 | 1 | 1.6 | 0.2 | 1 | 0.2 | 0.5 | 0.4 | 1.6 | 2 | 1 | 2 | 2 | 8 | 1 | 5 | 50 | 100 | 190 | 20 | | | | | | | |
| Inlet | Feb 21 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 2 | 1 | 2 | 2 | 2 | 1 | 5 | 50 | 380 | 350 | 20 | | | | | | | |
| Inlet | Mar 13 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Inlet | Mar 25 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | 2 | 1 | 5 | 50 | 100 | 21 | 20 | | | | | | | |
| Inlet | Apr 12 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 2 | 1 | 2 | 2 | 2 | 1 | 5 | 50 | 140 | 56 | 52 | | | | | | | |
| Inlet | Apr 25 | 0.4 | 0.4 | 0.2 | 0.4 | 0.2 | 0.5 | 0.2 | 0.4 | 2 | 3 | 2 | 2 | 9 | 1 | 5 | 50 | 880 | 150 | 20 | | | | | | | |
| Inlet | Apr 30 | | 0.6 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.4 | 3 | 4 | 2 | 2 | 10 | 3 | 6 | 50 | 430 | 110 | 20 | | | | | | | |
| Inlet | May 21 | | 1.4 | | 0.4 | 0.2 | 0.5 | 0.8 | 1 | 1 | 3 | 3 | 3 | 7 | 5 | 7 | 56 | 2000 | 140 | 20 | | | | | | | |
| Inlet | Jun 7 | | 3 | | 0.8 | 4.8 | 1 | 2 | 2.6 | 1 | 3 | 5 | 4 | 27 | 1 | 8 | 48 | 1400 | 930 | 20 | | | | | | | |
| Inlet | Jun 21 | | 1.2 | | 0.2 | 13 | 0.5 | 0.8 | 0.8 | 1 | 3 | 2 | 2 | 8 | 1 | 5 | 60 | 570 | 450 | 24 | | | | | | | |
| Inlet | Jul 10 | | | | | | | | | | | | | | | | 60 | 410 | 210 | 20 | | | | | | | |
| Inlet | Jul 12 | | | | | | | | | | | | | | | | 50 | 100 | 33 | 20 | 137 | | 430 | 2.64 | 21.1 | | 211 |
| Inlet | Jul 16 | | | | | | | | | | | | | | | | 190 | 2500 | 110 | 20 | | | | | | | |
| Inlet | Jul 22 | | | | | | | | | | | | | | | | 50 | 250 | 92 | 20 | | | | | | | |
| Inlet | Aug 8 | | | | | | | | | | | | | | | | 50 | 330 | 23 | 20 | | | | | | | |
| Inlet | Sep 9 | | | | | | | | | | | | | | | | 50 | 100 | 200 | 20 | 10.2 | 12.1 | 29 | 1.63 | 0.88 | 1.41 | 2.32 |
| Inlet | Sep 13 | | | | | | | | | | | | | | | | 50 | 100 | 73 | 20 | 21.8 | 40.7 | 58 | 1.66 | 0.88 | 7.31 | 2.8 |
| Inlet | Sep 30 | | | | | | | | | | | | | | | | 50 | 100 | 60 | 20 | 13.8 | 32.7 | 38.8 | 2.85 | 1.06 | 5.82 | 2.06 |
| Inlet | Oct 21 | | | | | | | | | | | | | | | | 50 | 340 | 260 | 20 | 15 | 16.2 | 41.6 | 4.68 | 1 | 1.02 | 3.08 |
| Inlet | Nov 4 | | | | | | | | | | | | | | | | 50 | 100 | 240 | 20 | 22.2 | 42 | 62.4 | 8.88 | 1.7 | 7.98 | 5.2 |
| Outlet | Jan 19 | | 1 | | 0.4 | 0.2 | 0.5 | 0.4 | 0.8 | 2 | 1 | 2 | 2 | 5 | 1 | 5 | 50 | 96 | 200 | 100 | | | | | | | |
| Outlet | Jan 24 | | 0.4 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.4 | 2 | 1 | 2 | 2 | 6 | 1 | 5 | 50 | 100 | 10 | 28 | | | | | | | |
| Outlet | Feb 8 | | 4.2 | | 1.6 | 0.2 | 0.5 | 3 | 3.2 | 3 | 1 | 5 | 6 | 19 | 6 | 20 | 50 | 100 | 120 | 20 | | | | | | | |
| Outlet | Feb 20 | 0.4 | 0.8 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.8 | 2 | 1 | 2 | 2 | 4 | 1 | 5 | 50 | 1300 | 88 | 62 | | | | | | | |
| Outlet | Feb 21 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | 3 | 1 | 5 | 50 | 520 | 150 | 40 | | | | | | | |
| Outlet | Mar 25 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | 2 | 1 | 5 | 50 | 100 | 10 | 20 | | | | | | | |
| Outlet | Apr 12 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | 2 | 1 | 5 | 50 | 100 | 10 | 24 | | | | | | | |
| Outlet | Apr 25 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 1 | 2 | 2 | 4 | 1 | 5 | 50 | 260 | 46 | 20 | | | | | | | |
| Outlet | Apr 30 | | 0.6 | | 0.2 | 0.2 | 0.5 | 0.4 | 0.6 | 2 | 3 | 2 | 2 | 12 | 3 | 5 | 50 | 480 | 160 | 48 | | | | | | | |
| Outlet | May 21 | | 0.2 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 2 | 2 | 2 | 3 | 1 | 5 | 50 | 500 | 220 | 20 | | | | | | | |
| Outlet | Jun 21 | | 0.2 | | 0.2 | 0.2 | 0.5 | 0.2 | 0.2 | 1 | 2 | 2 | 2 | 5 | 1 | 5 | 50 | 620 | 150 | 20 | | | | | | | |
| Outlet | Jul 10 | | | | | | | | | | | | | | | | 56 | 480 | 230 | 20 | | | | | | | |
| Outlet | Jul 12 | | | | | | | | | | | | | | | | 50 | 100 | 37 | 20 | 134 | | 420 | 2.6 | 20.6 | | 202 |
| Outlet | Jul 16 | | | | | | | | | | | | | | | | 100 | 1400 | 72 | 20 | | | | | | | |
| Outlet | Sep 9 | | | | | | | | | | | | | | | | 50 | 100 | 270 | 20 | 6.85 | 7.85 | 18.8 | 1.02 | 0.4 | 0.492 | 1.28 |
| Outlet | Sep 13 | | | | | | | | | | | | | | | | 50 | 750 | 130 | 20 | 41.7 | 49.6 | 128 | 2.5 | 5.84 | 6.56 | 61.2 |
| Outlet | Sep 30 | | | | | | | | | | | | | | | | 50 | 100 | 58 | 20 | 44.4 | 53.6 | 136 | 3.79 | 6.12 | 7.38 | 65.5 |
| Outlet | Oct 21 | | | | | | | | | | | | | | | | 50 | 390 | 89 | 20 | 36.6 | 38.6 | 110 | 4.31 | 4.48 | 4.89 | 43.9 |
| Outlet | Nov 4 | | | | | | | | | | | | | | | | 50 | 100 | 75 | 20 | 60.9 | 70.1 | 191 | 9.84 | 9.54 | 9.73 | 92.6 |

***Table 4.3:*** Summary of Average Contaminant Concentrations

| Variable | Units | MDL | CSO | Storm Influent | | | Storm Supernatant | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | overall | winter | summer | overall | winter | summer |
| Aluminum | mg/L | 0.05 | 0.72 | 0.67 | 0.35 | 0.94 | 0.35 | 0.39 | 0.32 |
| Arsenic | mg/L | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Barium | mg/L | 0.005 | 0.038 | 0.043 | 0.034 | 0.050 | 0.036 | 0.043 | 0.030 |
| Beryllium | mg/L | 0.0001 | 0.000 | 0.007 | 0.001 | 0.012 | 0.001 | 0.000 | 0.002 |
| Cadmium | mg/L | 0.0005 | 0.0006 | 0.0011 | 0.0012 | 0.0011 | 0.0005 | 0.0005 | 0.0005 |
| Cobalt | mg/L | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| Chromium | mg/L | 0.001 | 0.003 | 0.008 | 0.013 | 0.004 | 0.004 | 0.005 | 0.003 |
| Copper | mg/L | 0.001 | 0.027 | 0.041 | 0.038 | 0.043 | 0.021 | 0.025 | 0.018 |
| Iron | mg/L | 0.1 | 0.7 | 1.3 | 0.9 | 1.7 | 0.9 | 1.0 | 0.8 |
| Mercury | ug/L | 0.02 | 0.07 | 0.05 | 0.04 | 0.06 | 0.03 | 0.03 | 0.03 |
| Manganese | mg/L | 0.005 | 0.063 | 0.131 | 0.103 | 0.156 | 0.104 | 0.117 | 0.093 |
| Molybdenum | mg/L | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.000 | 0.001 | 0.000 |
| Nickel | mg/L | 0.005 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.005 |
| Lead | mg/L | 0.005 | 0.023 | 0.049 | 0.050 | 0.048 | 0.024 | 0.026 | 0.022 |
| Strontium | mg/L | 0.02 | 0.07 | 0.19 | 0.27 | 0.13 | 0.19 | 0.26 | 0.12 |
| Titanium | mg/L | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 |
| Vanadium | mg/L | 0.002 | 0.002 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 | 0.002 |
| Zinc | mg/L | 0.0025 | 0.1120 | 0.1710 | 0.1479 | 0.1905 | 0.1013 | 0.1220 | 0.0826 |
| Alkalinity | mg/L | 0.2 | 58.7 | 100.1 | 113.3 | 91.9 | 133.7 | 180.9 | 105.4 |
| Chloride | mg/L | 0.2 | 35.5 | 432.9 | 867.3 | 65.3 | 456.5 | 862.4 | 91.1 |
| Conductivity | umhos/cm | 1 | 274 | 1122 | 2274 | 413 | 1032 | 1872 | 529 |
| Carbon, Dissolved Inorganic | mg/L | 0.2 | 13.7 | 24.4 | 23.8 | 24.9 | 29.6 | 35.0 | 24.6 |
| Carbon, Dissolved Organic | mg/L | 0.1 | 5.4 | 6.5 | 6.7 | 6.3 | 5.3 | 5.9 | 4.8 |
| Anthracene | UNIT NF | 0.2 | 0.2 | 0.3 | 0.2 | 0.4 | 0.2 | 0.2 | 0.2 |
| Benzo(a)pyrene | UNIT NF | 0.2 | 0.2 | 0.6 | 0.6 | 0.7 | 0.4 | 0.5 | 0.2 |
| Chrysene | UNIT NF | 0.2 | 0.2 | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.2 |
| Ammonia + Ammoniu | mg/L | 0.002 | 1.025 | 1.198 | 2.087 | 0.514 | 1.180 | 2.118 | 0.335 |
| Nitrate + Nitrite | mg/L | 0.005 | 1.180 | 1.098 | 1.399 | 0.843 | 1.875 | 2.658 | 1.170 |
| Nitrite | mg/L | 0.001 | 0.653 | 0.110 | 0.098 | 0.120 | 0.097 | 0.089 | 0.104 |
| TKN | mg/L | 0.02 | 3.79 | 3.59 | 3.58 | 3.59 | 1.25 | 1.10 | 1.34 |
| pH | | | 7.5 | 7.6 | 7.6 | 7.7 | 7.8 | 7.9 | 7.7 |
| Phosphate | mg/L | 0.0005 | 0.2755 | 0.1548 | 0.1366 | 0.1702 | 0.1459 | 0.1284 | 0.1616 |
| Phosphorus | mg/L | 0.002 | 0.923 | 0.547 | 0.388 | 0.657 | 0.267 | 0.311 | 0.236 |
| Suspended Solids | mg/L | 2 | 48 | 106 | 67 | 135 | 55 | 56 | 54 |
| Silicon | mg/L | 0.1 | 1.0 | 1.7 | 1.7 | 1.7 | 2.3 | 2.7 | 1.9 |
| Solvent Extractable | mg/L | 0.5 | 4.2 | 6.8 | 5.8 | 7.5 | 3.8 | 4.5 | 3.2 |
| Turbidity | ftu | 0.01 | 20.89 | 33.19 | 31.62 | 34.49 | 25.23 | 33.81 | 17.60 |
| E. coli | #/100 mL | 3 | 380000 | | | 61750 | | | 38633 |
| Fecal Streptococcus | #/100 mL | 3 | 20000 | | | 94170 | | | 33517 |
| Pseudomonas aeruginosa | #/100 mL | | 4500 | | | 2727 | | | 194 |
| Benzo (a) Anthracene | ug/L | 0.2 | 0.2 | 0.4 | 0.3 | 0.7 | 0.3 | 0.3 | 0.2 |
| Benzo (A) Pyrene | ug/L | | | 0.4 | 0.4 | | 0.2 | 0.2 | |
| Benzo (a) Fluoranthene | ug/L | 0.2 | 0.2 | 0.6 | 0.6 | 0.7 | 0.4 | 0.5 | 0.2 |
| Biphenyl | ug/L | | | 0.2 | 0.2 | | 0.2 | 0.2 | |
| Benzo (k) Fluoranthene | ug/L | 0.2 | 0.2 | 0.5 | 0.5 | 0.7 | 0.3 | 0.3 | 0.2 |
| Chrysene | ug/L | | | 0.5 | 0.5 | | 0.2 | 0.2 | |
| Fluoranthene | ug/L | 0.2 | 0.2 | 1.3 | 1.1 | 1.9 | 0.7 | 0.9 | 0.2 |
| Fluorin | ug/L | | | | 0.2 | | | 0.2 | |
| Benzo (g,h,I,) Perylene | ug/L | 0.2 | 0.2 | 0.5 | 0.5 | 0.5 | 0.3 | 0.4 | 0.2 |
| Indole | ug/L | 0.2 | 0.2 | 1.5 | 0.2 | 6.0 | 0.2 | 0.2 | 0.2 |
| Indeno (1,2,3-c,d) Prene | ug/L | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.5 | 0.5 | 0.5 |
| Penanthrene | ug/L | 0.2 | 0.2 | 0.8 | 0.6 | 1.2 | 0.5 | 0.6 | 0.2 |
| Pyrene | ug/L | 0.2 | 0.2 | 1.1 | 0.9 | 1.5 | 0.6 | 0.7 | 0.2 |
| a-BHC | ng/L | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 1 |
| g-BHC | ug/L | 1 | 2 | 2 | 2 | 3 | 1 | 1 | 2 |
| a-Chlordane | ug/L | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| g-Chlordane | ug/L | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| Dieldrin | ug/L | | 4 | 12 | 12 | 14 | 6 | 6 | 4 |
| pp-DDE | ug/L | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 |
| pp-DDT | ug/L | 5 | 5 | 6 | 6 | 7 | 6 | 7 | 5 |
| Dicamba | ug/L | 50 | 50 | 57 | 50 | 63 | 53 | 50 | 56 |
| 2,4-D | ug/L | 100 | 350 | 538 | 392 | 638 | 400 | 340 | 454 |
| Pentachlorophenol | ug/L | 100 | 74 | 209 | 196 | 217 | 112 | 88 | 133 |
| 2,4,6-trichlorophenol | ug/L | 100 | 20 | 26 | 35 | 20 | 30 | 40 | 20 |
| Calcium | mg/L | | | | | 37 | | | 54 |
| Calcium m | mg/L | 0.01 | | | | 28.74 | | | 43.95 |
| Hardness | mg/L | | | | | 109.97 | | | 167.30 |
| Potassium | mg/L | | | | | 3.72 | | | 4.01 |
| Magnesium | mg/L | | | | | 4.44 | | | 7.83 |
| Magnesium m | mg/L | 0.01 | | | | 4.71 | | | 5.81 |
| Sodium | mg/L | | | | | 37.74 | | | 77.75 |

***Table 4.4:*** Summer/Autumn Statistical Analysis for Stormwater Samples

| Parameter | Units | DL | Inlet | | | | | | | | Outlet | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | #>DL | %>DL | MIN | MAX | MEAN | 95% CI-LL | 95% CI-UL | N | #>DL | %>DL | MIN | MAX | MEAN | 95% CI-LL | 95% CI-UL |
| Aluminum | mg/L | 0.05 | 13 | 13 | 100 | 0.07000 | 4.800 | 1.01178 | 0.48828 | 2.09657 | 10 | 10 | 100 | 0.03190 | 1.200000 | 0.342800 | 0.168730 | 0.696490 |
| Arsenic | mg/L | 0.001 | 13 | 3 | 23.1 | 0.00010 | 0.004 | 0.00102 | 0.00043 | 0.00242 | 10 | 1 | 10 | 0.00100 | 0.002000 | 0.000630 | 0.000460 | 0.000870 |
| Barium | mg/L | 0.005 | 13 | 13 | 100 | 0.01060 | 0.150 | 0.05075 | 0.03402 | 0.07570 | 10 | 10 | 100 | 0.00523 | 0.069000 | 0.032620 | 0.018440 | 0.057710 |
| Berylium | mg/L | 0.0001 | 13 | 3 | 23.1 | 0.00002 | 0.104 | 0.01496 | 0.00259 | 0.08632 | 10 | 3 | 30 | 0.00000 | 0.028400 | 0.006820 | 0.001060 | 0.043730 |
| Cadmium | mg/L | 0.0005 | 13 | 11 | 84.6 | 0.00010 | 0.002 | 0.00121 | 0.00076 | 0.00193 | 10 | 8 | 80 | 0.00004 | 0.001400 | 0.000630 | 0.000310 | 0.001320 |
| Cobalt | mg/L | 0.001 | 13 | 11 | 84.6 | 0.00004 | 0.002 | 0.00103 | 0.00050 | 0.00215 | 10 | 8 | 80 | 0.00020 | 0.004270 | 0.000850 | 0.000370 | 0.001960 |
| Chromium | mg/L | 0.001 | 13 | 13 | 100 | 0.00060 | 0.010 | 0.00440 | 0.00274 | 0.00706 | 10 | 10 | 100 | 0.00032 | 0.010000 | 0.002880 | 0.001540 | 0.005360 |
| Copper | mg/L | 0.001 | 13 | 13 | 100 | 0.00420 | 0.150 | 0.04667 | 0.02723 | 0.07998 | 10 | 10 | 100 | 0.00300 | 0.051000 | 0.019030 | 0.010860 | 0.033330 |
| Iron | mg/L | 0.1 | 13 | 13 | 100 | 0.300 | 4.000 | 1.80686 | 1.03324 | 3.15972 | 10 | 10 | 100 | 0.05460 | 3.200000 | 0.849190 | 0.388600 | 1.855680 |
| Mercury | µg/L | 0.02 | 13 | 7 | 53.8 | 0.020 | 0.340 | 0.05998 | 0.02610 | 0.13785 | 10 | 4 | 40 | 0.02000 | 0.060000 | 0.022740 | 0.013230 | 0.039110 |
| Manganese | mg/L | 0.005 | 13 | 12 | 92.3 | 0.00489 | 0.294 | 0.22438 | 0.10939 | 0.46023 | 10 | 10 | 100 | 0.01200 | 0.220000 | 0.101540 | 0.058640 | 0.175790 |
| Molybdenum | mg/L | 0.002 | 13 | 7 | 53.8 | 0.00005 | 0.001 | 0.00086 | 0.00060 | 0.00123 | 10 | 7 | 70 | 0.00004 | 0.002950 | 0.001140 | 0.000450 | 0.002910 |
| Nickel | mg/L | 0.005 | 13 | 12 | 92.3 | 0.00005 | 0.010 | 0.00464 | 0.00302 | 0.00713 | 10 | 10 | 100 | 0.00058 | 0.0320 | 0.004100 | 0.001790 | 0.009360 |
| Lead | mg/L | 0.005 | 13 | 12 | 92.3 | 0.0050 | 0.110 | 0.05806 | 0.02960 | 0.11388 | 10 | 8 | 80 | 0.00019 | 0.0900 | 0.025150 | 0.010900 | 0.058020 |
| Strontium | mg/L | 0.02 | 13 | 13 | 100 | 0.03350 | 0.330 | 0.12977 | 0.09199 | 0.18306 | 10 | 10 | 100 | 0.02170 | 0.3000 | 0.121740 | 0.070490 | 0.210250 |
| Titanium | mg/L | 0.001 | 13 | 11 | 84.6 | 0.0010 | 0.009 | 0.00450 | 0.00267 | 0.00759 | 10 | 7 | 70 | 0.00050 | 0.0500 | 0.008590 | 0.002620 | 0.028160 |
| Vanadium | mg/L | 0.002 | 13 | 13 | 100 | 0.00060 | 0.007 | 0.00385 | 0.00252 | 0.00590 | 10 | 10 | 100 | 0.00076 | 0.0062 | 0.002330 | 0.001440 | 0.003760 |
| Zinc | mg/L | 0.0025 | 13 | 13 | 100 | 0.02200 | 0.450 | 0.21246 | 0.12338 | 0.36585 | 10 | 10 | 100 | 0.01430 | 0.2500 | 0.087740 | 0.048590 | 0.158440 |
| Alkalinity | mg/L as $CaCO_3$ | 0.2 | 13 | 13 | 100 | 26.600 | 333.000 | 90.92258 | 61.84228 | 133.67740 | 10 | 10 | 100 | 19.8000 | 326.0000 | 109.29010 | 62.117630 | 192.28550 |
| Chloride | mg/L | 0.2 | 13 | 13 | 100 | 2.00 | 408.000 | 87.09578 | 32.61941 | 232.55100 | 10 | 10 | 100 | 1.6000 | 367.0000 | 138.50590 | 48.303620 | 397.15220 |
| Conducitivity | µS/cm | 1 | 13 | 13 | 100 | 80.00 | 1810.000 | 414.78920 | 242.12100 | 710.59550 | 10 | 10 | 100 | 54.0000 | 1760.0000 | 581.57110 | 292.487600 | 1156.37400 |
| Dissolved Inorganic Carbon | mg/L | 0.2 | 13 | 13 | 100 | 5.400 | 76.800 | 25.42569 | 15.96734 | 40.48674 | 10 | 10 | 100 | 3.8000 | 74.800 | 25.924030 | 14.338570 | 46.870450 |
| Dissolved Organic Carbon | mg/L | 0.1 | 13 | 13 | 100 | 1.700 | 13.100 | 6.44420 | 4.28781 | 9.68507 | 10 | 10 | 100 | 1.7000 | 11.000 | 4.873710 | 3.289310 | 7.221290 |
| Anthracene | µg/L | 0.2 | 3 | 1 | 33.3 | 0.200 | 0.800 | 0.41117 | 0.02083 | 8.11613 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Benzo(a)Pyrene | µg/L | 0.2 | 3 | 3 | 100 | 0.400 | 1.200 | 0.70544 | 0.14592 | 3.41046 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Chrysene | µg/L | 0.2 | 3 | 3 | 100 | 0.400 | 1.400 | 0.85279 | 0.17424 | 4.17385 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Ammonium | mg/L | 0.002 | 13 | 13 | 100 | 0.00200 | 2.570 | 1.16945 | 0.35785 | 3.82176 | 10 | 10 | 100 | 0.0960 | 0.8740 | 0.346750 | 0.196750 | 0.611080 |
| Nitrates | mg/L | 0.005 | 13 | 13 | 100 | 0.0300 | 3.110 | 1.23129 | 0.49318 | 3.07406 | 10 | 10 | 100 | 0.0250 | 3.0500 | 2.065430 | 0.693020 | 6.155660 |
| Nitrite | mg/L | 0.001 | 13 | 13 | 100 | 0.0050 | 0.460 | 0.16049 | 0.06186 | 0.41640 | 10 | 10 | 100 | 0.0100 | 0.5600 | 0.101110 | 0.046450 | 0.220080 |
| TKN | mg/L | 0.02 | 13 | 13 | 100 | 0.4600 | 24.000 | 3.14460 | 1.74751 | 5.65861 | 10 | 10 | 100 | 0.2000 | 3.8400 | 1.447650 | 0.792820 | 2.643320 |
| Phosphate | mg/L | 0.0005 | 13 | 13 | 100 | 0.01800 | 0.620 | 0.18007 | 0.09662 | 0.33557 | 10 | 10 | 100 | 0.0390 | 0.5250 | 0.166350 | 0.087100 | 0.317730 |
| Phosphorus | mg/L | 0.002 | 13 | 13 | 100 | 0.08800 | 4.200 | 0.59089 | 0.33447 | 1.04388 | 10 | 10 | 100 | 0.0100 | 0.6100 | 0.311630 | 0.137090 | 0.708360 |
| Benzo (B) Fluoranthene | µg/L | 0.2 | 3 | 3 | 100 | 0.400 | 1.200 | 0.77058 | 0.19383 | 3.06349 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Suspended Solids | mg/L | 2 | 12 | 12 | 100 | 11.000 | 282.000 | 163.35870 | 83.87631 | 318.15990 | 9 | 9 | 100 | 8.00 | 189.000 | 55.819720 | 28.070990 | 110.998600 |
| Silicates | mg/L | 0.1 | 13 | 13 | 100 | 0.3400 | 6.260 | 1.73971 | 1.05162 | 2.87803 | 10 | 10 | 100 | 0.2400 | 6.080 | 2.103570 | 1.071200 | 4.130920 |
| Solvent Extractables | mg/L | 3 | 12 | 12 | 100 | 1.0000 | 26.500 | 8.26700 | 4.52414 | 15.10635 | 10 | 9 | 90 | 0.500 | 12.000 | 3.379790 | 1.940920 | 5.885330 |
| Turbidity | FTU | 0.01 | 12 | 12 | 100 | 6.2400 | 106.000 | 36.61549 | 19.41229 | 69.06419 | 9 | 9 | 100 | 3.490 | 55.400 | 18.341410 | 9.901970 | 33.973810 |
| E. coli | #/100mL | 3 | 7 | 7 | 100 | 3700.00 | 18000.0 | 35052.270 | 9873.389 | 124441.700 | 6 | 6 | 100 | 4500.00 | 140000.000 | 44178.9900 | 9829.151000 | 198570.800 |
| Fecal Coliform | #/100mL | 3 | 7 | 7 | 100 | 600.00 | 102000.0 | 38292.520 | 6054.980 | 242167.100 | 6 | 6 | 100 | 2500.00 | 124000.000 | 43200.4900 | 7365.813000 | 253370.800 |
| Pseudomonas aeruginosa | #/100mL | 3 | 7 | 7 | 100 | 32.00 | 690.000 | 294.63260 | 111.90970 | 775.70000 | 6 | 6 | 100 | 20.00 | 520.000 | 275.157600 | 52.273780 | 1448.368 |
| Sodium | mg/L | 0.1 | 6 | 6 | 100 | 2.060 | 211.000 | 28.87986 | 4.47873 | 186.22390 | 6 | 6 | 100 | 1.28 | 202.000 | 191.387400 | 29.961170 | 1222.553 |
| Calcium | mg/L | 0.01 | 6 | 6 | 100 | 10.200 | 137.000 | 35.00395 | 13.23562 | 92.57416 | 6 | 6 | 100 | 6.85 | 134.000 | 63.625960 | 22.820470 | 177.39610 |
| Hardness | mg/L | 1 | 6 | 6 | 100 | 29.000 | 430.000 | 103.41070 | 37.37349 | 286.13260 | 6 | 6 | 100 | 18.800 | 420.000 | 201.700700 | 68.813650 | 591.20780 |
| Calcium | mg/L | 0.01 | 5 | 5 | 100 | 12.100 | 42.000 | 30.06208 | 14.84991 | 60.85752 | 5 | 5 | 100 | 7.8500 | 70.100 | 51.854040 | 17.604640 | 152.73480 |
| Magnesium | mg/L | 0.01 | 6 | 6 | 100 | 0.880 | 21.100 | 3.79860 | 1.03186 | 13.98389 | 6 | 6 | 100 | 0.4000 | 20.600 | 11.710180 | 2.893380 | 47.39380 |
| Potassium | mg/L | 0.1 | 6 | 6 | 100 | 1.6300 | 8.880 | 3.79899 | 1.92016 | 7.51621 | 6 | 6 | 100 | 1.0200 | 9.840 | 4.224650 | 1.928660 | 9.253880 |
| Magnesium | mg/L | 0.01 | 5 | 5 | 100 | 1.0200 | 7.980 | 5.56460 | 1.65245 | 18.73866 | 5 | 5 | 100 | 0.4920 | 9.730 | 8.470150 | 1.889880 | 37.961940 |
| pH | | | 13 | 13 | 100 | 7.2400 | 8.250 | 7.66510 | 7.47547 | 7.85955 | 10 | 10 | 100 | 7.3800 | 8.280 | 7.730590 | 7.511560 | 7.956010 |

***Table 4.5:*** Winter/Spring Statical Analysis for Stormwater Samples

| Parameter | Units | DL | Inlet N | Inlet #>DL | Inlet %>DL | Inlet MINIMUM | Inlet MAXIMUM | Inlet MEAN | Inlet 95% CI-LL | Inlet 95% CI-UL | Outlet N | Outlet #>DL | Outlet %>DL | Outlet MINIMUM | Outlet MAXIMUM | Outlet MEAN | Outlet 95% CI-LL | Outlet 95% CI-UL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | mg/L | 0.05 | 11 | 10 | 90.9 | 0.02 | 1.00 | 0.47 | 0.18 | 1.21 | 11 | 11 | 100.0 | 0.03 | 1.20 | 0.45 | 0.23 | 0.88 |
| Arsenic | mg/L | 0.001 | 11 | 3 | 27.3 | 0.001 | 0.003 | 0.001 | 0.000 | 0.002 | 11 | 2 | 18.2 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 |
| Barium | mg/L | 0.005 | 11 | 11 | 100.0 | 0.009 | 0.100 | 0.035 | 0.021 | 0.056 | 11 | 11 | 100.0 | 0.012 | 0.074 | 0.039 | 0.023 | 0.066 |
| Berylium | mg/L | 0.0001 | 11 | 1 | 9.1 | 0.0001 | 0.0030 | 0.0002 | 0.0001 | 0.0004 | 11 | 1 | 9.1 | 0.0001 | 0.0029 | 0.0002 | 0.0001 | 0.0004 |
| Cadmium | mg/L | 0.0005 | 11 | 6 | 54.5 | 0.0001 | 0.0068 | 0.0010 | 0.0004 | 0.0022 | 11 | 8 | 72.7 | 0.0001 | 0.0025 | 0.0005 | 0.0003 | 0.0008 |
| Cobalt | mg/L | 0.001 | 11 | 6 | 54.5 | 0.0002 | 0.006 | 0.001 | 0.000 | 0.003 | 11 | 6 | 54.5 | 0.0002 | 0.001 | 0.000 | 0.0002 | 0.001 |
| Chromium | mg/L | 0.001 | 11 | 9 | 81.8 | 0.0002 | 0.088 | 0.014 | 0.005 | 0.039 | 11 | 10 | 90.9 | 0.0002 | 0.023 | 0.005 | 0.003 | 0.009 |
| Copper | mg/L | 0.001 | 11 | 11 | 100.0 | 0.002 | 0.090 | 0.046 | 0.023 | 0.090 | 11 | 11 | 100.0 | 0.003 | 0.081 | 0.026 | 0.015 | 0.046 |
| Iron | mg/L | 0.1 | 11 | 11 | 100.0 | 0.1 | 3.0 | 1.0 | 0.5 | 1.9 | 11 | 11 | 100.0 | 0.3 | 2.5 | 0.9 | 0.6 | 1.5 |
| Mercury | µg/L | 0.02 | 10 | 7 | 70.0 | 0.02 | 0.07 | 0.04 | 0.02 | 0.06 | 11 | 7 | 63.6 | 0.02 | 0.08 | 0.03 | 0.02 | 0.05 |
| Manganese | mg/L | 0.005 | 11 | 11 | 100.0 | 0.038 | 0.250 | 0.103 | 0.069 | 0.154 | 11 | 11 | 100.0 | 0.048 | 0.280 | 0.105 | 0.071 | 0.156 |
| Molybdenum | mg/L | 0.002 | 11 | 7 | 63.6 | 0.0002 | 0.009 | 0.002 | 0.001 | 0.003 | 9 | 3 | 33.3 | 0.0002 | 0.002 | 0.001 | 0.001 | 0.002 |
| Nickel | mg/L | 0.005 | 11 | 10 | 90.9 | 0.002 | 0.008 | 0.003 | 0.002 | 0.004 | 9 | 7 | 77.8 | 0.001 | 0.013 | 0.004 | 0.002 | 0.008 |
| Lead | mg/L | 0.005 | 11 | 10 | 90.9 | 0.005 | 0.180 | 0.057 | 0.026 | 0.123 | 9 | 9 | 100.0 | 0.010 | 0.075 | 0.026 | 0.016 | 0.042 |
| Strontium | mg/L | 0.02 | 11 | 11 | 100.0 | 0.06 | 0.52 | 0.28 | 0.18 | 0.44 | 9 | 9 | 100.0 | 0.07 | 0.59 | 0.28 | 0.15 | 0.52 |
| Titanium | mg/L | 0.001 | 11 | 8 | 72.7 | 0.001 | 0.032 | 0.010 | 0.004 | 0.028 | 9 | 7 | 77.8 | 0.001 | 0.034 | 0.011 | 0.004 | 0.032 |
| Vanadium | mg/L | 0.001 | 11 | 11 | 100.0 | 0.001 | 0.013 | 0.005 | 0.003 | 0.008 | 9 | 8 | 88.9 | 0.0002 | 0.015 | 0.004 | 0.002 | 0.010 |
| Zinc | mg/L | 0.0025 | 11 | 11 | 100.0 | 0.0180 | 0.4200 | 0.1589 | 0.0858 | 0.2943 | 9 | 9 | 100.0 | 0.0140 | 0.3700 | 0.1355 | 0.0627 | 0.2928 |
| Alkalinity | mg/L as CaCO3 | 0.2 | 8 | 8 | 100.0 | 42.4 | 349.0 | 112.1 | 62.6 | 200.6 | 6 | 6 | 100.0 | 45.8 | 345.0 | 200.0 | 80.0 | 500.2 |
| Chloride | mg/L | 0.2 | 11 | 11 | 100.0 | 12.8 | 3570.0 | 1609.1 | 495.8 | 5222.6 | 9 | 9 | 100.0 | 30.0 | 4230.0 | 1052.5 | 333.1 | 3325.1 |
| Conducitivity | µS/cm | 1 | 8 | 8 | 100.0 | 281 | 5360 | 2754 | 1109 | 6838 | 6 | 6 | 100.0 | 447 | 4680 | 2034 | 817 | 5065 |
| Dissolved Inorganic Carbon | mg/L | 0.2 | 11 | 11 | 100.0 | 7.0 | 83.4 | 23.4 | 14.7 | 37.3 | 9 | 9 | 100.0 | 10.0 | 80.2 | 36.8 | 19.8 | 68.7 |
| Dissolved Organic Carbon | mg/L | 0.1 | 11 | 11 | 100.0 | 1.3 | 20.2 | 6.9 | 4.3 | 11.0 | 9 | 9 | 100.0 | 1.7 | 19.5 | 5.8 | 3.4 | 10.0 |
| Anthracene | µg/L | 0.2 | 5 | N/D | N/D | N/D | N/D | N/D | N/D | N/D | 4 | N/D | N/D | N/D | N/D | N/D | N/D | N/D |
| Benzo(a)Pyrene | µg/L | 0.2 | 5 | 4 | 80.0 | 0.2 | 1.2 | 0.7 | 0.2 | 2.4 | 4 | 3 | 75.0 | 0.2 | 1.2 | 0.6 | 0.1 | 3.0 |
| Chrysene | µg/L | 0.2 | 5 | 3 | 60.0 | 0.2 | 2.2 | 1.3 | 0.2 | 9.0 | 4 | 3 | 75.0 | 0.2 | 2.0 | 0.9 | 0.1 | 6.7 |
| Ammonium | mg/L | 0.002 | 10 | 10 | 100.0 | 0.022 | 6.350 | 4.883 | 1.061 | 22.467 | 9 | 8 | 88.9 | 0.002 | 6.550 | 0.292 | 0.029 | 2.973 |
| Nitrates | mg/L | 0.005 | 11 | 11 | 100.0 | 0.320 | 2.440 | 1.465 | 0.993 | 2.163 | 9 | 9 | 100.0 | 0.600 | 4.680 | 2.854 | 1.606 | 5.071 |
| Nitrite | mg/L | 0.001 | 11 | 11 | 100.0 | 0.014 | 0.330 | 0.104 | 0.052 | 0.206 | 9 | 8 | 88.9 | 0.001 | 0.370 | 0.212 | 0.050 | 0.906 |
| TKN | mg/L | 0.02 | 9 | 9 | 100.0 | 0.34 | 10.30 | 4.13 | 1.67 | 10.23 | 6 | 6 | 100.0 | 0.28 | 2.10 | 1.17 | 0.52 | 2.66 |
| Phosphate | mg/L | 0.0005 | 11 | 11 | 100.0 | 0.0055 | 0.3300 | 0.2069 | 0.0814 | 0.5262 | 9 | 9 | 100.0 | 0.0180 | 0.3000 | 0.1462 | 0.0694 | 0.3078 |
| Phosphorus | mg/L | 0.0005 | 9 | 9 | 100.0 | 0.0860 | 0.8900 | 0.4166 | 0.2129 | 0.8152 | 7 | 7 | 100.0 | 0.0780 | 0.8500 | 0.3362 | 0.1409 | 0.8023 |
| Benzo (B) Fluoranthene | µg/L | 0.002 | 10 | 5 | 50.0 | 0.200 | 1.600 | 0.778 | 0.248 | 2.437 | 9 | 4 | 44.4 | 0.060 | 1.800 | 0.395 | 0.121 | 1.290 |
| Suspended Solids | mg/L | 2 | 9 | 9 | 100.0 | 20 | 199 | 68 | 38 | 121 | 7 | 7 | 100.0 | 13 | 198 | 56 | 24 | 131 |
| Silicates | mg/L | 0.10 | 11 | 11 | 100.0 | 0.48 | 6.38 | 1.70 | 1.05 | 2.75 | 9 | 9 | 100.0 | 0.74 | 6.20 | 2.76 | 1.49 | 5.13 |
| Solvent Extractables | mg/L | 1 | 9 | 8 | 88.9 | 1 | 17 | 7 | 3 | 15 | 8 | 6 | 75.0 | 1 | 14 | 5 | 2 | 12 |
| Turbidity | FTU | 0.01 | 10 | 10 | 100.0 | 2.07 | 115 | 40.73 | 16.11 | 102.92 | 8 | 8 | 100.0 | 2.67 | 146.00 | 39.01 | 13.21 | 115.18 |
| pH | | | 8 | 8 | 100.0 | 7.42 | 8.06 | 7.61 | 7.43 | 7.80 | 6 | 6 | 100.0 | 7.53 | 8.26 | 7.87 | 7.52 | 8.23 |

***Table 4.6:*** Statistical Analysis for CSO Samples

| Parameter | Units | DL | N | #>DL | %>DL | MIN | MAX | MEAN | 95% CI-LL | 95% CI-UL |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | mg/L | 0.05 | 3 | 3 | 100 | 0.18 | 1.60 | 0.88 | 0.06 | 14.00 |
| Arsenic | mg/L | 0.001 | 3 | 3 | 100 | 0.002 | 0.003 | 0.002 | 0.001 | 0.004 |
| Barium | mg/L | 0.005 | 3 | 3 | 100 | 0.019 | 0.074 | 0.041 | 0.006 | 0.265 |
| Berylium | mg/L | 0.0001 | 3 | 1 | 33.3 | 0.0001 | 0.0004 | 0.0002 | 0.0000 | 0.0041 |
| Cadmium | mg/L | 0.0005 | 3 | 2 | 66.7 | 0.0001 | 0.0012 | 0.0008 | 0.0001 | 0.0054 |
| Cobalt | mg/L | 0.001 | 3 | 2 | 66.7 | 0.0002 | 0.001 | 0.001 | 0.000 | 0.016 |
| Chromium | mg/L | 0.001 | 3 | 3 | 100 | 0.001 | 0.005 | 0.003 | 0.001 | 0.018 |
| Copper | mg/L | 0.001 | 3 | 3 | 100 | 0.009 | 0.053 | 0.031 | 0.003 | 0.289 |
| Iron | mg/L | 0.1 | 3 | 3 | 100 | 0.4 | 1.2 | 0.7 | 0.1 | 3.5 |
| Mercury | ug/L | 0.02 | 3 | 2 | 66.7 | 0.02 | 0.16 | 0.10 | 0.00 | 3.09 |
| Manganese | mg/L | 0.005 | 3 | 3 | 100 | 0.044 | 0.096 | 0.065 | 0.023 | 0.184 |
| Molybdenum | mg/L | 0.002 | 3 | 2 | 66.7 | 0.0002 | 0.001 | 0.001 | 0.000 | 0.001 |
| Nickel | mg/L | 0.005 | 3 | 3 | 100 | 0.001 | 0.006 | 0.003 | 0.000 | 0.027 |
| Lead | mg/L | 0.005 | 3 | 3 | 100 | 0.010 | 0.040 | 0.025 | 0.005 | 0.142 |
| Strontium | mg/L | 0.02 | 3 | 3 | 100 | 0.05 | 0.09 | 0.07 | 0.04 | 0.14 |
| Titanium | mg/L | 0.001 | 3 | 2 | 66.7 | 0.001 | 0.002 | 0.002 | 0.000 | 0.013 |
| Vanadium | mg/L | 0.002 | 3 | 3 | 100 | 0.001 | 0.004 | 0.002 | 0.001 | 0.010 |
| Zinc | mg/L | 0.0025 | 3 | 3 | 100 | 0.0380 | 0.2000 | 0.1283 | 0.0162 | 1.0161 |
| Alkalinity | mg/L as $CaCO_3$ | 0.2 | 3 | 3 | 100 | 34.6 | 85.6 | 60.8 | 19.7 | 187.5 |
| Chloride | mg/L | 0.2 | 3 | 3 | 100 | 14.8 | 65.4 | 39.0 | 6.1 | 250.6 |
| Conducitivity | uS/cm | 1 | 3 | 3 | 100 | 194 | 422 | 282 | 97 | 823 |
| DIC | mg/L | 0.2 | 3 | 3 | 100 | 7.8 | 20.6 | 14.3 | 4.3 | 47.8 |
| DOC | mg/L | 0.1 | 3 | 3 | 100 | 2.0 | 11.8 | 6.2 | 0.5 | 71.5 |
| Ammonium | mg/L | 0.002 | 3 | 3 | 100 | 0.156 | 2.360 | 1.486 | 0.051 | 43.495 |
| Nitrates | mg/L | 0.005 | 3 | 3 | 100 | 0.295 | 2.300 | 1.466 | 0.113 | 18.932 |
| Nitrite | mg/L | 0.001 | 3 | 3 | 100 | 0.117 | 1.650 | 0.897 | 0.027 | 29.493 |
| TKN | mg/L | 0.02 | 3 | 3 | 100 | 1.06 | 7.00 | 4.56 | 0.43 | 48.35 |
| Phosphate | mg/L | 0.0005 | 3 | 3 | 100 | 0.0565 | 0.4500 | 0.3735 | 0.0235 | 5.9277 |
| Phosphorus | mg/L | 0.002 | 3 | 3 | 100 | 0.220 | 2.000 | 1.152 | 0.073 | 18.117 |
| Suspended Solids | mg/L | 2 | 3 | 3 | 100 | 13 | 97 | 57 | 5 | 699 |
| Silicates | mg/L | 0.1 | 3 | 3 | 100 | 0.6 | 1.5 | 1.0 | 0.4 | 2.9 |
| Solvent Extractables | mg/L | 3 | 3 | 2 | 66.7 | 1 | 10 | 5 | 0 | 66 |
| Turbidity | FTU | 0.01 | 3 | 3 | 100 | 2.10 | 55.10 | 35.18 | 0.54 | 2284.33 |
| E. coli | #/100mL | 3 | 2 | 2 | 100 | 240,000 | 380,000 | 318,362 | 17,185 | 5,897,954 |
| Fecal Coliform | #/100mL | 3 | 2 | 2 | 100 | 20,000 | 570,000 | 294,999 | 0.000170 | NR |
| pH | | | 3 | 3 | 100 | 7.25 | 7.95 | 7.53 | 6.68 | 8.50 |

***Table 4.7:*** Comparison of Results to Other Studies

| Parameter | Units | DL | PWQO | Metro Bylaw Target | Wet Weather | NURP | Summer/Autumn Inlet | | | Summer/Autumn Outlet | | | Winter/Spring Inlet | | | Winter/Spring Outlet | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | MEAN | 95% CI-LL | 95% CI-UL | MEAN | 95% CI-LL | 95% CI-UL | MEAN | 95% CI-LL | 95% CI-UL | MEAN | 95% CI-LL | 95% CI-UL |
| Aluminum | mg/L | 0.05 | 0.075 | | 1.400 | | 1.01 | 0.49 | 2.10 | 0.34 | 0.17 | 0.70 | 0.47 | 0.18 | 1.21 | 0.45 | 0.23 | 0.88 |
| Arsenic | mg/L | 0.001 | 0.100 | | | | 0.001 | 0.000 | 0.002 | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.002 | 0.001 | 0.001 | 0.001 |
| Barium | mg/L | 0.005 | | | 0.041 | | 0.051 | 0.034 | 0.076 | 0.033 | 0.018 | 0.058 | 0.035 | 0.021 | 0.056 | 0.039 | 0.023 | 0.066 |
| Berylium | mg/L | 0.0001 | 1.1000 | | 0.0001 | | 0.0150 | 0.0026 | 0.0863 | 0.0068 | 0.0011 | 0.0437 | 0.0002 | 0.0001 | 0.0004 | 0.0002 | 0.0001 | 0.0004 |
| Cadmium | mg/L | 0.0005 | 0.200 | 0.001 | 0.007 | | 0.0012 | 0.0008 | 0.0019 | 0.0006 | 0.0003 | 0.0013 | 0.0010 | 0.0004 | 0.0022 | 0.0005 | 0.0003 | 0.0008 |
| Cobalt | mg/L | 0.001 | 0.600 | | | | 0.001 | 0.001 | 0.002 | 0.001 | 0.000 | 0.002 | 0.001 | 0.000 | 0.003 | 0.000 | 0.000 | 0.001 |
| Chromium | mg/L | 0.001 | 0.100 | 0.2 | 0.007 | 0.014 | 0.004 | 0.003 | 0.007 | 0.003 | 0.002 | 0.005 | 0.014 | 0.005 | 0.039 | 0.005 | 0.003 | 0.009 |
| Copper | mg/L | 0.001 | 0.005 | 0.01 | 0.005 | | 0.047 | 0.027 | 0.080 | 0.019 | 0.011 | 0.033 | 0.046 | 0.023 | 0.090 | 0.026 | 0.015 | 0.046 |
| Iron | mg/L | 0.1 | 0.3 | | 2.8 | 0.1 | 1.8 | 1.0 | 3.2 | 0.8 | 0.4 | 1.9 | 1.0 | 0.5 | 1.9 | 0.9 | 0.6 | 1.5 |
| Mercury | ug/L | 0.02 | 0.20 | 1.00 | 0.04 | | 0.06 | 0.03 | 0.14 | 0.02 | 0.01 | 0.04 | 0.04 | 0.02 | 0.06 | 0.03 | 0.02 | 0.05 |
| Manganese | mg/L | 0.005 | | | 0.160 | | 0.224 | 0.109 | 0.460 | 0.102 | 0.059 | 0.176 | 0.103 | 0.069 | 0.154 | 0.105 | 0.071 | 0.156 |
| Molybdenum | mg/L | 0.002 | 0.010 | | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.003 | 0.002 | 0.001 | 0.003 | 0.001 | 0.001 | 0.002 |
| Nickel | mg/L | 0.005 | 0.025 | 0.05 | 0.010 | 0.001-0.18 | 0.005 | 0.003 | 0.007 | 0.004 | 0.002 | 0.009 | 0.003 | 0.002 | 0.004 | 0.004 | 0.002 | 0.008 |
| Lead | mg/L | 0.005 | 0.025 | 0.05 | 0.057 | 0.006-0.46 | 0.058 | 0.030 | 0.114 | 0.025 | 0.011 | 0.058 | 0.057 | 0.026 | 0.123 | 0.026 | 0.016 | 0.042 |
| Strontium | mg/L | 0.02 | | | | | 0.13 | 0.09 | 0.18 | 0.12 | 0.07 | 0.21 | 0.28 | 0.18 | 0.44 | 0.28 | 0.15 | 0.52 |
| Titanium | mg/L | 0.001 | | | | | 0.005 | 0.003 | 0.008 | 0.009 | 0.003 | 0.028 | 0.010 | 0.004 | 0.028 | 0.011 | 0.004 | 0.032 |
| Vanadium | mg/L | 0.002 | 0.007 | | | | 0.004 | 0.003 | 0.006 | 0.002 | 0.001 | 0.004 | 0.005 | 0.003 | 0.008 | 0.004 | 0.002 | 0.010 |
| Zinc | mg/L | 0.0025 | 0.0300 | 0.05 | 0.1500 | 0.01-2.40 | 0.2125 | 0.1234 | 0.3659 | 0.0877 | 0.0486 | 0.1584 | 0.1589 | 0.0858 | 0.2943 | 0.1355 | 0.0627 | 0.2928 |
| Alkalinity | mg/L as CaCO | 0.2 | | | 97.5 | | 90.9 | 61.8 | 133.7 | 109.3 | 62.1 | 192.3 | 112.1 | 62.6 | 200.6 | 200.0 | 80.0 | 500.2 |
| Chloride | mg/L | 0.2 | | | | | 87.1 | 32.6 | 232.6 | 138.5 | 48.3 | 397.2 | 1609.1 | 495.8 | 5222.6 | 1052.5 | 333.1 | 3325.1 |
| Conducitivity | uS/cm | 1 | | | | | 415 | 242 | 711 | 582 | 292 | 1156 | 2754 | 1109 | 6838 | 2034 | 817 | 5065 |
| DIC | mg/L | 0.2 | | | | | 25.4 | 16.0 | 40.5 | 25.9 | 14.3 | 46.9 | 23.4 | 14.7 | 37.3 | 36.8 | 19.8 | 68.7 |
| DOC | mg/L | 0.1 | | | | | 6.4 | 4.3 | 9.7 | 4.9 | 3.3 | 7.2 | 6.9 | 4.3 | 11.0 | 5.8 | 3.4 | 10.0 |
| Anthracene | ug/L | 0.2 | 0.0008 | | 0.0940 | | 0.4 | 0.0 | 8.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Benzo(a)Pyrene | ug/L | 0.2 | | | 0.048 | | 0.7 | 0.1 | 3.4 | 0.1 | 0.0 | 0.0 | 0.7 | 0.2 | 2.4 | 0.6 | 0.1 | 3.0 |
| Chrysene | ug/L | 0.2 | 0.0001 | | 0.0800 | | 0.9 | 0.2 | 4.2 | 0.1 | 0.0 | 0.0 | 1.3 | 0.2 | 9.0 | 0.9 | 0.1 | 6.7 |
| Ammonium | mg/L | 0.002 | | | 0.080 | | 1.169 | 0.358 | 3.822 | 0.347 | 0.197 | 0.611 | 4.883 | 1.061 | 22.467 | 0.292 | 0.029 | 2.973 |
| Nitrates | mg/L | 0.005 | | | 1.960 | | 1.231 | 0.493 | 3.074 | 2.065 | 0.693 | 6.156 | 1.465 | 0.993 | 2.163 | 2.854 | 1.606 | 5.071 |
| Nitrite | mg/L | 0.001 | | | 0.140 | | 0.160 | 0.062 | 0.416 | 0.101 | 0.046 | 0.220 | 0.104 | 0.052 | 0.206 | 0.212 | 0.050 | 0.906 |
| TKN | mg/L | 0.02 | | | 4.11 | 1.18-1.9 | 3.14 | 1.75 | 5.66 | 1.45 | 0.79 | 2.64 | 4.13 | 1.67 | 10.23 | 1.17 | 0.52 | 2.66 |
| Phosphate | mg/L | 0.0005 | | | | | 0.1801 | 0.0966 | 0.3356 | 0.1664 | 0.0871 | 0.3177 | 0.2069 | 0.0814 | 0.5262 | 0.1462 | 0.0694 | 0.3078 |
| Phosphorus | mg/L | 0.002 | 0.020 | | 0.820 | 0.2-0.38 | 0.591 | 0.334 | 1.044 | 0.312 | 0.137 | 0.708 | 0.4166 | 0.2129 | 0.8152 | 0.3362 | 0.1409 | 0.8023 |
| Benzo (B) Fluoranthene | ug/L | 0.2 | | | 0.12 | | 0.8 | 0.2 | 3.1 | 0.1 | 0.0 | 0.0 | 0.778 | 0.248 | 2.437 | 0.395 | 0.121 | 1.290 |
| Suspended Solids | mg/L | 2 | | 15 | 238 | 67-101 | 163 | 84 | 318 | 56 | 28 | 111 | 68 | 38 | 121 | 56 | 24 | 131 |
| Silicates | mg/L | 0.1 | | | | | 1.7 | 1.1 | 2.9 | 2.1 | 1.1 | 4.1 | 1.70 | 1.05 | 2.75 | 2.76 | 1.49 | 5.13 |
| Solvent Extractables | mg/L | 3 | | | 4.1 | | 8 | 5 | 15 | 3 | 2 | 6 | 7 | 3 | 15 | 5 | 2 | 12 |
| Turbidity | FTU | 0.01 | +10% | | | | 36.62 | 19.41 | 69.06 | 18.34 | 9.90 | 33.97 | 40.73 | 16.11 | 102.92 | 39.01 | 13.21 | 115.18 |
| E. coli | #/100ml | 3 | 100 | | 409,000 | | 35,052 | 9,873 | 124,442 | 44,179 | 9,829 | 198,571 | | | | | | |
| Fecal Coliform | #/100ml | 3 | | 200 | 528,000 | 21,000 | 38,293 | 6,055 | 242,167 | 43,200 | 7,366 | 253,371 | | | | | | |
| Pseudomonas aeruginosa | #/100ml | 3 | | | 988 | | 295 | 112 | 776 | 275 | 52 | 1,448 | | | | | | |
| pH | | | 6.5-8.5 | | | | 7.67 | 7.48 | 7.86 | 7.73 | 7.51 | 7.96 | 7.61 | 7.43 | 7.80 | 7.87 | 7.52 | 8.23 |

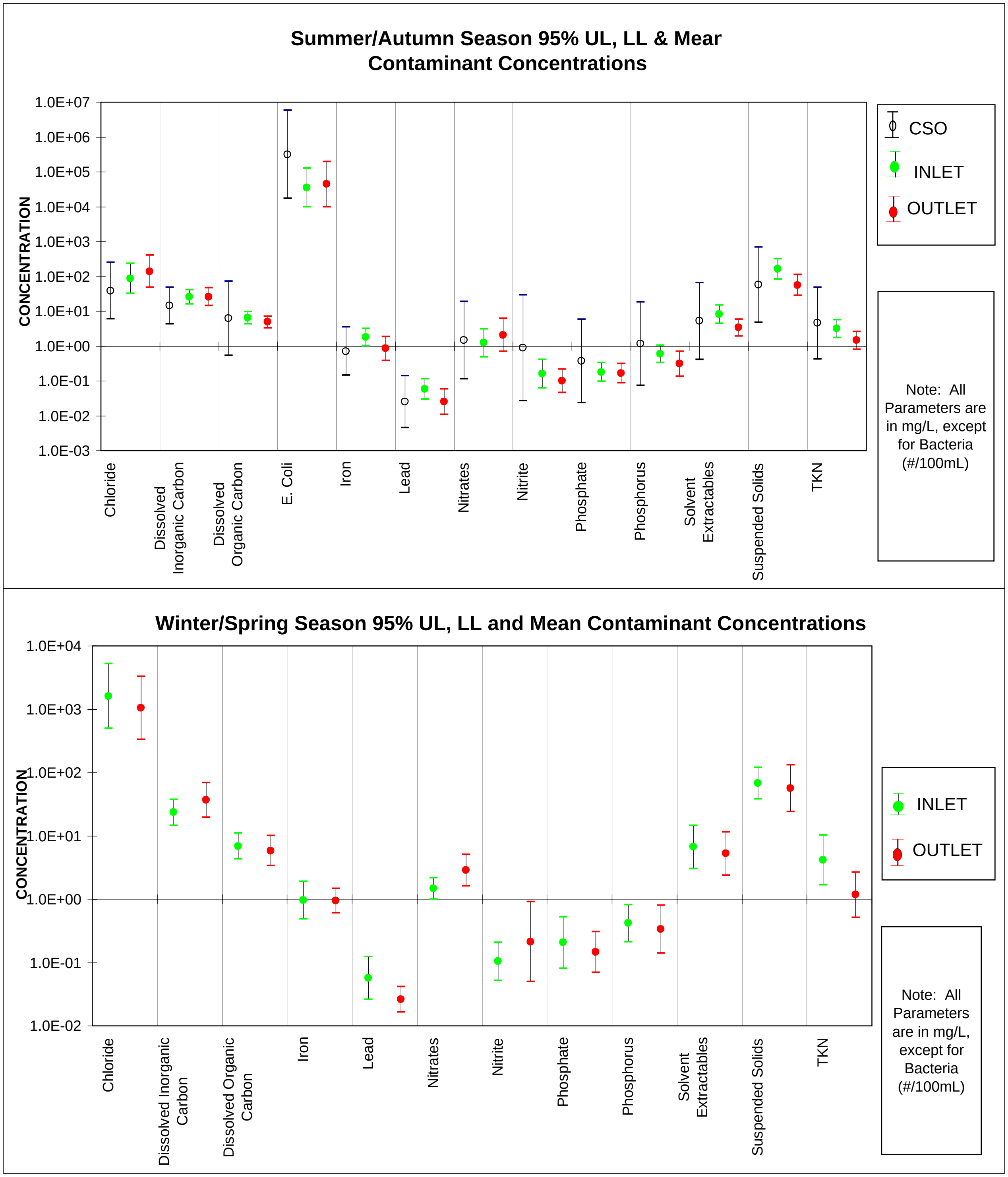


***Figure 4.1 :*** 95% UL, LL and Mean Contaminant Concentrations

# 5.0 PERFORMANCE ASSESSMENT

## 5.1 Methodology

The system performance assessment conduced in this chapter is based on the pollutant removal efficiency of the tank which is obtained from the pollutant reduction of the system divided by the total pollutant mass load. The system performance assessment of runoff quantity control is presented in Chapter 3. Also, the performance analysis herein refers to the storm compartment, as the CSO compartment does not treat the captured runoff. Runoff quantity and quality control analysis results from Chapters 3 and 4 are used here to calculate pollutant loading. The assumptions made in Chapter 4 are recalled again below:

1. The inflow event mean concentration of the monitored Glen Manor Drive storm sewer is equal to that of the Balsam Avenue storm sewer. Thus, the event mean concentration data collected at the Balsam Avenue storm sewer is used to represent the total inflow concentration of the storm compartment.
2. The outflow concentration data collected at 2.3 m above the invert level of the trough 7.5 hours after the detention period started is used to represent the supernatant concentration.

The performance of the storm compartment of the Maclean Avenue detention tank is evaluated based on two scenarios: a "system" performance scenario and a "tank" performance scenario. Both an event-by-event analysis and a total pollutant load analysis are conducted for these two scenarios.

In the "system" performance scenario, the total runoff volume (Vin-total) through the storm compartment is considered in the performance evaluation. The total runoff volume includes both the volume intercepted by the tank and the overflow volume. Here, the overflow volume includes the near shore overflow through the channels and the 400m off-shore overflow.

In the "tank" performance scenario, only the runoff volume intercepted by the storm compartment is considered in the assessment of pollutant removal efficiency. Overflows are not included in the analysis. Therefore, the "tank performance" scenario allows an evaluation of the performance of detention tank itself, which is widely considered to be one of the more effective urban stormwater management practices. Thus, the performance evaluation of this study may be transferable and applicable to other sites as a reference.

## 5.2 Performance Analysis Equations

The system performance assessment is based on a pollutant mass balance calculation for the tank system. The pollutant load entering and leaving the tank is computed and the difference between the entry and exit of the tank is the mass intercepted by the facility. The performances of both the "system" scenario and the "tank" scenario are then calculated by expressing this intercepted load as a percentage of the total system load or total tank load, respectively. There are two ways to express the pollutant removal efficiency: one is based on the evaluation of each individual event. This is called the individual event performance (IEP) which is conducted event-by-event and the average IEP can be obtained as a reference for the system performance efficiency. The other method is to calculate the seasonal total pollutant load reduction and entire year pollutant load reduction to represent the performance efficiency. This method is called the total load performance (TLP).

There were 24 events with measured inlet contaminant concentrations and 19 events with measured outlet contaminant concentrations available. A total of 12 events had measured inlet and outlet concentrations and runoff quantity data. Thus, these 12 events are used in the performance analysis in this chapter. These 12 events spread over the entire 1996 year: 2 in January, 2 in February, 1 in April, 1 in May, 2 in June, 1 in July, 2 in September and 1 in November. Since rainfall is stochastic, and these 12 events are evenly distributed over the year, the performance evaluation based on these 12 events is assumed to represent the entire year's performance.

The winter season is defined as from December to April, and the summer season is defined as from May to November in this study.

Both the IEP and TLP for both the "system performance" scenario and the "tank performance" scenario were calculated by the following equations:

$$IEP_{(SYSTEM)} = \frac{V_{detained} \, x \, EMC_{in} - V_{out} \, x EMC_{out}}{V_{in\text{-}total} \, x \, EMC_{in}} \, x100\% \tag{5.1}$$

$$IEP_{(TANK)} = \frac{V_{detained} \, x \, EMC_{in} - V_{out} \, x EMC_{out}}{V_{detained} \, x \, EMC_{in}} \, x100\% \tag{5.2}$$

$$TLP_{(SYSTEM)} = \frac{\sum_{i=1}^{n} \left[ V_{detainedi} \times EMC_{ini} - V_{outi} \times EMC_{outi} \right]}{\sum_{i=1}^{n} \left[ V_{in\text{-}totali} \times EMC_{ini} \right]} \, x100\% \tag{5.3}$$

$$TLP_{(TANK)} = \frac{\sum_{i=1}^{n} \left[ V_{detainedi} \times EMC_{ini} - V_{outi} \times EMC_{outi} \right]}{\sum_{i=1}^{n} \left[ V_{detainedi} \times EMC_{ini} \right]} \, x100\% \tag{5.4}$$

where:
$EMC_{ini}$ - quality constituent event mean concentration at the inlet for event i (mg/L)
$EMC_{outi}$ - quality constituent event mean concentration at the outlet for event i (mg/L)
$V_{in\text{-}totali}$ - total volume of stormwater runoff for event i ($m^3$)

$V_{detainedi}$ - volume captured by tank before detention started for event i ($m^3$)
$V_{outi}$ - supernatant volume pumped out after detention for event i ($m^3$)
n - total number of events monitored

The value of each volume used here is derived from the quantity analysis in Chapter 3. Table 3.1 shows that there is a difference between $V_{detained}$ and $V_{out}$. Some events have $V_{detained}$ greater and some less than $V_{out}$. This is due to the dry weather flow continuing to enter the tank during the 8-hour detention period plus the leakage from storm cell to CSO cell through the sluice gate. Because this fact has already influenced the influent and effluent pollutant concentrations, using these two volumes to calculate the pollutant load is viewed as a reasonable approximation.

The quantity ($V_{detained}$ x $EMC_{in}$ – $V_{out}$ x $EMC_{out}$) represents the pollutant reduction by the treatment in the tank. This reduction is used for both the "system" scenario and the "tank" scenario. The quantity ($V_{in\text{-}total}$ x $EMC_{in}$) represents the total load for the "system" scenario, while ($V_{detained}$ x $EMC_{in}$) represents the total load for the "tank" scenario. The removal efficiency for both the "system" and "tank" scenarios are computed according to this calculation protocol.

## 5.3 Performance Analysis Results

Pollutant loads for each of the water quality parameters are calculated using the volumes and the event mean concentrations determined in Chapters 3 and 4. Tables 5.1, 5.2, and 5.3 present the estimated contaminant mass loads to the "tank", to the "system", and pumped out from the system, respectively. In these tables, contaminant masses for each rainfall event are calculated and used to obtain the respective contaminant mass in the summer/fall, and winter/spring season accordingly. The total annual masses presented in the tables are computed by summing the loads generated for all of the monitored events. Since the 12 events involved in the performance analysis here are evenly distributed over the year, it is assumed that these 12 events represent the entire year's performance. The total rainfall volume for these 12 events is 230.8mm, which represents 31% of the total rainfall volume in 1996. At the same time, the total inflow volume ($V_{in\text{-}total}$) for these 12 events is 91,542$m^3$, which represents 32% of the total inflow runoff volume to the system in 1996. Thus, the total load calculated from these 12 events might represent one third of the total load of the entire 1996 year based on the above observation. The calculated pollutant masses shown in Tables 5.1, 5.2, and 5.3 are used to estimate the pollutant removal efficiency under the "tank" scenario and the "system" scenario. The performance analysis results are illustrated in Tables 5.4 and 5.5.

As can be seen from the data in Tables 5.1 and 5.2, iron and aluminum are the two highest loads among all the heavy metals. The lowest loads contributed by heavy metals are mercury, arsenic, cadmium and cobalt. As for nutrients, the highest and lowest loads recorded were for TKN and nitrites, respectively. Based on these 12 events, the estimated total suspended solids (TSS) loaded to the "system" is 10,102 Kg. Thus, the year's total load to the system might be around 30,000 kg by extrapolating these 12 events. The total TSS load is 57,000 kg for the study area in 1995. This significant difference requires further investigation.

Table 5.3 presents the estimated pollutant mass pumped out to the Lake after the 8 hour detention in the tank. The yearly total mass of TSS to the Lake is about 8280 Kg by extrapolating the 12 analyzed events. This amount does not consider the pollutants in the overflows without treatment by the tank. The amounts of the E. coli counts are significant, in the order of magnitude of $10^9$ for individual events.

Tables 5.4 and 5.5 show the removal efficiencies calculated for the "system" scenario and the "tank" scenario. The difference is obvious between the two scenarios. The performance of the "tank" itself is noticeably better than for the "system" due to the overflows considered in the system scenario. As shown in Table 5.5 for the "tank" scenario, the TSS removal is 46.8% for the yearly IEP and 45.8% for the yearly TLP. The events that occurred on February 8 and July 12 had removal efficiencies of 0.4% and -11.2%, respectively, which cannot be considered reasonable. If these two events are eliminated from the calculations, the removal efficiency for the yearly IEP is 53.2%. This value might represent the pollutant removal efficiency of the Maclean Avenue detention tank itself under the 8-hour detention period. In the "tank" scenario, both of the IEP and TLP calculations show that the facility performs better in the warmer season than in the winter season. This observation is consistent with the treatment mechanisms of the detention tank since the particle settling velocity is greater in the warmer season than in than winter season. In addition, chloride stratification occurred in the winter due to the usage of salt as a de-icing agent, which also slows down the particle settling process. However, in the "system" scenario, there is no discernable difference between the summer and winter, which is because more overflows occur in the summer and these overflows are not treated by the facility.

The "system" performance analysis results illustrated in Table 5.5 show that the yearly IEP of the TSS is 26.3%, only half of the yearly IEP in the "tank" scenario. This observation is consistent with the result of the quantity control analysis conducted in Chapter 4 that about half of the tank's inflow overflowed to the Lake in 1996. The other pollutant removal efficiencies were also calculated to be about half those of the "tank" scenario. This observation implies that the 12 analyzed events might represent the system performance for the entire year to a certain degree. The significant reduction in pollutant removal under the "system" scenario requires an evaluation of the appropriateness of tank sizing.

Most of the heavy metals show obvious removal by the tank. In Table 5.4, the greatest heavy metal reduction is 94.5% for Chromium, and most of the other heavy metals are removed by about 50%. These heavy metals are largely bound on TSS and settle to the bottom of the tank together with the TSS. Ironically, the removal of bacteria (E. coli) is negative after detention, although the main objective for the implementation of the tank was to reduce the number of beach postings. The reduction in number of beach postings in this case was possibly due to discharging the stormwater runoff 400m offshore.

***Table 5.1:*** Summary of Contaminant Mass Load into the Tank = $V_{detained}$ x $EMC_{in}$

| Date | Aluminum | Arsenic | Barium | Beryllium | Cadmium | Cobalt | Chromium | Copper | Iron | Mercury | Manganese | Molybdenum | Nickel | Lead | Strontium | Titanium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | g | Kg | Kg | Kg | Kg | Kg | Kg |
| Jan 19 | | 0.008 | 0.110 | 0.0102 | 0.010 | 0.023 | 0.020 | 0.207 | 2.761 | 0.203 | 0.487 | 0.020 | 0.051 | 0.508 | 1.421 | 0.102 |
| Jan 24 | 2.4 | 0.005 | 0.087 | 0.0005 | 0.005 | 0.004 | 0.032 | 0.160 | 5.478 | 0.183 | 0.429 | 0.005 | 0.018 | 0.183 | 0.822 | 0.041 |
| Feb 8 | 4.7 | 0.009 | | 0.0140 | 0.032 | 0.001 | 0.079 | 0.419 | 9.765 | 0.326 | 1.070 | 0.040 | | 0.837 | | 0.149 |
| Feb 20 | 3.8 | 0.005 | 0.235 | 0.0005 | 0.000 | 0.001 | 0.031 | 0.248 | 13.554 | 0.271 | 1.130 | 0.001 | 0.034 | 0.316 | 2.349 | 0.063 |
| Apr 12 | 0.8 | 0.005 | | 0.0005 | 0.002 | 0.002 | 0.016 | 0.347 | 1.553 | 0.091 | | 0.005 | 0.014 | 0.069 | 1.371 | 0.018 |
| May 21 | 3.1 | 0.008 | 0.153 | 0.0004 | 0.008 | 0.004 | 0.018 | 0.165 | 5.744 | 0.115 | 0.766 | 0.002 | 0.017 | 0.191 | 0.613 | 0.023 |
| Jun 21 | 1.7 | 0.004 | 0.142 | 0.0004 | 0.006 | 0.002 | 0.012 | 0.119 | 3.826 | | 0.421 | 0.002 | 0.013 | 0.115 | 0.574 | 0.015 |
| July 12 | 0.8 | 0.004 | 0.304 | 0.0004 | | 0.001 | | 0.017 | 1.185 | 0.079 | 0.553 | 0.002 | 0.004 | 0.020 | 1.303 | 0.004 |
| July 16 | 4.4 | 0.006 | 0.178 | 0.0003 | 0.006 | | | 0.203 | 10.608 | 0.281 | 0.780 | 0.001 | 0.023 | 0.281 | 0.593 | 0.028 |
| Sep 13 | 5.7 | 0.004 | 0.280 | 0.3945 | 0.007 | 0.005 | 0.025 | 0.159 | 12.820 | 0.266 | 0.891 | 0.008 | 0.019 | 0.417 | 0.301 | 0.025 |
| Sep 30 | 4.0 | 0.004 | 0.169 | 0.2217 | 0.009 | 0.003 | 0.021 | 0.134 | 9.649 | 0.090 | 0.709 | 0.005 | 0.015 | 0.173 | 0.282 | 0.007 |
| Nov 4 | 2.7 | 0.002 | 0.100 | 0.0002 | 0.002 | 0.004 | 0.013 | 0.164 | 6.518 | 0.088 | 0.647 | 0.001 | 0.016 | 0.175 | 0.166 | 0.014 |
| Winter total | 11.6 | 0.031 | 0.431 | 0.0255 | 0.049 | 0.030 | 0.178 | 1.381 | 33.112 | 1.074 | 3.115 | 0.070 | 0.117 | 1.912 | 5.963 | 0.373 |
| Summer total | 22.2 | 0.032 | 1.326 | 0.6178 | 0.039 | 0.018 | 0.089 | 0.959 | 50.350 | 0.918 | 4.767 | 0.022 | 0.108 | 1.372 | 3.832 | 0.116 |
| Annual total | 33.9 | 0.063 | 1.757 | 0.6433 | 0.088 | 0.048 | 0.267 | 2.341 | 83.462 | 1.992 | 7.883 | 0.093 | 0.224 | 3.284 | 9.796 | 0.489 |

| Date | Zinc | Chloride | Carbon, Dissolved Inorganic | Carbon, Dissolved Organic | Ammonia + Ammonium | Nitrate + Nitrite | Nitrite | TKN | Phosphate | Phosphorus | Suspended Solids | Silicon | Solvent Extractables | E. coli | Fecal Streptococci | Pseudomonas aeruginosa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | counts | counts | counts |
| Jan 19 | 0.731 | 4995.0 | 79.6 | 25.6 | 19.9 | 3.7 | 0.9 | 37.4 | 1.3 | 3.6 | 532.0 | 5.4 | 24.4 | | | |
| Jan 24 | 0.776 | 1077.3 | 57.5 | 23.3 | 3.2 | 6.6 | 0.5 | 11.4 | 1.1 | 1.9 | 292.2 | 5.5 | 27.4 | | | |
| Feb 8 | 1.953 | | 63.2 | 24.2 | 29.5 | 6.5 | 0.8 | 47.9 | 0.7 | 4.1 | 925.4 | 3.8 | 76.7 | | | |
| Feb 20 | 1.581 | 16129.3 | 97.6 | 91.3 | | 6.7 | 1.5 | | | | | 4.8 | 56.5 | | | |
| Apr 12 | 0.224 | 2238.8 | 182.8 | 21.9 | 0.5 | | | 4.6 | 0.1 | 0.6 | 169.1 | 13.9 | 4.6 | | | |
| May 21 | 0.957 | 219.0 | 90.4 | 50.2 | 2.9 | 0.2 | | 13.0 | 0.3 | 2.0 | 448.0 | 4.0 | 28.7 | | | |
| Jun 21 | 0.957 | 322.9 | 101.8 | 21.4 | 1.1 | 8.2 | 0.7 | 7.0 | 1.0 | 1.6 | | 8.6 | 28.7 | 1.3E+09 | 3.9E+09 | 5.4E+06 |
| July 12 | 0.087 | 1611.2 | 303.3 | 7.1 | 0.7 | 12.3 | 0.3 | 1.8 | 0.2 | 0.3 | 43.4 | 24.7 | 3.9 | | | |
| July 16 | 0.842 | 289.5 | 92.4 | 26.2 | 3.7 | 4.4 | 1.4 | 14.0 | 0.2 | 2.3 | 658.3 | 6.1 | 34.3 | 5.6E+09 | 2.2E+09 | 1.5E+07 |
| Sep 13 | 1.142 | 11.4 | 38.7 | 11.8 | 0.1 | 0.9 | 0.1 | 2.4 | 0.1 | 0.4 | 1046.9 | 1.7 | | | | |
| Sep 30 | 1.113 | 9.0 | 35.9 | 18.8 | 0.1 | 0.5 | 0.0 | 9.0 | 0.1 | 1.2 | 565.5 | 2.2 | 22.4 | 2.4E+08 | 8.4E+07 | 4.0E+06 |
| Nov 4 | 0.575 | 22.9 | 38.3 | 24.7 | 0.0 | 0.1 | 0.0 | 3.0 | 0.9 | 1.2 | 411.8 | 2.4 | 25.3 | | | |
| Winter total | 5.265 | 24440.4 | 480.7 | 186.2 | 53.2 | 23.5 | 3.7 | 101.2 | 3.2 | 10.3 | 1918.6 | 33.3 | 189.5 | | | |
| Summer total | 5.672 | 2485.9 | 700.7 | 160.2 | 8.7 | 26.6 | 2.5 | 50.3 | 2.8 | 9.1 | 3173.9 | 49.8 | 143.4 | 7.2E+09 | 6.2E+09 | 2.4E+07 |
| Annual total | 10.938 | 26926.4 | 1181.4 | 346.4 | 61.9 | 50.1 | 6.1 | 151.6 | 6.0 | 19.3 | 5092.4 | 83.1 | 333.0 | 7.2E+09 | 6.2E+09 | 2.4E+07 |

***Table 5.2:*** Summary of Total Contaminant Mass Load into the System = V $_{in\text{-}total}$ x EMC $_{in}$

| Date | Aluminum | Arsenic | Barium | Beryllium | Cadmium | Cobalt | Chromium | Copper | Iron | Mercury | Manganese | Molybdenum | Nickel | Lead | Strontium | Titanium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | g | Kg | Kg | Kg | Kg | Kg | Kg |
| Jan 19 | 0.0000 | 0.0174 | 0.2354 | 0.0218 | 0.0218 | 0.0488 | 0.0436 | 0.4446 | 5.9282 | 0.4359 | 8.7180 | 0.0436 | 0.1090 | 1.0898 | 3.0513 | 0.2180 |
| Jan 24 | 2.3738 | 0.0046 | 0.0867 | 0.0005 | 0.0046 | 0.0037 | 0.0320 | 0.1598 | 5.4780 | 0.1826 | 4.5650 | 0.0046 | 0.0183 | 0.1826 | 0.8217 | 0.0411 |
| Feb 8 | 9.9460 | 0.0199 | 0.0000 | 0.0298 | 0.0676 | 0.0020 | 0.1691 | 0.8951 | 20.8866 | 0.6962 | 9.9460 | 0.0855 | 0.0000 | 1.7903 | 0.0000 | 0.3183 |
| Feb 20 | 3.8403 | 0.0045 | 0.2349 | 0.0005 | 0.0005 | 0.0009 | 0.0307 | 0.2485 | 13.5540 | 0.2711 | 4.5180 | 0.0009 | 0.0339 | 0.3163 | 2.3494 | 0.0633 |
| Apr 12 | 2.0721 | 0.0122 | 0.0000 | 0.0012 | 0.0061 | 0.0049 | 0.0414 | 0.9264 | 4.1443 | 0.2438 | 12.1890 | 0.0122 | 0.0366 | 0.1828 | 3.6567 | 0.0488 |
| May 21 | 11.0632 | 0.0277 | 0.5532 | 0.0014 | 0.0304 | 0.0138 | 0.0664 | 0.5946 | 20.7435 | 0.4149 | 13.8290 | 0.0083 | 0.0622 | 0.6915 | 2.2126 | 0.0830 |
| Jun 21 | 3.0309 | 0.0069 | 0.2549 | 0.0007 | 0.0110 | 0.0028 | 0.0220 | 0.2135 | 6.8885 | 0.0000 | 6.8885 | 0.0041 | 0.0241 | 0.2067 | 1.0333 | 0.0276 |
| July 12 | 1.6553 | 0.0087 | 0.6708 | 0.0009 | 0.0000 | 0.0017 | 0.0000 | 0.0366 | 2.6136 | 0.1742 | 8.7120 | 0.0052 | 0.0087 | 0.0436 | 2.8750 | 0.0087 |
| July 16 | 4.3680 | 0.0062 | 0.1778 | 0.0003 | 0.0059 | 0.0000 | 0.0312 | 0.2028 | 10.6080 | 0.2808 | 3.1200 | 0.0012 | 0.0234 | 0.2808 | 0.5928 | 0.0281 |
| Sep 13 | 13.2208 | 0.0089 | 0.6548 | 0.9228 | 0.0163 | 0.0121 | 0.0577 | 0.3709 | 29.9907 | 0.6211 | 8.8730 | 0.0184 | 0.0447 | 0.9760 | 0.7045 | 0.0591 |
| Sep 30 | 7.1749 | 0.0080 | 0.3009 | 0.3943 | 0.0164 | 0.0057 | 0.0367 | 0.2378 | 17.1592 | 0.1596 | 7.9810 | 0.0089 | 0.0269 | 0.3081 | 0.5020 | 0.0120 |
| Nov 4 | 2.6864 | 0.0022 | 0.0998 | 0.0002 | 0.0024 | 0.0037 | 0.0132 | 0.1645 | 6.5179 | 0.0881 | 2.2020 | 0.0012 | 0.0156 | 0.1751 | 0.1665 | 0.0136 |
| Winter total | 18.2322 | 0.0586 | 0.5571 | 0.0538 | 0.1005 | 0.0999 | 0.3168 | 2.6744 | 49.9911 | 1.8296 | 39.9360 | 0.1468 | 0.1977 | 3.5617 | 9.8791 | 0.6893 |
| Summer total | 43.1995 | 0.0686 | 2.7122 | 1.3205 | 0.0825 | 0.0397 | 0.2272 | 1.8208 | 94.5214 | 1.7387 | 51.6055 | 0.0473 | 0.2057 | 2.6816 | 8.0867 | 0.2320 |
| Annual total | 61.4318 | 0.1272 | 3.2692 | 1.3743 | 0.1831 | 0.0999 | 0.5440 | 4.4952 | 144.5125 | 3.5683 | 91.5415 | 0.1941 | 0.4033 | 6.2433 | 17.9657 | 0.9213 |

| Date | Zinc | Chloride | Carbon, Dissolved Inorganic | Carbon, Dissolved Organic | Ammonia + Ammonium | Nitrate + Nitrite | Nitrite | TKN | Phosphate | Phosphorus | Suspended Solids | Silicon | Solvent Extractables | E. coli | Fecal Streptococci | Pseudomonas aeruginosa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | counts | counts | counts |
| Jan 19 | 1.569 | 10723.1 | 170.9 | 54.9 | 42.7 | 8.0 | 1.9 | 80.2 | 2.9 | 7.8 | 1142.1 | 11.5 | 52.3 | | | |
| Jan 24 | 0.776 | 1077.3 | 57.5 | 23.3 | 3.2 | 6.6 | 0.5 | 11.4 | 1.1 | 1.9 | 292.2 | 5.5 | 27.4 | | | |
| Feb 8 | 4.177 | 0.0 | 135.3 | 51.7 | 63.2 | 13.8 | 1.7 | 102.4 | 1.6 | 8.9 | 1979.3 | 8.2 | 164.1 | | | |
| Feb 20 | 1.581 | 16129.3 | 97.6 | 91.3 | | 6.7 | 1.5 | | 0.0 | 0.0 | 0.0 | 4.8 | 56.5 | | | |
| Apr 12 | 0.597 | 5972.6 | 487.6 | 58.5 | 1.4 | | | 12.2 | 0.1 | 1.6 | 451.0 | 37.1 | 12.2 | | | |
| May 21 | 3.457 | 791.0 | 326.4 | 181.2 | 10.6 | 0.8 | 0.0 | 47.0 | 1.1 | 7.2 | 1618.0 | 14.4 | 103.7 | | | 0.000 |
| Jun 21 | 1.722 | 581.4 | 183.2 | 38.6 | 2.1 | 14.8 | 1.2 | 12.7 | 1.9 | 2.9 | 0.0 | 15.4 | 51.7 | 2.3E+09 | 7.0E+09 | 9.6E+06 |
| July 12 | 0.192 | 3554.5 | 669.1 | 15.7 | 1.5 | 27.1 | 0.6 | 4.0 | 0.4 | 0.8 | 95.8 | 54.5 | 8.7 | 0.0E+00 | 0.0E+00 | 0.0E+00 |
| July 16 | 0.842 | 289.5 | 92.4 | 26.2 | 3.7 | 4.4 | 1.4 | 14.0 | 0.2 | 2.3 | 658.3 | 6.1 | 34.3 | 5.6E+09 | 2.2E+09 | 1.5E+07 |
| Sep 13 | 2.671 | 26.6 | 90.5 | 27.5 | 0.3 | 2.1 | 0.2 | 5.7 | 0.3 | 1.0 | 2448.9 | 4.1 | 0.0 | 0.0E+00 | 0.0E+00 | 0.0E+00 |
| Sep 30 | 1.979 | 16.0 | 63.8 | 33.5 | 0.1 | 0.9 | 0.0 | 16.0 | 0.1 | 2.2 | 1005.6 | 4.0 | 39.9 | 4.3E+08 | 1.5E+08 | 7.2E+06 |
| Nov 4 | 0.575 | 22.9 | 38.3 | 24.7 | 0.0 | 0.1 | 0.0 | 3.0 | 0.9 | 1.2 | 411.8 | 2.4 | 25.3 | 0.0E+00 | 0.0E+00 | 0.0E+00 |
| Winter total | 8.701 | 33902.4 | 948.8 | 279.7 | 110.6 | 35.2 | 5.6 | 206.3 | 5.7 | 20.1 | 3864.5 | 67.0 | 312.5 | 0.0E+00 | 0.0E+00 | 0.0E+00 |
| Summer total | 8.701 | 5281.9 | 1463.7 | 347.3 | 18.3 | 50.2 | 3.4 | 102.4 | 4.9 | 17.5 | 6238.5 | 101.0 | 263.6 | 8.4E+09 | 9.4E+09 | 3.2E+07 |
| Annual total | 20.139 | 39184.3 | 2412.5 | 627.0 | 128.9 | 85.3 | 9.0 | 308.6 | 10.6 | 37.6 | 10102.9 | 167.9 | 576.1 | 8.4E+09 | 9.4E+09 | 3.2E+07 |

***Table 5.3:*** Summary of Pumped out Supernatant Contaminant Mass = $V_{out} \times EMC_{out}$

| Date | Aluminum | Arsenic | Barium | Beryllium | Cadmium | Cobalt | Chromium | Copper | Iron | Mercury | Manganese | Molybdenum | Nickel | Lead | Strontium | Titanium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | g | Kg | Kg | Kg | Kg | Kg | Kg |
| Jan 19 | | 0.0042 | 0.0632 | 0.0004 | 0.0013 | 0.0025 | 0.0025 | 0.0843 | 2.9512 | 0.1686 | 0.2487 | 0.0008 | 0.0042 | 0.1265 | 0.3541 | 0.0253 |
| Jan 24 | 1.6290 | 0.0045 | 0.0588 | 0.0005 | 0.0018 | 0.0018 | 0.0018 | 0.0996 | 3.5295 | 0.1358 | 0.2625 | 0.0027 | 0.0113 | 0.1131 | 0.3801 | 0.0317 |
| Feb 8 | 5.5872 | 0.0093 | | 0.0135 | 0.0116 | 0.0009 | 0.0009 | 0.3771 | 10.7088 | 0.3725 | 1.3037 | 0.0009 | | 0.3492 | | 0.1583 |
| Feb 20 | 3.4448 | 0.0046 | 0.2756 | 0.0005 | 0.0005 | 0.0009 | 0.0009 | 0.1883 | 11.4825 | 0.2297 | 1.1023 | 0.0009 | 0.0344 | 0.0919 | 2.7099 | 0.0643 |
| Apr 12 | 0.3687 | 0.0046 | | 0.0005 | 0.0005 | 0.0009 | 0.0009 | 0.0378 | 1.6592 | 0.0922 | | 0.0009 | 0.0046 | 0.0461 | 1.6132 | 0.0046 |
| May 21 | 0.7395 | 0.0044 | 0.0566 | 0.0004 | 0.0017 | 0.0017 | 0.0017 | 0.0609 | 1.4790 | 0.0870 | 0.2175 | 0.0009 | 0.0065 | 0.0653 | 0.2784 | 0.0087 |
| Jun 21 | 1.3455 | 0.0045 | 0.0897 | 0.0004 | 0.0018 | 0.0009 | 0.0009 | 0.0762 | 3.2292 | | 0.3633 | 0.0018 | 0.0112 | 0.0897 | 0.3319 | 0.0090 |
| July 12 | 0.6489 | 0.0038 | 0.2634 | 0.0004 | | 0.0008 | 0.0008 | 0.0115 | 1.2214 | 0.0763 | 0.3817 | 0.0023 | 0.0038 | 0.0191 | 1.1451 | 0.0038 |
| July 16 | 4.6488 | 0.0077 | 0.1860 | 0.0004 | 0.0054 | | | 0.1976 | 12.3968 | 0.2324 | 0.8523 | 0.0015 | 0.0271 | 0.3487 | 0.5811 | 0.0349 |
| Sep 13 | 1.1787 | 0.0046 | 0.1520 | 0.0737 | 0.0027 | 0.0012 | 0.0012 | 0.0660 | 2.8717 | 0.0910 | 0.3359 | 0.0002 | 0.0056 | 0.0605 | 0.5780 | 0.0136 |
| Sep 30 | 1.7872 | 0.0045 | 0.1656 | 0.1288 | 0.0053 | 0.0020 | 0.0020 | 0.0653 | 3.9690 | 0.1361 | 0.5534 | 0.0024 | 0.0073 | 0.1220 | 0.6033 | 0.0274 |
| Nov 4 | 0.3339 | 0.0029 | 0.1164 | 0.0000 | 0.0002 | 0.0008 | 0.0008 | 0.0528 | 1.6696 | 0.0571 | 0.3425 | 0.0006 | 0.0040 | 0.0176 | 0.4681 | 0.0014 |
| Winter total | 11.0297 | 0.0273 | 0.3976 | 0.0153 | 0.0156 | 0.0071 | 0.0071 | 0.7871 | 30.3312 | 0.9987 | 2.9172 | 0.0063 | 0.0546 | 0.7268 | 5.0573 | 0.2842 |
| Summer total | 10.6825 | 0.0323 | 1.0296 | 0.2042 | 0.0172 | 0.0075 | 0.0075 | 0.5303 | 26.8367 | 0.6800 | 3.0465 | 0.0096 | 0.0657 | 0.7228 | 3.9858 | 0.0988 |
| Annual total | 21.7122 | 0.0596 | 1.4272 | 0.2195 | 0.0328 | 0.0146 | 0.0146 | 1.3174 | 57.1680 | 1.6787 | 5.9637 | 0.0096 | 0.1203 | 1.4496 | 9.0431 | 0.3830 |

| Date | Zinc | Chloride | Carbon, Dissolved Inorganic | Carbon, Dissolved Organic | Ammonia + Ammonium | Nitrate + Nitrite | Nitrite | TKN | Phosphate | Phosphorus | Suspended Solids | Silicon | Solvent Extractables | E. Coli | Fecal Streptococci | Pseudomonas aeruginosa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | Kg | counts | counts | counts |
| Jan 19 | 0.396 | 361.7 | 50.6 | 14.8 | 1.6 | 2.5 | 0.2 | 8.9 | 0.7 | 2.0 | 307.8 | 4.0 | 23.2 | | | |
| Jan 24 | 0.398 | 610.9 | 45.3 | 17.2 | 2.8 | 5.2 | 0.3 | 9.5 | 1.0 | 1.7 | 149.3 | 4.0 | 15.8 | | | |
| Feb 8 | 1.723 | | 112.7 | 31.2 | 30.5 | 10.3 | 0.3 | | 0.6 | 4.0 | 921.9 | 8.8 | 62.9 | | | |
| Feb 20 | 1.102 | 19428.4 | 154.3 | 89.6 | | 15.2 | 1.7 | | | | | 10.0 | 39.0 | | | |
| Apr 12 | 0.129 | 2041.8 | 326.3 | 13.4 | 1.0 | | | 3.9 | 0.2 | 0.4 | 83.0 | 25.2 | 2.3 | | | |
| May 21 | 0.357 | 81.8 | 45.2 | 17.4 | 2.8 | 0.4 | | 7.3 | 0.4 | 0.9 | 91.4 | 2.0 | 4.4 | | | |
| Jun 21 | 0.341 | 132.8 | 48.4 | 22.9 | 2.4 | 4.0 | 0.4 | 4.0 | 1.1 | 1.0 | | 3.9 | 22.4 | 2.9E+09 | 5.6E+09 | 2.3E+07 |
| July 12 | 0.099 | 1400.8 | 285.5 | 8.0 | 0.8 | 11.6 | 0.2 | 1.8 | 0.2 | 0.3 | 30.5 | 23.2 | 5.7 | | | |
| July 16 | 0.969 | 243.3 | 87.6 | 27.5 | 3.4 | 5.8 | 2.2 | 14.9 | 0.2 | 2.4 | 732.2 | 5.6 | 46.5 | 5.4E+09 | 2.4E+09 | 1.8E+07 |
| Sep 13 | 0.282 | 434.2 | 108.3 | 20.0 | 0.4 | 6.6 | 0.3 | 5.6 | 0.4 | 0.9 | 141.1 | 10.1 | 9.1 | | | |
| Sep 30 | 0.381 | 450.9 | 104.3 | 13.2 | 0.5 | 6.8 | 0.3 | 5.3 | 0.3 | 1.0 | 217.7 | 10.9 | 9.1 | 4.3E+08 | 2.0E+08 | 9.1E+05 |
| Nov 4 | 0.300 | 402.4 | 125.6 | 31.4 | 0.6 | 0.1 | 0.0 | 0.6 | 1.5 | 0.0 | 85.6 | 8.4 | 4.3 | | | |
| Winter total | 3.749 | 22442.8 | 689.2 | 166.1 | 35.9 | 33.3 | 2.4 | 22.2 | 2.5 | 8.0 | 1461.9 | 51.9 | 143.2 | | | |
| Summer total | 2.728 | 3146.1 | 805.0 | 140.4 | 10.9 | 35.3 | 3.4 | 39.4 | 3.9 | 6.5 | 1298.5 | 64.1 | 101.4 | 8.8E+09 | 8.2E+09 | 4.2E+07 |
| Annual total | 6.477 | 25588.9 | 1494.1 | 306.4 | 46.8 | 68.6 | 5.8 | 61.6 | 6.4 | 14.5 | 2760.4 | 116.0 | 244.7 | 8.8E+09 | 8.2E+09 | 8.4E+07 |

***Table 5.4:*** Tank Performance (% Pollutant Removal)

| Date | Aluminum | Arsenic | Barium | Beryllium | Cadmium | Cobalt | Chromium | Copper | Iron | Mercury | Manganese | Molybdenum | Nickel | Lead | Strontium | Titanium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 19 | | 48.1 | 42.3 | 95.8 | 87.5 | 88.9 | 87.5 | 59.3 | -6.9 | 16.9 | 49.0 | 95.8 | 91.7 | 75.1 | 75.1 | 75.1 |
| Jan 24 | 31.4 | 0.9 | 32.2 | 0.9 | 60.4 | 50.4 | 94.3 | 37.7 | 35.6 | 25.7 | 38.8 | 40.5 | 38.0 | 38.0 | 53.7 | 22.9 |
| Feb 8 | -20.2 | -0.1 | | 3.2 | 63.2 | -0.1 | 98.8 | 9.9 | -9.7 | -14.4 | -21.9 | 97.7 | | 58.3 | | -6.4 |
| Feb 20 | 10.3 | -1.7 | -17.3 | -1.7 | -1.7 | -1.7 | 97.0 | 24.2 | 15.3 | 15.3 | 2.4 | -1.7 | -1.7 | 71.0 | -15.3 | -1.7 |
| Apr 12 | 52.5 | -0.9 | | -0.9 | 79.8 | 49.6 | 94.1 | 89.1 | -6.8 | -0.9 | | 79.8 | 66.4 | 32.7 | -17.7 | 74.8 |
| May 21 | 75.9 | 43.2 | 63.1 | -13.6 | 79.3 | 54.6 | 90.5 | 63.0 | 74.2 | 24.3 | 71.6 | 62.1 | 62.1 | 65.9 | 54.6 | 62.1 |
| Jun 21 | 20.1 | -17.2 | 36.6 | -17.2 | 70.7 | 41.4 | 92.7 | 35.7 | 15.6 | | 13.7 | 21.9 | 16.3 | 21.9 | 42.2 | 41.4 |
| July 12 | 13.5 | 3.3 | 13.4 | 3.3 | | 3.3 | | 31.0 | -3.1 | 3.3 | 31.0 | 3.3 | 3.3 | 3.3 | 12.1 | 3.3 |
| July 16 | -6.4 | -24.2 | -4.6 | -24.2 | 8.5 | | | 2.6 | -16.9 | 17.2 | -9.3 | -24.2 | -15.9 | -24.2 | 2.0 | -24.2 |
| Sep 13 | 79.1 | -20.0 | 45.7 | 81.3 | 61.3 | 75.9 | 95.0 | 58.4 | 77.6 | 65.7 | 62.3 | 97.9 | 70.5 | 85.5 | -91.9 | 46.1 |
| Sep 30 | 55.7 | -1.1 | 2.1 | 41.9 | 43.1 | 35.6 | 90.1 | 51.2 | 58.9 | -51.6 | 22.0 | 52.5 | 51.4 | 29.6 | -113.7 | -307.6 |
| Nov 4 | 87.6 | -29.6 | -16.7 | 82.1 | 89.7 | 77.1 | 93.7 | 67.9 | 74.4 | 35.2 | 47.1 | 51.4 | 74.2 | 90.0 | -181.2 | 89.4 |
| Winter IEP | 18.5 | 9.3 | 19.1 | 19.5 | 57.8 | 37.4 | 94.4 | 44.0 | 5.5 | 8.5 | 17.1 | 62.4 | 48.6 | 55.0 | 23.9 | 32.9 |
| Summer IEP | 46.5 | -6.5 | 19.9 | 21.9 | 58.8 | 48.0 | 92.4 | 44.2 | 40.1 | 15.7 | 34.0 | 37.8 | 37.4 | 38.9 | -39.4 | -12.8 |
| Yearly IEP | 36.3 | 0.1 | 19.7 | 20.9 | 58.4 | 43.2 | 93.4 | 44.2 | 25.7 | 12.4 | 27.9 | 48.4 | 41.5 | 45.6 | -16.4 | 6.3 |
| Winter TLP | 5.3 | 12.3 | 7.8 | 39.9 | 68.1 | 76.3 | 96.0 | 43.0 | 8.4 | 7.0 | 6.4 | 91.0 | 53.2 | 62.0 | 15.2 | 23.8 |
| Summer TLP | 52.0 | -0.6 | 22.3 | 66.9 | 56.1 | 58.5 | 91.6 | 44.7 | 46.7 | 25.9 | 36.1 | 56.8 | 39.1 | 47.3 | -4.0 | 14.7 |
| Yearly TLP | 35.9 | 5.7 | 18.8 | 65.9 | 62.8 | 69.6 | 94.5 | 43.7 | 31.5 | 15.7 | 24.3 | 89.6 | 46.4 | 55.9 | 7.7 | 21.6 |

| Date | Zinc | Chloride | Carbon, Dissolved Inorganic | Carbon, Dissolved Organic | Ammonia + Ammonium | Nitrate + Nitrite | Nitrite | TKN | Phosphate | Phosphorus | Suspended Solids | Silicon | Solvent Extractables | E. coli | Fecal Streptococci | Pseudomonas aeruginosa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 19 | 45.8 | 92.8 | 36.4 | 42.3 | 91.9 | 31.9 | 82.6 | 76.3 | 46.5 | 45.2 | 42.1 | 26.1 | 4.8 | | | |
| Jan 24 | 48.7 | 43.3 | 21.3 | 26.1 | 14.3 | 20.7 | 45.3 | 16.7 | 5.1 | 12.7 | 48.9 | 27.3 | 42.2 | | | |
| Feb 8 | 11.8 | | -78.2 | -29.0 | -3.3 | -59.2 | 68.0 | | 24.9 | 4.4 | 0.4 | -129.6 | 18.1 | | | |
| Feb 20 | 30.3 | -20.5 | -58.1 | 1.9 | | -125.8 | -14.0 | | | | | -109.1 | 30.9 | | | |
| Apr 12 | 42.4 | 8.8 | -78.5 | 39.1 | -84.7 | | | 15.3 | -211.8 | 30.2 | 50.9 | -81.2 | 49.6 | | | |
| May 21 | 62.7 | 62.7 | 49.9 | 65.3 | 5.7 | -75.6 | | 43.9 | -13.6 | 54.1 | 79.6 | 49.8 | 84.9 | | | |
| Jun 21 | 64.4 | 58.9 | 52.4 | -6.8 | -104.8 | 50.9 | 37.4 | 42.7 | -8.5 | 39.2 | | 55.0 | 21.9 | -124.1 | -42.5 | -335.4 |
| July 12 | -14.2 | 13.1 | 5.9 | -12.8 | -22.5 | 5.2 | 13.9 | 3.3 | 11.4 | 14.3 | 29.7 | 6.1 | -45.0 | | | |
| July 16 | -15.0 | 16.0 | 5.2 | -5.0 | 9.6 | -31.2 | -51.2 | -6.0 | 12.7 | -3.8 | -11.2 | 8.8 | -35.5 | 3.4 | -8.4 | -19.0 |
| Sep 13 | 75.3 | -3715.5 | -180.0 | -70.3 | -238.8 | -624.9 | -288.2 | -128.7 | -177.0 | -107.4 | 86.5 | -479.1 | | | | |
| Sep 30 | 65.7 | -4923.2 | -190.6 | 30.2 | -645.4 | -1227.1 | -1213.9 | 41.4 | -214.4 | 21.4 | 61.5 | -385.1 | 59.6 | -75.9 | -131.2 | 77.5 |
| Nov 4 | 47.9 | -1657.2 | -227.7 | -27.3 | -13120.2 | -8.0 | -85.2 | 80.9 | -66.0 | 97.6 | 79.2 | -248.8 | 83.1 | | | |
| Winter IEP | 35.8 | 31.1 | -31.4 | 16.1 | 4.6 | -33.1 | 45.5 | 36.1 | -33.8 | 23.1 | 35.6 | -53.3 | 29.1 | | | |
| Summer IEP | 41.0 | -1449.3 | -69.3 | -3.8 | -2016.6 | -272.9 | -264.5 | 11.1 | -65.1 | 16.5 | 54.2 | -141.9 | 28.2 | -65.5 | -60.7 | -92.3 |
| Yearly IEP | 38.8 | -911.0 | -53.5 | 4.5 | -1281.6 | -185.7 | -140.5 | 18.6 | -53.7 | 18.9 | 46.8 | -105.0 | 28.6 | -65.5 | -60.7 | -92.3 |
| Winter TLP | 28.8 | 8.2 | -43.4 | 10.8 | 32.6 | -41.4 | 35.0 | 78.0 | 23.6 | 21.8 | 23.8 | -55.6 | 24.4 | | | |
| Summer TLP | 51.9 | -26.6 | -14.9 | 12.4 | -25.0 | -32.8 | -37.3 | 21.8 | -38.5 | 28.6 | 59.1 | -28.7 | 29.3 | -22.4 | -31.5 | -72.5 |
| Yearly TLP | 40.8 | 5.0 | -26.5 | 11.5 | 24.5 | -36.8 | 5.9 | 59.4 | -5.4 | 25.0 | 45.8 | -39.5 | 26.5 | -22.4 | -31.5 | -245.1 |

***Table 5.5:*** System Performance (% Pollutant Removal)

| Date | Aluminum | Arsenic | Barium | Beryllium | Cadmium | Cobalt | Chromium | Copper | Iron | Mercury | Manganese | Molybdenum | Nickel | Lead | Strontium | Titanium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 19 | | 22.4 | 19.7 | 44.6 | 40.8 | 41.4 | 40.8 | 27.6 | -3.2 | 7.9 | 2.7 | 44.6 | 42.7 | 35.0 | 35.0 | 35.0 |
| Jan 24 | 31.4 | 0.9 | 32.2 | 0.9 | 60.4 | 50.4 | 94.3 | 37.7 | 35.6 | 25.7 | 3.7 | 40.5 | 38.0 | 38.0 | 53.7 | 22.9 |
| Feb 8 | -9.4 | -0.1 | | 1.5 | 29.5 | -0.1 | 46.2 | 4.6 | -4.5 | -6.7 | -2.4 | 45.7 | | 27.2 | | -3.0 |
| Feb 20 | 10.3 | -1.7 | -17.3 | -1.7 | -1.7 | -1.7 | 97.0 | 24.2 | 15.3 | 15.3 | 0.6 | -1.7 | -1.7 | 71.0 | -15.3 | -1.7 |
| Apr 12 | 19.7 | -0.3 | | -0.3 | 29.9 | 18.6 | 35.3 | 33.4 | -2.6 | -0.3 | | 29.9 | 24.9 | 12.3 | -6.6 | 28.0 |
| May 21 | 21.0 | 12.0 | 17.5 | -3.8 | 22.0 | 15.1 | 25.1 | 17.4 | 20.6 | 6.7 | 4.0 | 17.2 | 17.2 | 18.3 | 15.1 | 17.2 |
| Jun 21 | 11.1 | -9.6 | 20.3 | -9.6 | 39.3 | 23.0 | 51.5 | 19.8 | 8.7 | | 0.8 | 12.1 | 9.0 | 12.1 | 23.4 | 23.0 |
| July 12 | 6.1 | 1.5 | 6.1 | 1.5 | | 1.5 | | 14.0 | -1.4 | 1.5 | 2.0 | 1.5 | 1.5 | 1.5 | 5.5 | 1.5 |
| July 16 | -6.4 | -24.2 | -4.6 | -24.2 | 8.5 | | | 2.6 | -16.9 | 17.2 | -2.3 | -24.2 | -15.9 | -24.2 | 2.0 | -24.2 |
| Sep 13 | 33.8 | -8.5 | 19.5 | 34.8 | 26.2 | 32.5 | 40.6 | 25.0 | 33.2 | 28.1 | 6.3 | 41.9 | 30.1 | 36.5 | -39.3 | 19.7 |
| Sep 30 | 31.3 | -0.6 | 1.2 | 23.6 | 24.2 | 20.0 | 50.7 | 28.8 | 33.1 | -29.0 | 2.0 | 29.5 | 28.9 | 16.6 | -63.9 | -173.0 |
| Nov 4 | 87.6 | -29.6 | -16.7 | 82.1 | 89.7 | 77.1 | 93.7 | 67.9 | 74.4 | 35.2 | 13.8 | 51.4 | 74.2 | 90.0 | -181.2 | 89.4 |
| Winter IEP | 13.0 | 4.2 | 11.5 | 9.0 | 31.8 | 21.7 | 62.7 | 127.6 | 8.1 | 8.4 | 1.2 | 31.8 | 26.0 | 36.7 | 16.7 | 16.3 |
| Summer IEP | 26.4 | -8.4 | 6.2 | 14.9 | 35.0 | 28.2 | 52.3 | 25.1 | 21.7 | 10.0 | 3.8 | 18.5 | 20.7 | 21.6 | -34.1 | -6.6 |
| Yearly IEP | 21.5 | -3.1 | 7.8 | 12.5 | 33.5 | 25.3 | 57.5 | 25.3 | 16.0 | 9.2 | 2.8 | 24.2 | 22.6 | 27.9 | -15.6 | 2.9 |
| Winter TLP | 3.4 | 6.5 | 6.0 | 18.9 | 33.3 | 23.0 | 53.8 | 22.2 | 5.6 | 4.1 | 0.5 | 43.6 | 31.4 | 33.3 | 9.2 | 12.9 |
| Summer TLP | 26.3 | -0.3 | 10.7 | 31.3 | 26.2 | 25.9 | 34.2 | 23.1 | 24.6 | 13.2 | 3.2 | 26.0 | 20.1 | 23.8 | -1.9 | 7.2 |
| Yearly TLP | 19.6 | 2.8 | 10.0 | 30.8 | 30.0 | 33.2 | 45.4 | 22.6 | 18.1 | 8.6 | 2.0 | 42.5 | 25.5 | 29.2 | 4.2 | 11.4 |

| Date | Zinc | Chloride | Carbon, Dissolved Inorganic | Carbon, Dissolved Organic | Ammonia + Ammonium | Nitrate + Nitrite | Nitrite | TKN | Phosphate | Phosphorus | Suspended Solids | Silicon | Solvent Extractables | E. coli | Fecal Streptococci | Pseudomonas aeruginosa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan 19 | 21.3 | 43.2 | 17.0 | 19.7 | 42.8 | 14.9 | 38.5 | 35.5 | 21.7 | 21.0 | 19.6 | 12.1 | 2.3 | | | |
| Jan 24 | 48.7 | 43.3 | 21.3 | 26.1 | 14.3 | 20.7 | 45.3 | 16.7 | 5.1 | 12.7 | 48.9 | 27.3 | 42.2 | | | |
| Feb 8 | 5.5 | | -36.5 | -13.6 | -1.5 | -27.7 | 31.8 | 46.8 | 11.6 | 2.0 | 0.2 | -60.6 | 8.5 | | | |
| Feb 20 | 30.3 | -20.5 | -58.1 | 1.9 | | -125.8 | -14.0 | | | | | -109.1 | 30.9 | | | |
| Apr 12 | 15.9 | 3.3 | -29.4 | 14.6 | -31.7 | | | 5.7 | -79.4 | 11.3 | 19.1 | -30.4 | 18.6 | | | |
| May 21 | 17.4 | 17.3 | 13.8 | 18.1 | 1.6 | -20.9 | | 12.1 | -3.8 | 15.0 | 22.0 | 13.8 | 23.5 | | | |
| Jun 21 | 35.7 | 32.7 | 29.1 | -3.8 | -58.2 | 28.3 | 20.8 | 23.7 | -4.7 | 21.8 | | 30.5 | 12.1 | -68.9 | -23.6 | -186.3 |
| July 12 | -6.5 | 5.9 | 2.7 | -5.8 | -10.2 | 2.4 | 6.3 | 1.5 | 5.2 | 6.5 | 13.5 | 2.8 | -20.4 | | | |
| July 16 | -15.0 | 16.0 | 5.2 | -5.0 | 9.6 | -31.2 | -51.2 | -6.0 | 12.7 | -3.8 | -11.2 | 8.8 | -35.5 | 3.4 | -8.4 | -19.0 |
| Sep 13 | 32.2 | -1588.3 | -76.9 | -30.1 | -102.1 | -267.1 | -123.2 | -55.0 | -75.7 | -45.9 | 37.0 | -204.8 | | | | |
| Sep 30 | 37.0 | -2768.5 | -107.2 | 17.0 | -362.9 | -690.0 | -682.6 | 23.3 | -120.6 | 12.0 | 34.6 | -216.6 | 33.5 | -42.7 | -73.8 | 43.6 |
| Nov 4 | 47.9 | -1657.2 | -227.7 | -27.3 | -13120.2 | -8.0 | -85.2 | 80.9 | -66.0 | 97.6 | 79.2 | -248.8 | 83.1 | | | |
| Winter IEP | 24.3 | 17.3 | -17.2 | 9.8 | 6.0 | -29.5 | 25.4 | 26.2 | -10.2 | 11.8 | 21.9 | -32.1 | 20.5 | | | |
| Summer IEP | 21.2 | -848.9 | -51.6 | -5.3 | -1948.9 | -141.0 | -152.5 | 11.5 | -36.1 | 14.7 | 29.2 | -87.8 | 16.1 | -36.1 | -35.3 | -53.9 |
| Yearly IEP | 22.5 | -533.9 | -37.2 | 1.0 | -1238.0 | -100.4 | -81.3 | 16.8 | -26.7 | 13.7 | 26.3 | -64.6 | 18.1 | -36.1 | -35.3 | -53.9 |
| Winter TLP | 17.4 | 5.9 | -22.0 | 7.2 | 15.7 | -27.7 | 23.0 | 38.3 | 13.3 | 11.1 | 11.8 | -27.7 | 14.8 | | | |
| Summer TLP | 33.8 | -12.4 | -7.0 | 5.6 | -11.2 | -15.8 | -13.2 | 10.0 | -19.3 | 13.9 | 29.7 | -14.0 | 15.9 | -9.7 | -19.9 | -13.7 |
| Yearly TLP | 21.9 | 3.4 | -12.9 | 6.3 | 11.7 | -20.5 | 2.9 | 28.5 | -2.9 | 12.4 | 22.9 | -19.4 | 15.3 | -9.7 | -19.9 | -46.4 |

# 6.0 TANK SIZING ANALYSIS

The Maclean Avenue detention tank was designed to operate in two phases: the interim stage and the ultimate stage. The interim phase is the current condition that the 8000$m^3$ tank is equally divided into two cells to receive storm water and combined sewage overflows, respectively. In the future, when the Kingswood Trunk Relief Sewer along Queen Street is constructed, its diameter would be oversized to provide in-line storage for the CSOs that are currently discharged to the CSO compartment. At that time, the entire tank volume would be used to treat stormwater only.

The flow analysis for the tank operation condition in the interim stage and the final stage was performed using the City's QQS model developed by Dorsch Consultants. Table 6.1 summarizes the flow analysis for the two stages, as well as the existing conditions for comparison. (Gore & Storrie and MacViro, design report,1993 (a))

***Table 6.1:*** Maclean Avenue Detention Tank Design Objectives

| Condition | Overflow events | | | Overflow volume ($m^3$) | | | TSS (Kg) | | |
|---|---|---|---|---|---|---|---|---|---|
| | CSO[1] | Storm[2] | Total | CSO[1] | Storm[2] | Total | CSO[1] | Storm[2] | Total |
| Existing | 128 | 124 | 128 | 124,798 | 292,290 | 394,008 | 16,392 | 33,481 | 49,873 |
| Interim | 7 | 9 | 16 | 23,056 | 37,130 | 60,186 | 2,825 | 5,593 | 8,418 |
| Reduction* | 95% | 93% | 85% | 82% | 87% | 54% | 83% | 83% | 83% |
| Final | 0 | 4 | 4 | 0 | 12,330 | 12,330 | 0 | 1,942 | 1,942 |
| Reduction* | 100% | 97% | 97% | 100% | 96% | 97% | 100% | 94% | 96% |

[1]CSO – Maclean Avenue Outfall

[2]Storm – Glen Manor Drive Outfall and Balsam Avenue Outfall

* Both the interim and final reductions are based on the existing condition (i.e., the condition before the tank was constructed)

The results in the table are based on the analysis of two years (April to November) of continuous rainfall record, 1980 and 1982. These two years were selected as being representative of average precipitation years. Thus, the annual performance parameters of the tank - overflow events, overflow volumes, and TSS loads - are half of the values shown in Table 6.1. There is significant environmental improvement after implementation of the tank according to the QQS model prediction. In the interim stage, overflow events would occur 3.5 times per year from the CSO compartment to the storm compartment. Also, the overflow from the storm compartment to the Lake would occur only 4.5 times per year. However, the data analysis in this study revealed that overflow events occurred 22 times in 1996 from the storm compartment to the Lake and 2 times from the CSO compartment to the storm compartment.

There is a substantial difference between the QQS simulation results and the actual operation of the system in 1996. It is true that the one year's performance may not be representative of the long term average performance. Thus, in order to evaluate the appropriateness of tank sizing, analytical probabilistic models are adopted here. The analytical probabilistic models were developed at the University of Toronto, and are efficient tools for urban stormwater management planning compared to continuous simulation models. The inputs of the models are based on statistical parameters of long-term rainfall data and catchment characteristics; thus, the predictions by the models, such as overflow volumes, overflow number, are long-term average annual values. The analytical probabilistic models are especially efficient for screening level analysis to compare alternatives for stormwater management. This is the primary reason to adopt the analytical probabilistic models here, given the time limitation for this study.

The theory, the derivation process, and the implementation of the analytical probabilistic models are documented in detail elsewhere by Adams and Papa (2000). The reader is referred to this book for background and detailed information. In this Chapter, the derivation and the implementation of the analytical model are presented specifically for the operation of the Maclean Avenue detention tank.

Characteristics of rainfall events (volume, duration, intensity, and interevent time) are considered as independent random variables. Statistics analyses of long term rainfall data in the Toronto area demonstrate that the probability density functions (PDFs) of these meteorological characteristics are adequately represented by exponential distributions, and are given by the following expressions:

PDF of rainfall volume, v

$$f_V(v) = \zeta e^{-\zeta v}, \quad v \geq 0 \quad \text{where } \zeta = \frac{1}{\bar{v}} \quad (\text{mm}^{-1})$$

PDF of rainfall duration, t

$$f_T(t) = \lambda e^{-\lambda t}, \quad t \geq 0 \quad \text{where } \lambda = \frac{1}{\bar{t}} \quad (\text{h}^{-1})$$

PDF of rainfall intensity, i

$$f_I(i) = \beta e^{-\beta i}, \quad i \geq 0 \quad \text{where } i = \frac{1}{\bar{i}} \quad (\text{h/mm})$$

PDF of interevent time, b

$$f_B(b) = \psi e^{-\psi(b-IETD)}, \quad b \geq IETD \quad \text{where } \psi = \frac{1}{\bar{b} - IETD} \quad (\text{h}^{-1})$$

where $\bar{v}$, $\bar{t}$, $\bar{i}$, and $\bar{b}$ are the mean event rainfall volume, duration, intensity and interevent time, respectively.

In the derivation of the analytical probabilistic models, these rainfall variables are assumed independent and the joint PDF of V, B, T, $f_{V,B,T}(v,b,t)$, is given by the product of their marginal distributions as follows:

$$f_{V,B,T}(v,b,t) = f_V(v)\, f_B(b)\, f_T(t) = \zeta\lambda\psi e^{-\lambda t - \psi(b-IETD) - \zeta v}$$

The model of the drainage system is illustrated by the figure below:

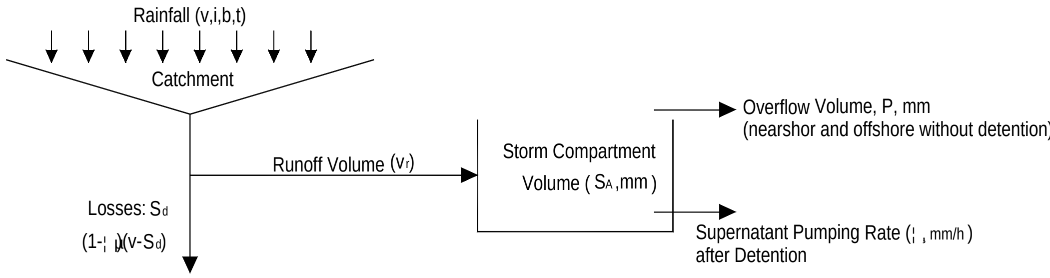


***Figure 6.1:*** Schematic model of urban drainage system

The catchment transforms the rainfall volume, v (mm), to runoff volume, $v_r$ (mm) according the following relationship:

$$v_r = \begin{cases} 0, v \le s_d \\ \phi(v - s_d), v > s_d \end{cases}$$

where: $S_d$ is the depression storage of the catchment (mm)

$\phi$ is the runoff coefficient

The time histories of the different cases in the operation of the Maclean Avenue detention tank are illustrated in Figure 6.2. The most conservative condition, that the tank is full at the end of the preceding rainfall event, is considered here in the model derivation. The 400m off-shore overflow which is pumped out by the storm pump without detention is viewed as an overflow. The modeling in this chapter only considers the performance of the storm compartment of the Maclean Avenue tank, since the quantity data on the CSO tank was not obtained in this study.

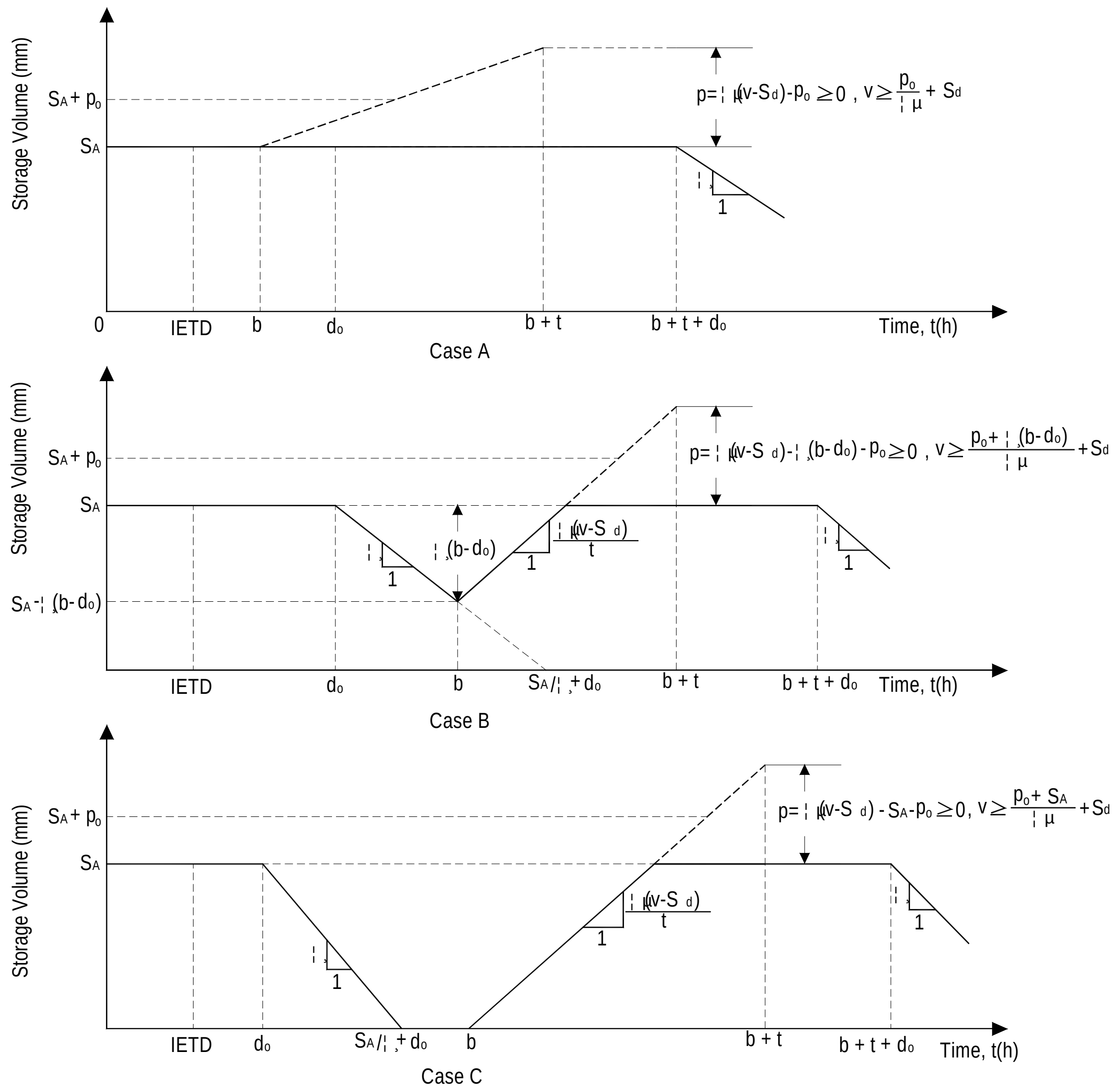


***Figure 6.2:*** Time histories of the tank contents.

$d_0$ is the detention time which is 8 hours for the Maclean Avenue tank.
Case A: Tank is full when subsequent event occurs; IETD≤b≤$d_0$.
Case B: Tank is partly drained at the onset of the subsequent event; IETD≤$d_0$ ≤b≤$S_A/\Omega+d_0$.
Case C: Tank is completely drained at the beginning of subsequent event; IETD≤$d_0$≤$S_A/\Omega+d_0$≤b.

The probability per rainfall event of an overflow volume equaling or exceeding a value $p_0$, $G_p(p_0)$, is derived as follows: (IETD is simplified to equal 0 for this derivation)

$$G_p(p_0) = \int_{t=0}^{\infty}\int_{b=0}^{d_0}\int_{v=\frac{p_0}{\phi}+s_d}^{\infty} f_{V,B,T}(v,b,t)dvdbdt + \int_{t=0}^{\infty}\int_{b=d_0}^{\frac{S_A}{\Omega}+d_0}\int_{v=\frac{p_0+\Omega(b-d_0)}{\phi}+s_d}^{\infty} f_{V,B,T}(v,b,t)dvdbdt$$

$$+\int_{t=0}^{\infty}\int_{b=\frac{S_A}{\Omega}+d_0}^{\infty}\int_{v=\frac{p_0+S_A}{\phi}+S_d}^{\infty} f_{V,B,T}(v,b,t)dvdbdt$$

$$= e^{-\zeta\left(\frac{p_0}{\phi}+s_d\right)-\psi d_0}\left[e^{\psi d_0} - 1 + \frac{\psi + \frac{\zeta\Omega}{\phi}e^{-S_A\left(\frac{\psi}{\Omega}+\frac{\zeta}{\phi}\right)}}{\psi + \frac{\zeta\Omega}{\phi}}\right] \quad (6.1)$$

A particularly useful expression is the probability per rainfall event that a overflow of any magnitude ($p_0$ >0) will occur, $G_p(0)$, which can be obtained by substituting $p_0$=0 into Equation 6.1.

Then, the average annual overflows number $n_s$ is:

$$n_s = \theta\, G_p(p_0) \quad (6.2)$$

where θ is the average annual number of rainfall events.

The expected value of overflow volume per rainfall event, E[P], is given by

$$E[P] = \frac{\phi}{\zeta} G_p(0) \quad (6.3)$$

The average annual overflow volume, $P_u$, is given by

$$P_u = \theta \frac{\phi}{\zeta} G_p(0) \quad (6.4)$$

In order to apply the derived model to evaluate the Maclean tank performance, the parameters in the model have to be chosen properly.

The long-term rainfall data of the Toronto Bloor Street rain gauge station is used here. Since the long-term performance evaluation is the aim of this study, the meteorological characteristics of the Bloor Street rain gauge station are considered to represent the Maclean Avenue tank drainage area. The Maclean tank drainage area is 114ha, thus, an IETD=2h is reasonable. Then, the statistical parameters of rainfall data are (Adams and Papa, 2000):

$\zeta$=0.193, $\psi$ = 0.0142, $\lambda$=0.288, $\theta$ = 89.4

Since the Bloor Street rain gauge data is from March to November, θ, the average annual number of rainfall events, is the number of rainfall events occurring from March to November. Thus, only the events occurring in the Maclean Avenue tank catchment from March to November are involved in the model predictions.

Analysis of the 1996 data shows that the maximum rainfall volume that did not generate any runoff (no data recorded in the tank) was 0.5mm. Thus, the depression storage, $S_d$ is selected to equal 0.5mm for the analytical model.

In order to obtain an appropriate value of the runoff coefficient, $\phi$ , reference is made to the QQS model input. The QQS model inputs for the design of the tank provided by the City staff are shown in Table 6.2.

***Table 6.2:*** QQS Model Inputs for the Maclean Avenue Tank Storm Compartment

| QQS area code | S324 | S325 | I321 | S323 | S326 | S347 | S341 | S348 | S34G |
|---|---|---|---|---|---|---|---|---|---|
| Area (ha) | 14.41 | 15.66 | 6.35 | 12.35 | 16.94 | 24.71 | 4.32 | 9.84 | 9.31 |
| Imperviousness | 0.288 | 0.364 | 0.364 | 0.256 | 0.212 | 0.190 | 0.220 | 0.301 | 0.696 |

The total drainage area is 114ha, and the average imperviousness is 0.30 calculated from the data in Table 6.3. At the same time, by checking the rain gauge data records of the Kew Beach station and the water depth variation curves in the tank during the rainfall events in 1996, there are 4 events which are qualified to calculated the runoff coefficient, occurring on April 19, April 20, July 30, and October 30. The runoff coefficients calculated from these 4 events are 0.273, 0.282, 0.2276, and 0.282 respectively. The average is 0.27. Thus, runoff coefficient equaling to 0.27 is applied in the analytical model.

The storm compartment storage volume is calculated from the elevation 69.68m at which the pump shuts down from pumping the dry weather flow and supernatant, to the elevation 75.24m at which the storm pump starts to pump excess runoff inflow during the event; the resulting storage is $4900m^3$. Normalizing the tank storage over the drainage area (114ha) yields $S_A$=4.3mm. The value of Ω in the model is the pumping rate ($1059m^3/h$ = 0.9289mm/h) and the detention time $d_o$ = 8 hr.

By substituting these values into Equations 6.1 and 6.2, $n_s$=13.3, which is the average annual number of overflows based on the long term rainfall data record applied to the Maclean Avenue tank.

There is a total of 5 years of data available on the Maclean tank: 1995, 1996, 1997, 1998, and 1999. The numbers of overflows from the storm compartment to the Lake is counted and tabulated in Table 6.3.

***Table 6.3:*** Overflow Events Occurring in Storm Compartment

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| March– November | 10 | 15 | 8 | 8 | 10 |
| December – February | 1 | 7 | 1 | 3 | 2 |

Since the long-term rainfall data of the Bloor Street station is recorded from March to November, the overflow events that occurred in this time period are counted for comparison. An average of 10.2 per year is calculated from these five years of data from March to November. Both the model prediction and the 5 years of observed data show that the year 1996 might be a relatively wet year with 15 overflows from March to November and 22 in the entire year.

Based on the original design of the tank, the CSO compartment is to be eventually converted to collect stormwater when the entire storage capacity of the tank, $8000m^3$, would treat storm runoff only. Also, the results of this study show that the performance of the tank is far from achieving the original design objectives. Thus, optimization of the tank performance is needed both for the current condition and the ultimate stage of the tank operation. The analytical probabilistic models are used to evaluate possible operation scenarios for the tank both in the current condition and in the future.

There are a few variables which determine the performance of the system: the tank storage volume, $S_A$; the pumping rate, $\Omega$; the detention time, $d_o$; the characteristics of the drainage area ($\phi$, $S_d$); the particle size distribution in the runoff, etc. Among these parameters, the pumping rate and the detention time are the most flexible parameters to optimize the system performance with both the current tank storage volume and the future tank storage volume. The average annual overflow number, $n_s$, is considered here to represent the tank performance. Three scenarios are evaluated below.

Scenario 1: Optimize the pumping rate and the detention time for the current tank storage volume, $S_A$ = 4.3mm.

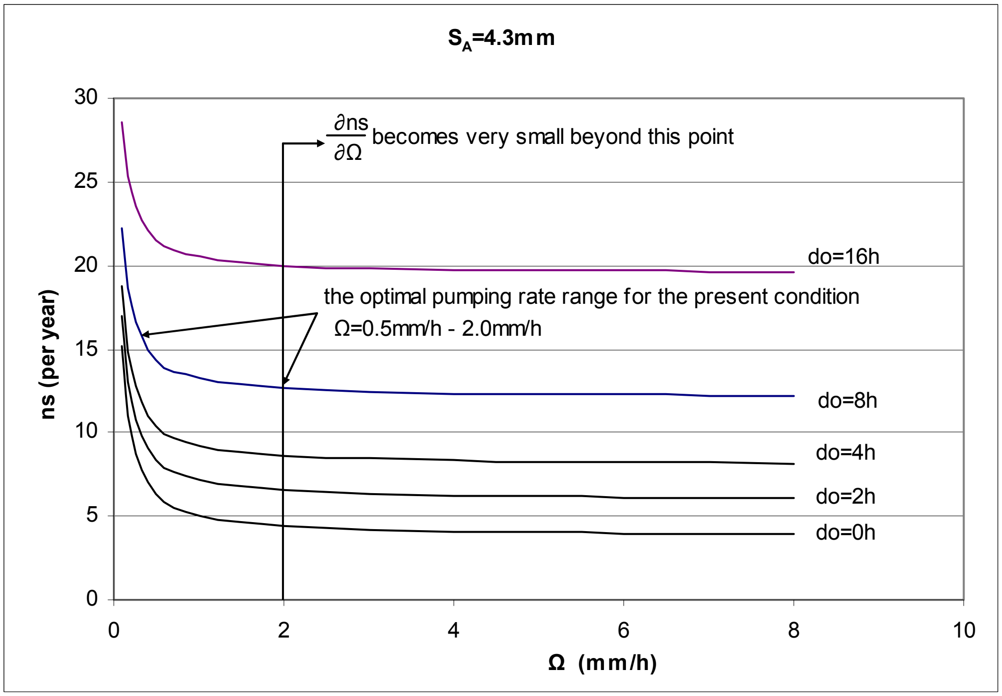


***Figure 6.3:*** Model Predictions for the Current Tank Storage Volume

Several alternative detention times (0, 2h, 4h, 8h, and 16h) are tested for the current storage volume. The curves of overflow number corresponding to variations in pumping rate are shown in Figure 6.3. Regardless of the detention time, when the pumping rate increases beyond about 2.0mm/h, there is no obvious improvement in the system performance as illustrated in the graph. With the current detention time of 8 hours, when the pumping rate is increased to 2.0mm/h, the average annual number of overflows decreases to 12.5 per year. Recalling the modeling results for the current operation stage ($S_A$=4.3mm, $\Omega$ = 0.97mm/h, $d_0$ = 8hr), $n_s$= 13.3. The detention time of the tank is a key factor in determining the TSS removal efficiency in the settling process. Longer detention times mean better pollutant removal, but at the same time, also cause more overflow events; consequently, the overall performance of the system will be affected. The system performance analysis conducted in Chapter 5 also verified this mechanism: the TSS removal for the tank itself reaches 53.2% for the average event performance, but the entire system performance is 26.3% when the overflow influence is considered. Thus, an optimal detention time has to be determined, which requires a more comprehensive analysis of the entire system. Optimization of the detention time will be conducted in future research of the authors.

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Scenario 2: Optimize the system performance for the future tank storage volume, $S_A$=8.6mm.

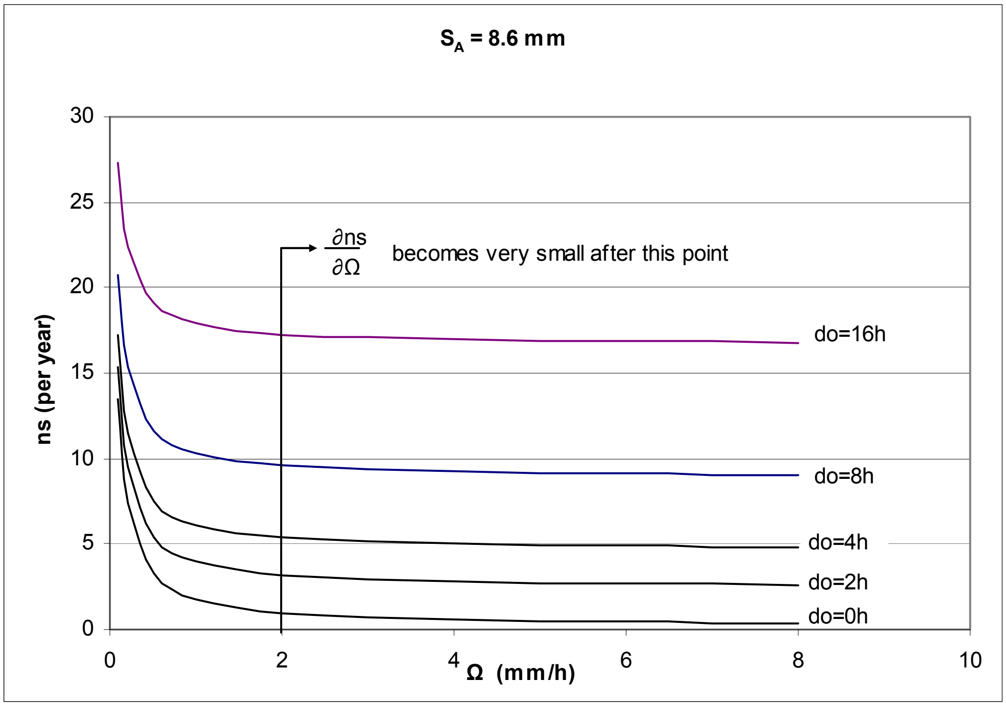


***Figure 6.4:*** Model Predictions for the Future Tank Storage Condition

Figure 6.4 illustrates the tank performance corresponding to changes in pumping rate for different detention times when the storm tank storage volume is doubled. The curve shapes are similar to those in Figure 6.3. After the pumping rate exceeds about 2mm/h, the tank performance is not sensitive to an increase in Ω for any detention time. If the same pump is used in the future (Ω = 0.97mm/h), $n_s$=10.4. The design target in the final stage, that the number of overflows to the Lake is 2 per year, would not be reached according to the modeling results. A possible way to achieve the design objective is to vary the detention time.

The tank performance analysis conducted in Chapter 5 shows that the TSS removal reaches 53.2% in the tank scenario under an 8 hour detention time. If this removal is acceptable and the tank storage volume is possible to change, optimizing the tank storage volume ($S_A$) is also of interest. Another scenario is modeled here to optimize the tank storage under the 8-hour detention time.

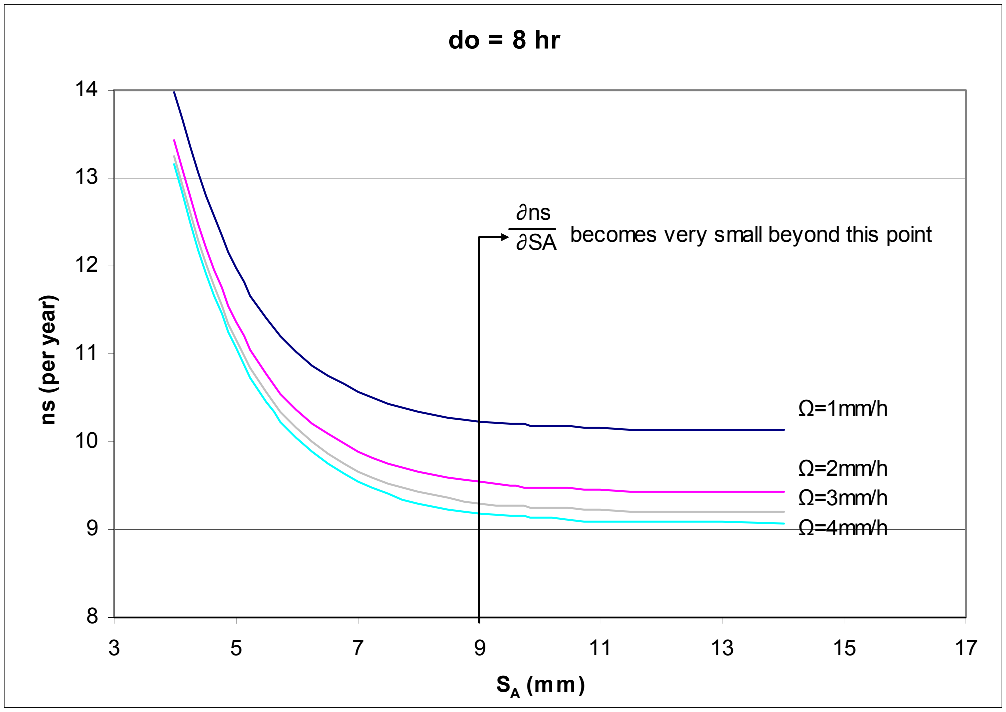


***Figure 6.5*****:** Model Predictions for the Current Detention Period

Figure 6.5 illustrates that tank storage volumes greater than 9mm do not substantially improve the system performance. Also, after pumping rate exceeds 2mm/h, increasing the pumping rate does not substantially decrease the number of overflows; this phenomenon is also observed in the analysis of Scenario 2.

The modeling results for the three scenarios show that the optimal operation condition for the future stage ($S_A$ = 8.6mm) might be to double the pumping capacity, Ω to 2mm/h, and if the detention time remains at 8 hours, then $n_s$ = 9.6.

The above prediction is based on the analytical probabilistic model of the Maclean Avenue tank operation. Future research will pursue a more comprehensive optimization of the system with the analytical models. It is suggested that the City staff further investigate these findings with QQS simulation studies.

# 7.0 REFERENCES

1. Adams, B.J., Papa, F., Urban Stormwater Management Planning with Analytical Probabilistic Models, John Wiley & Sons, Inc., NY, 2000.
2. Gore & Storrie Limited, MacViro Consultants Inc., Design Report of Eastern Beaches Maclean Avenue Detention Tank, April 1993 (a).
3. Gore & Storrie Limited, MacViro Consultants Inc., Eastern Beaches Maclean Avenue Detention Drawings, June 1993(b).

# APPENDIX A

# Historical Context of the SWAMP Program

# HISTORICAL CONTEXT OF THE SWAMP PROGRAM

In the latter part of the 20th century, the Great Lakes Basin experienced rapid urban growth. Stormwater runoff associated with this growth has been identified as a major contributor to the degradation of water quality and the destruction of fish habitats. In response to these concerns, a variety of stormwater management programs have been developed in the Great Lakes basin.

A number of complementary programs have been established at the international, national, provincial and municipal levels to protect the Great Lakes ecosystem. The SWAMP program and the study that is the subject of this report are parts of the overall effort.

## International Joint Commission

The International Joint Commission (IJC) prevents and resolves disputes between the United States of America and Canada under the Boundary Waters Treaty of 1909. The IJC pursues the common good of both countries as an independent and objective advisor of the two governments.

In particular, the IJC rules upon applications for approval of projects affecting boundary or transboundary waters and may regulate the operation of these projects; it assists the two countries in the protection of the transboundary environment. Among the responsibilities of the IJC is the implementation of the Great Lakes Water Quality Agreement.

## Great Lakes Water Quality Agreement

The first Great Lakes Water Quality Agreement (GLWQA) between Canada and the United States was signed in 1972 in recognition of the urgent need to improve environmental conditions in the Great Lakes. The focus of the agreement was to improve water quality through pollution control programs. Objectives included the reduction of nuisance conditions and control of toxic substances. Specific numerical targets were included for the reduction of phosphorus loadings.

The Great Lakes Water Quality Agreement was amended in 1978 to include the objective of controlling persistent toxic substances. The new agreement also incorporated the ecosystem approach to environmental management.

In 1987, the Canadian and U.S. governments signed a protocol that identified local Areas of Concern (AOC's) where beneficial uses of the ecosystem had been significantly degraded. Remedial Action Plans (RAP's) were to be prepared by various levels of government for the AOC's. The plans would contain strategies to clean up problem areas in the Great Lakes region. In addition, the 1987 protocol included annexes addressing specific subjects such as non-point contaminant sources and contaminated sediments.

In total, 43 Areas of Concern were identified throughout the Great Lakes basin. Of the total, 17 AOC's were in Canada.

## Great Lakes Sustainability Fund

The Canadian federal government's commitment to the Great Lakes ecosystem was initially managed through the Great Lakes Action Plan (GLAP). In 1990, the Great Lakes Cleanup Fund (GLCuF) was created to provide support for environmental projects designed to benefit the Great Lakes basin ecosystem.

In 1994, GLAP was replaced by the Great Lakes 2000 Program. GLCuF was extended and renamed the Great Lakes 2000 Cleanup Fund. In 2000, the Great Lakes Basin 2020 Action Plan was introduced in addition to the successor to the GLCuF, the Great Lakes Sustainability Fund (GLSF). The new plan and fund place priority on the restoration of environmental quality in Canada's remaining 16 Areas of Concern.

The GLSF supports the implementation of remedial actions falling within federal responsibilities that will lead to the restoration of beneficial uses in the Canadian Great Lakes Areas of Concern. The five-year, $30 million GLSF builds on past successes and is administered by Environment Canada on behalf of eight Government of Canada departments.

To restore these beneficial uses in the Great Lakes Areas of Concern, joint Canada-Ontario teams work in consultation with local Public Advisory Committees to develop Remedial Action Plans (RAPs) aimed at eliminating or reducing the major sources of contamination in these areas. When all beneficial uses in an AOC have been restored, the area is delisted. The RAPs have had some important successes. Collingwood Harbour was delisted in 1994, and Spanish Harbour was designated an Area of Recovery in 1999.

## Canada – Ontario Agreement

Canada and Ontario have had Great Lakes environmental agreements in effect since 1971. The latest version of the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) was signed in June, 2002. The agreement provides the framework for systematic and strategic coordination of shared federal and provincial responsibilities for environmental management in the Great Lakes basin. The main objectives are to restore degraded areas, to prevent and control pollution, and to conserve and protect human and ecosystem health.

## Ontario Ministry of the Environment

The Ontario Ministry of the Environment (OMOE) manages a number of programs that contribute to the protection and clean-up of the Great Lakes basin. The Provincial Water Protection Fund assists municipalities to address water and sewage treatment problems and to undertake related studies. The Ontario Great Lakes Renewal Foundation, established in 1998, provides seed money to support local projects that include habitat restoration and stormwater management. The OMOE works in partnership with federal and state agencies and municipal governments to achieve numerous environmental goals; the Great Lakes Remedial Action Plans have been a prominent example of such work.

## Toronto and Region Conservation Authority

The Toronto and Region Conservation Authority (TRCA) is one of 38 conservation authorities in Ontario that develop and implement programs for the management of water and natural resources on a watershed basis. Conservation authorities are created and given their mandate under the Conservation Authorities Act and involve a partnership of the municipalilties within a watershed and the Province of Ontario. The TRCA jurisdiction includes nine watersheds in the Toronto Region.

The TRCA and the Waterfront Regeneration Trust are the local coordinating agencies for the Toronto and Region Remedial Action Plan. The two agencies help the provincial and federal governments fulfill their obligations under the Great Lakes Water Quality Agreement and Canada-Ontario Agreement. The TRCA's general RAP role is to focus implementation activities on an individual watershed basis and provide technical expertise to its implementation partners. Stormwater management and the remediation of combined sewer overflows are integral to the restoration of the Toronto and Region Area of Concern.

## SWAMP

In 1995, the Storm Water Assessment Monitoring and Performance Program (SWAMP) was created as a cooperative initiative of agencies interested in monitoring and evaluating the performance of various stormwater management technologies. The SWAMP program acts as a vehicle whereby federal, provincial, municipal and other interested agencies can pool their resources in support of shared research interests.

The objective of SWAMP is to collect data and report on the performance of stormwater treatment facilities. SWAMP is supported by the Great Lakes Sustainability Fund, the Ontario Ministry of the Environment, the Toronto and Region Conservation Authority, the Municipal Engineers Association, a number of individual municipalities in Great Lakes Areas of Concern, and other owner/operator agencies.

A variety of stormwater management technologies have been developed to mitigate the impacts of urbanization on the natural environment. Prior to the creation of SWAMP, these technologies had been studied using computer models and pilot-scale testing, but had not undergone extensive field-level evaluation in southern Ontario.

The objectives of the SWAMP Program are:

- to monitor and evaluate the effectiveness of new or innovative stormwater management technologies,
- to disseminate study results and recommendations within the stormwater management community.

Technologies that have been addressed by the SWAMP program include:

- wet ponds and constructed wetlands,
- underground storage tanks,
- flow balancing systems,
- oil and grit separators,
- conveyance exfiltration systems.

A number of people have been part of the SWAMP team since the inception of the program. In alphabetical order, the staff members are or were:

David Averill Program Coordinator [July 2001 to May 2003]
David Fellowes
Dajana Grgic
Weng-Yau Liang Program Coordinator [1995 to 2000]
Serge Ristic
Derek Smith
Sheldon Smith
William Snodgrass Program Coordinator [December 2000 to June 2001]
Michael Thompson
Tim Van Seters

In addition, several student employees contributed to the success of the projects. Staff of the Ontario Ministry of Environment and Energy, Standards Development Branch, provided administrative and facility support. In addition, Standards Development Branch staff have contributed their technical expertise through informal advice and review of draft reports.

**Contacts**

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Toronto and Region Conservation Authority
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Email: Tim_Van_Seters@trca.on.ca

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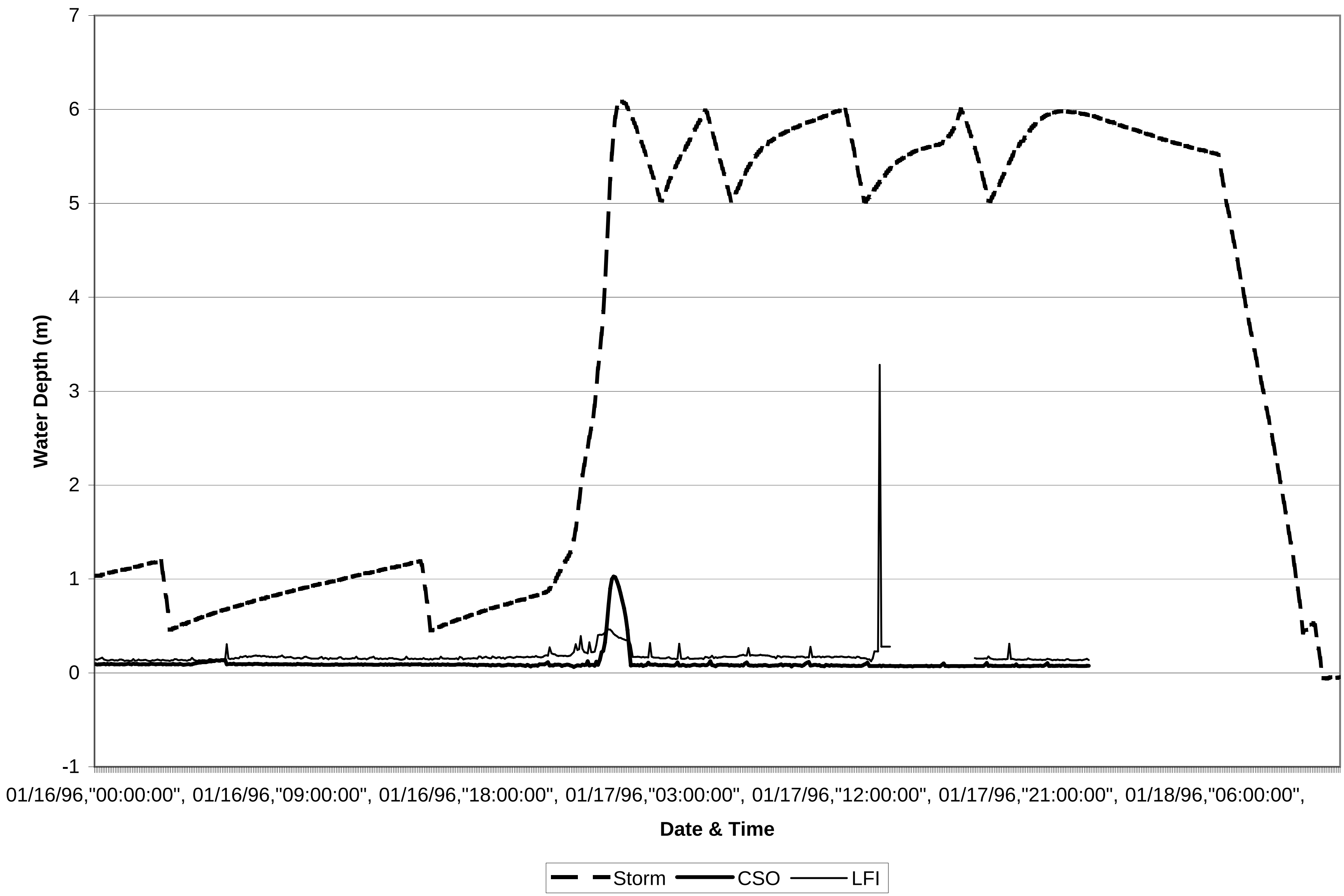
Environment Canada
Great lakes Sustainability Fund
Phone: 905-336-6281
Fax: 905-336-6272
Email: Sandra.Kok@ec.gc.ca

# APPENDIX B

# Graphs of tank water level variations during runoff events in 1996



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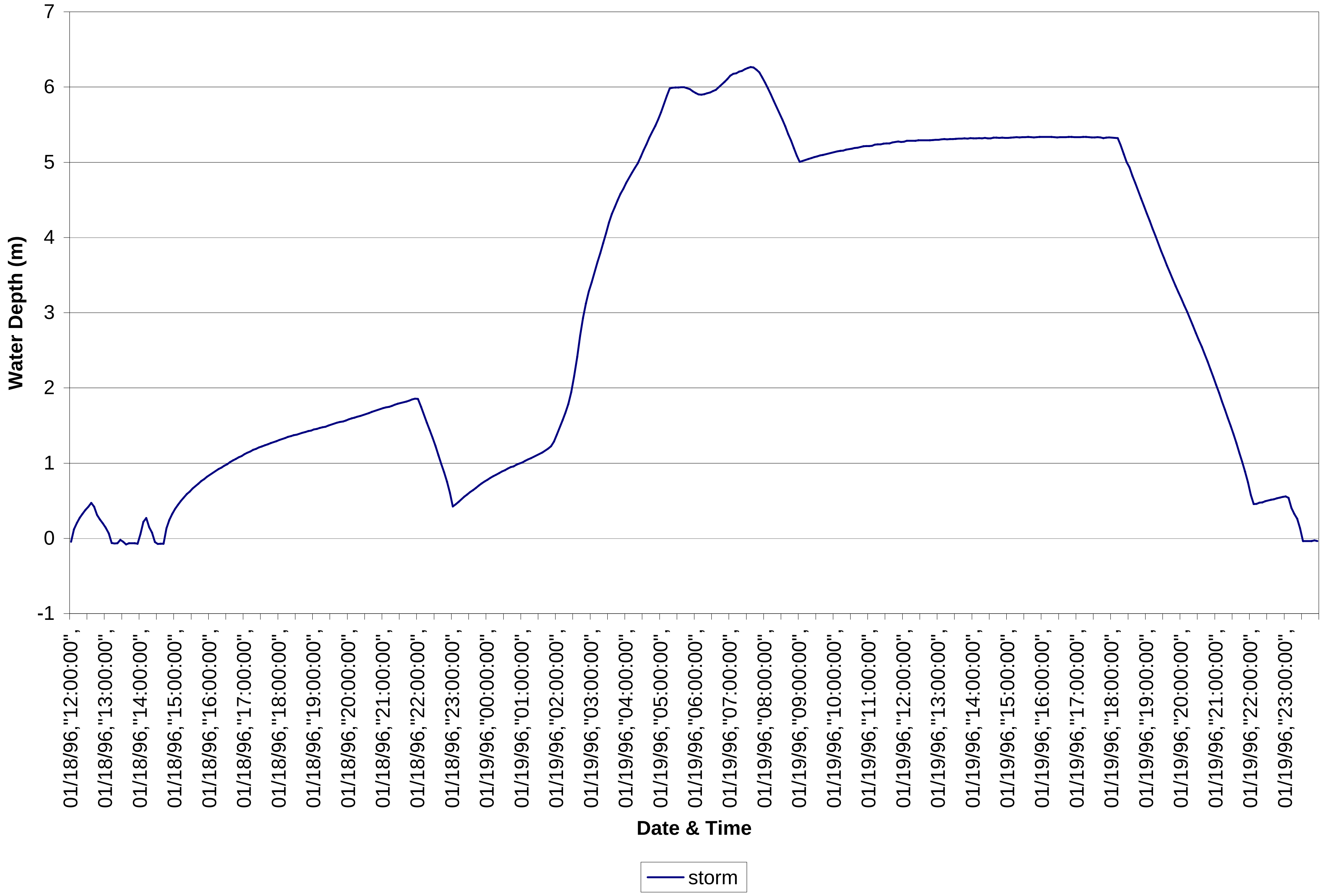
Storm
CSO
LFI



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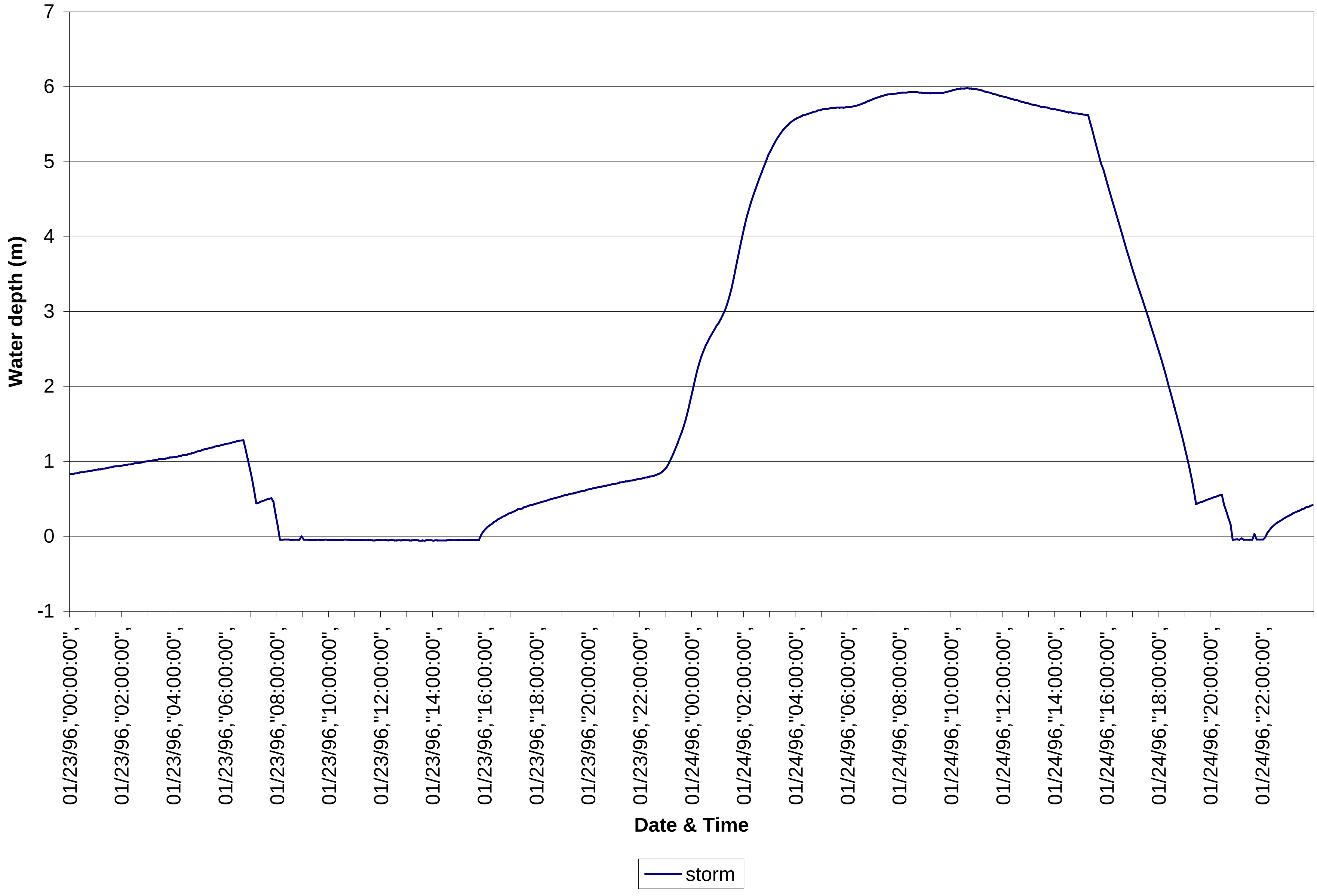
Date & Time
storm



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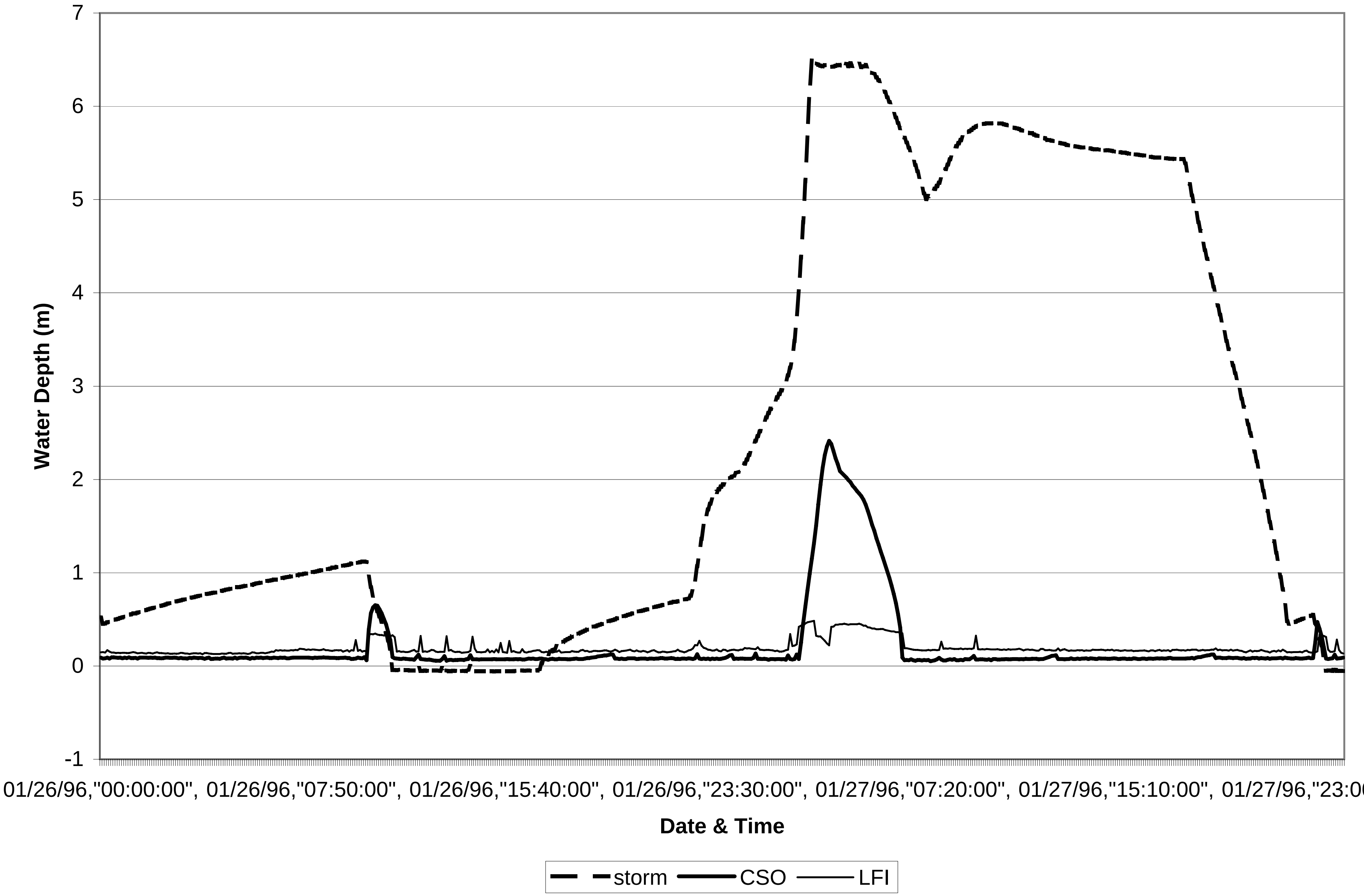

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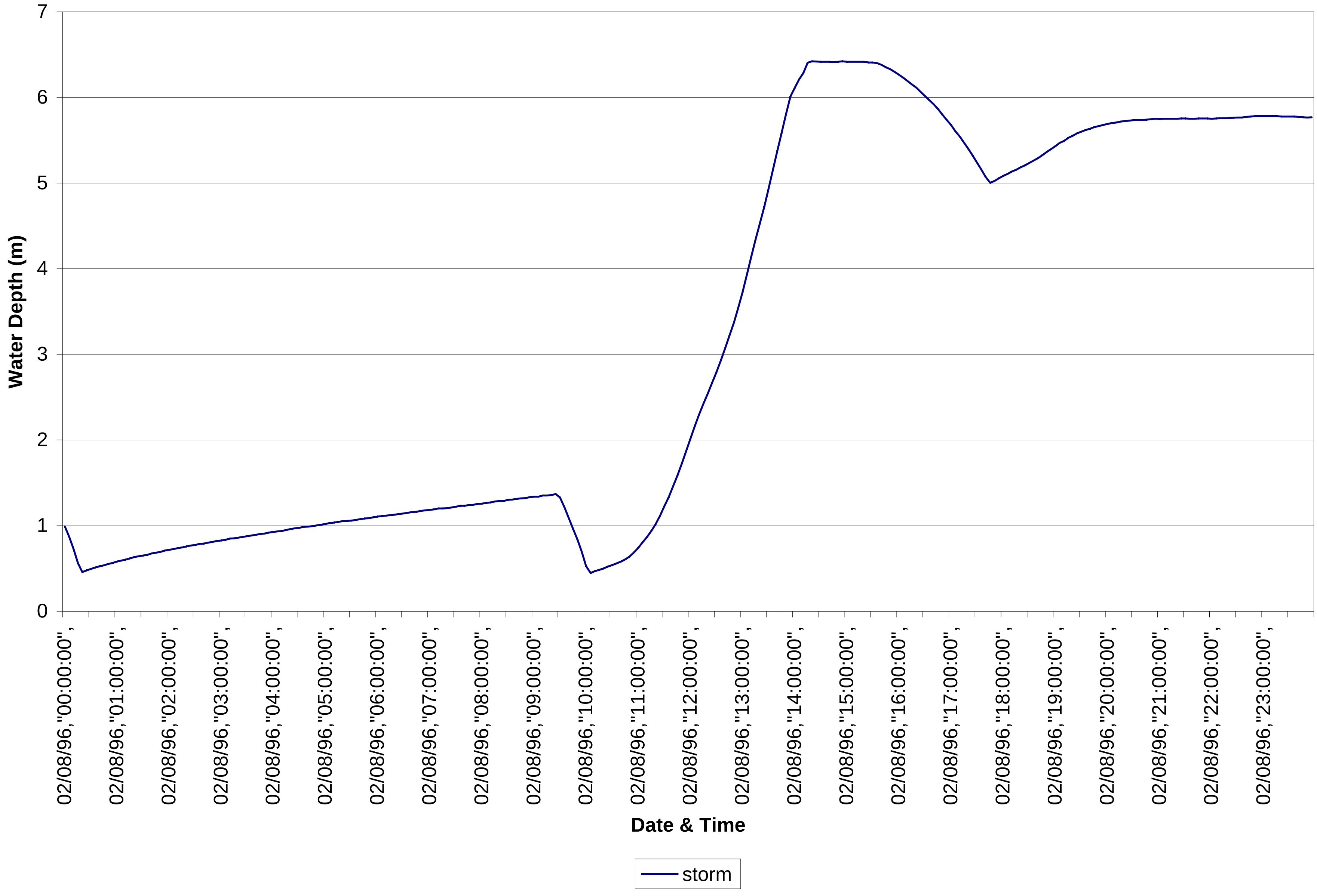
Date & Time
storm
CSO
LFI



Water Depth (m)
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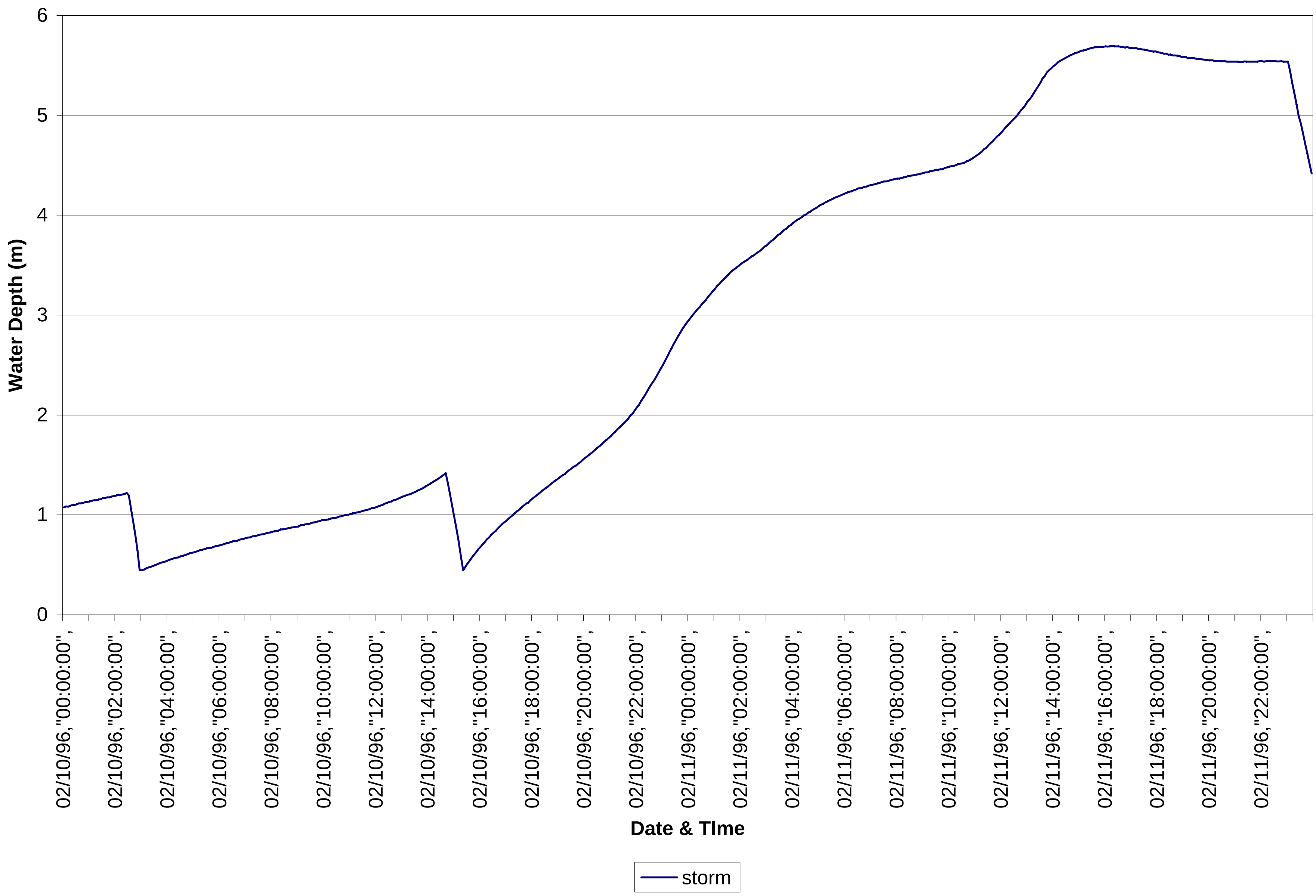
storm



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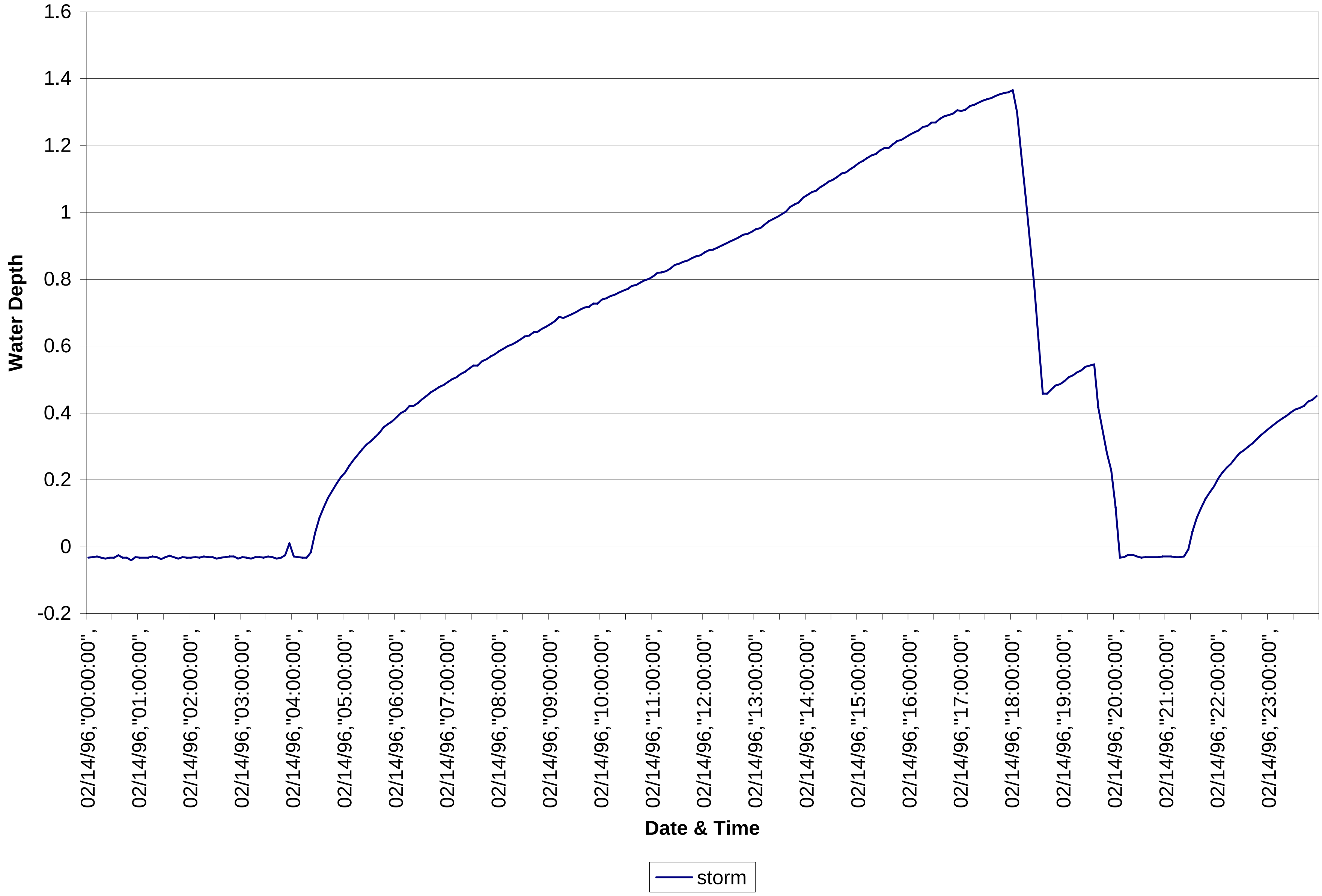

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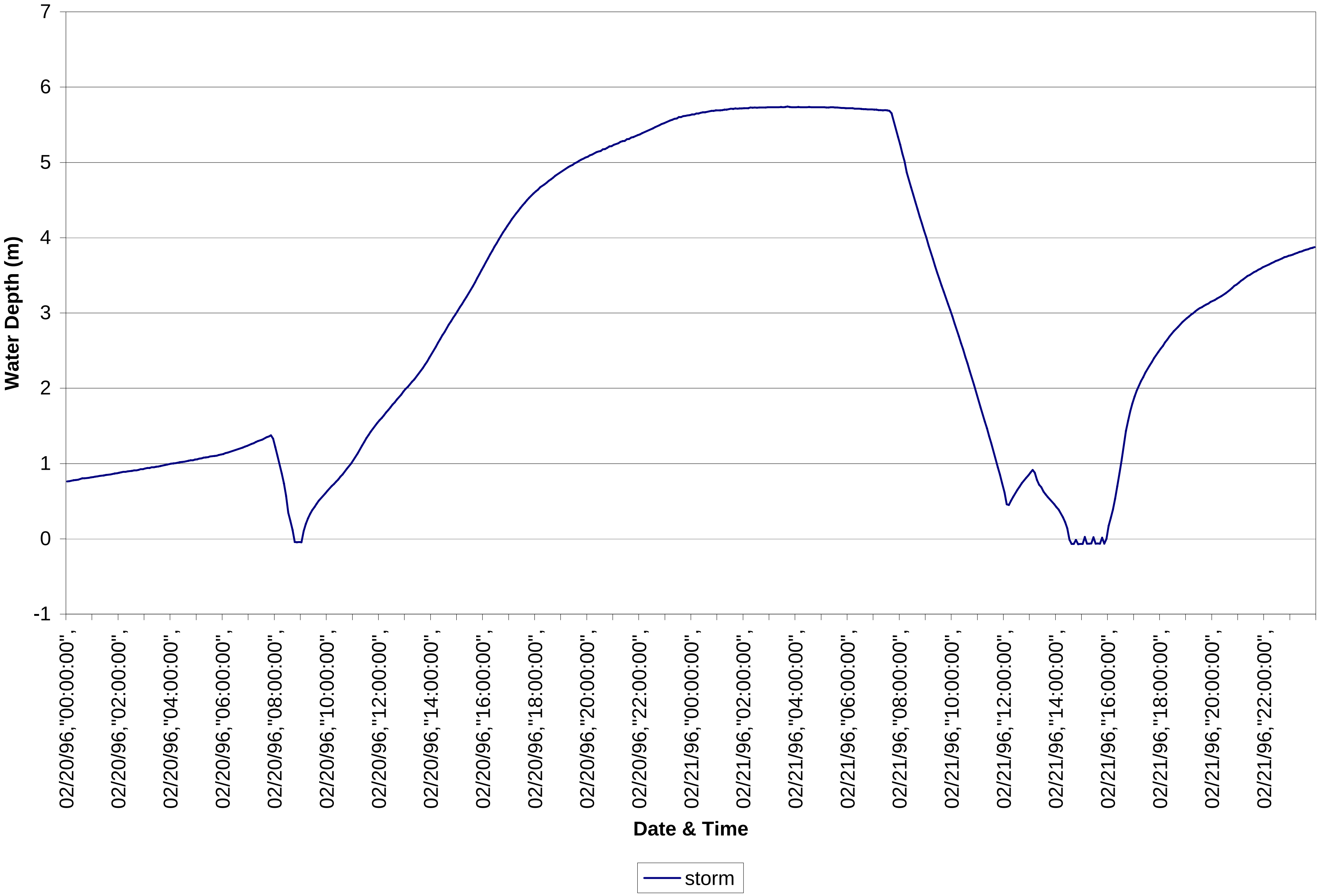

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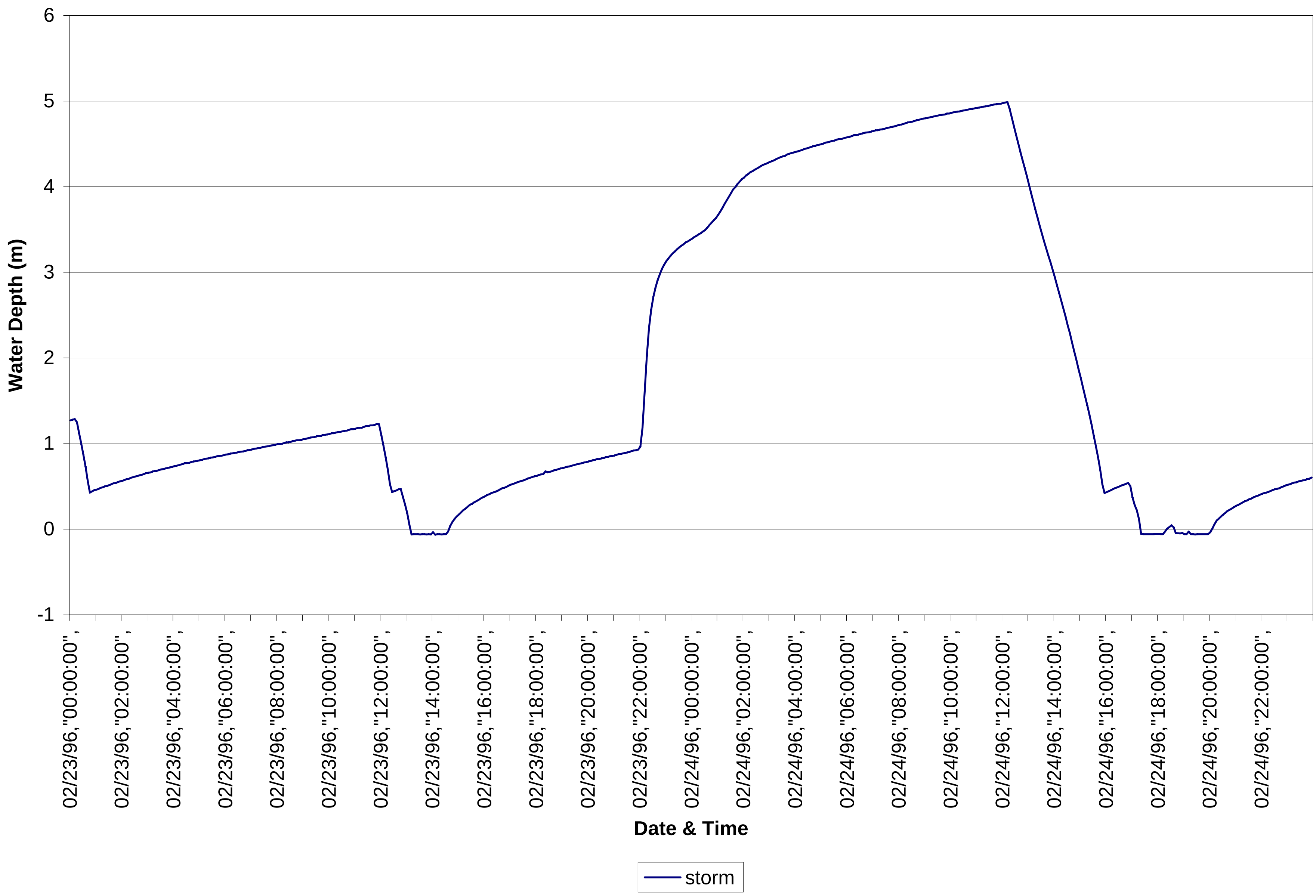

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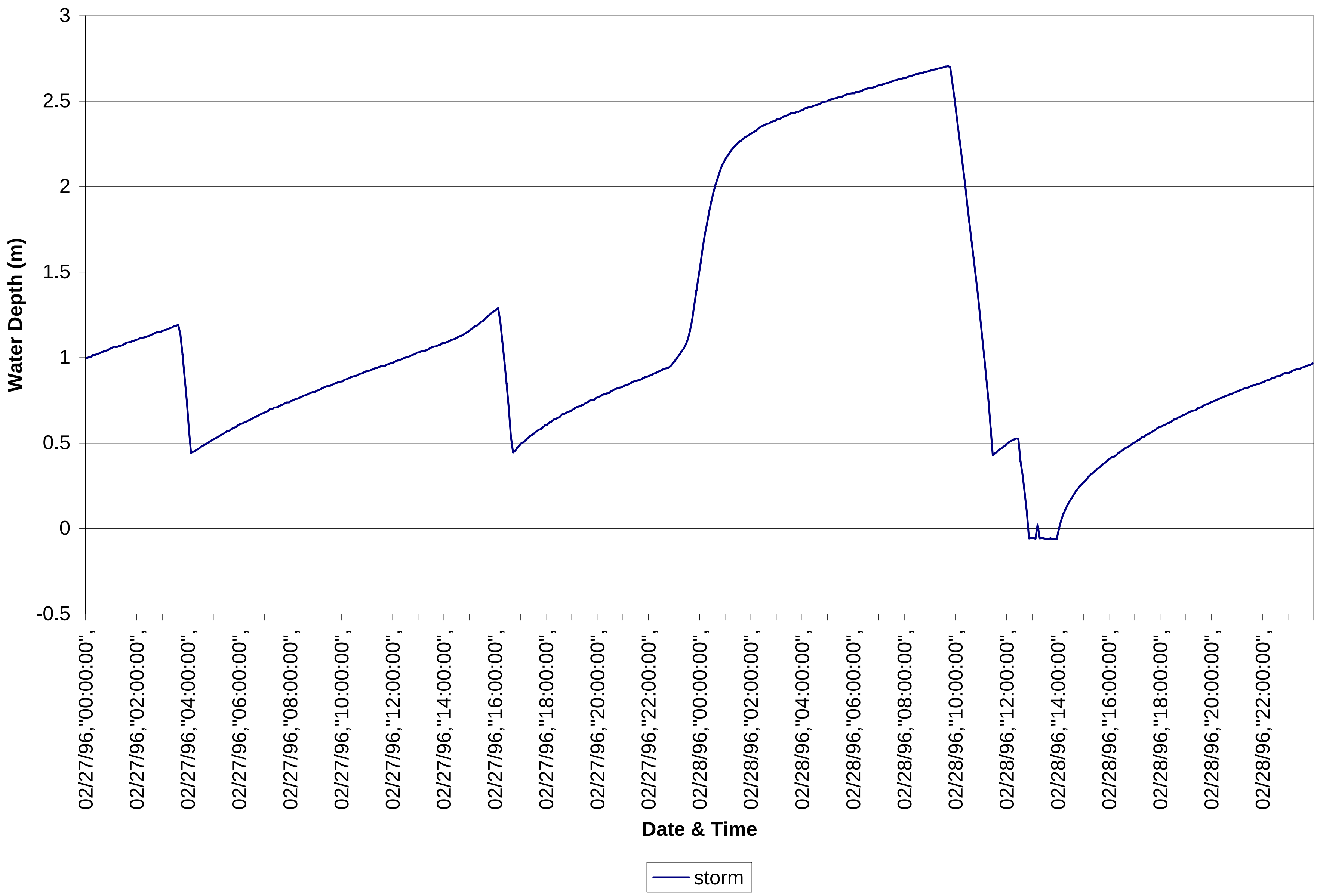

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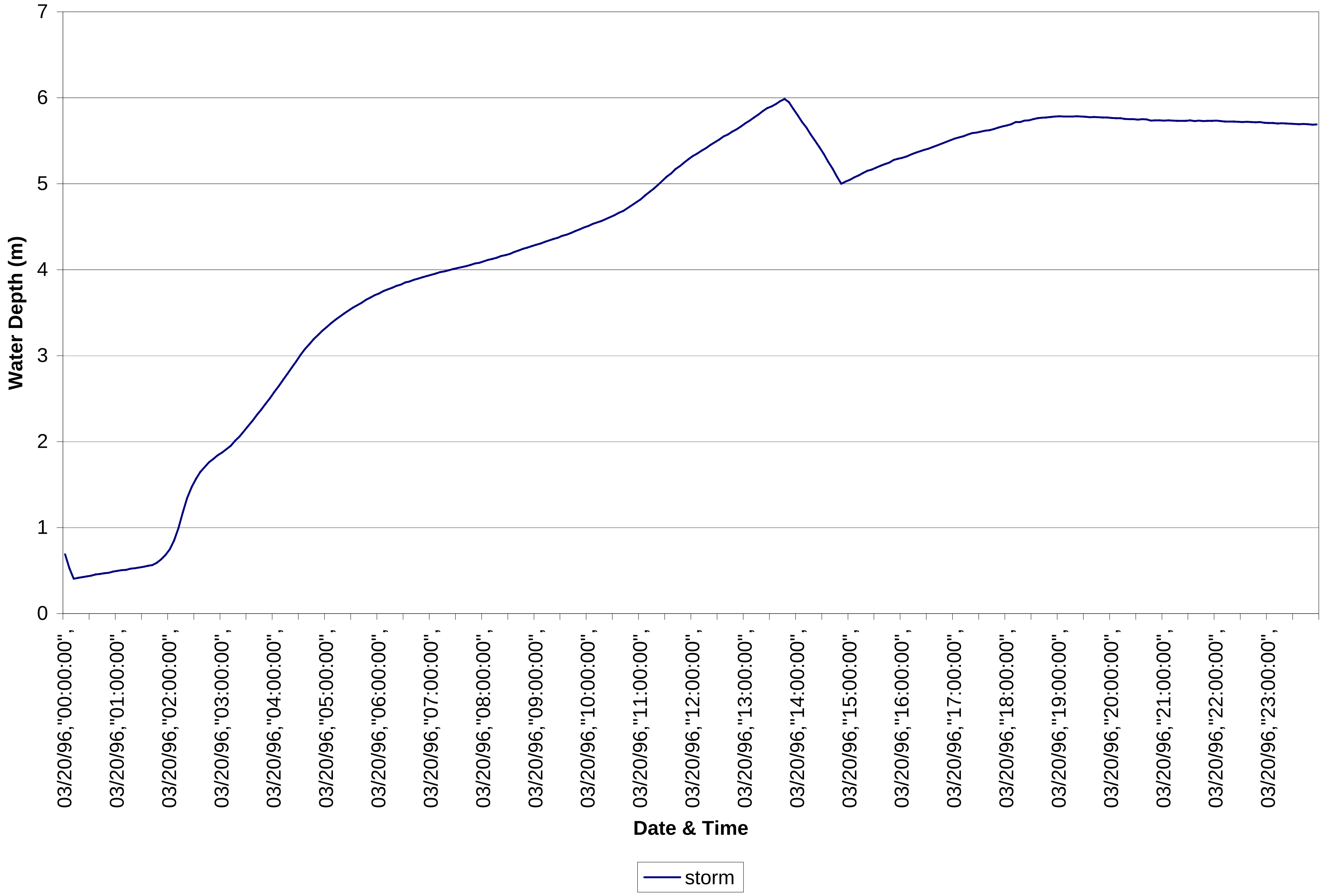

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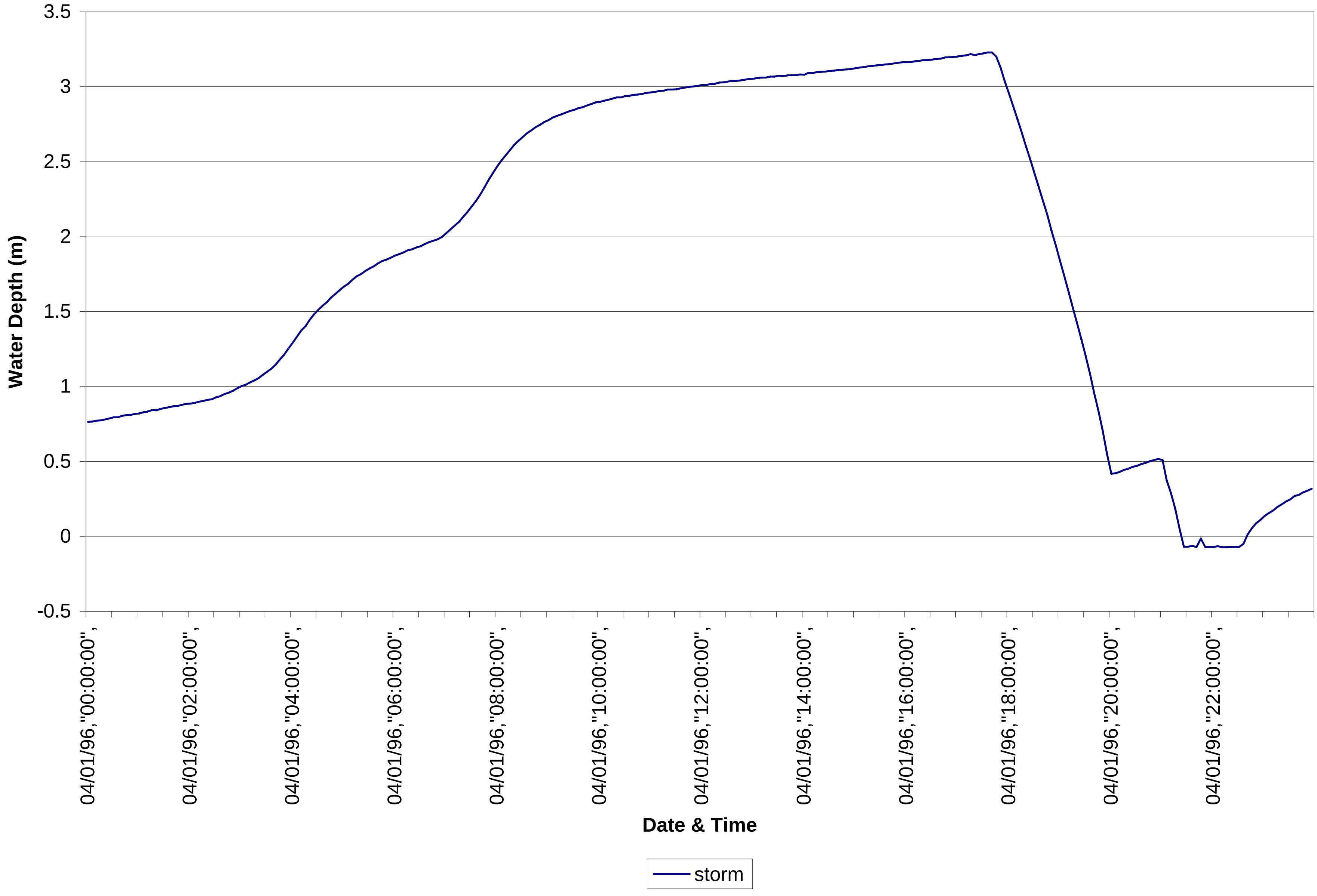

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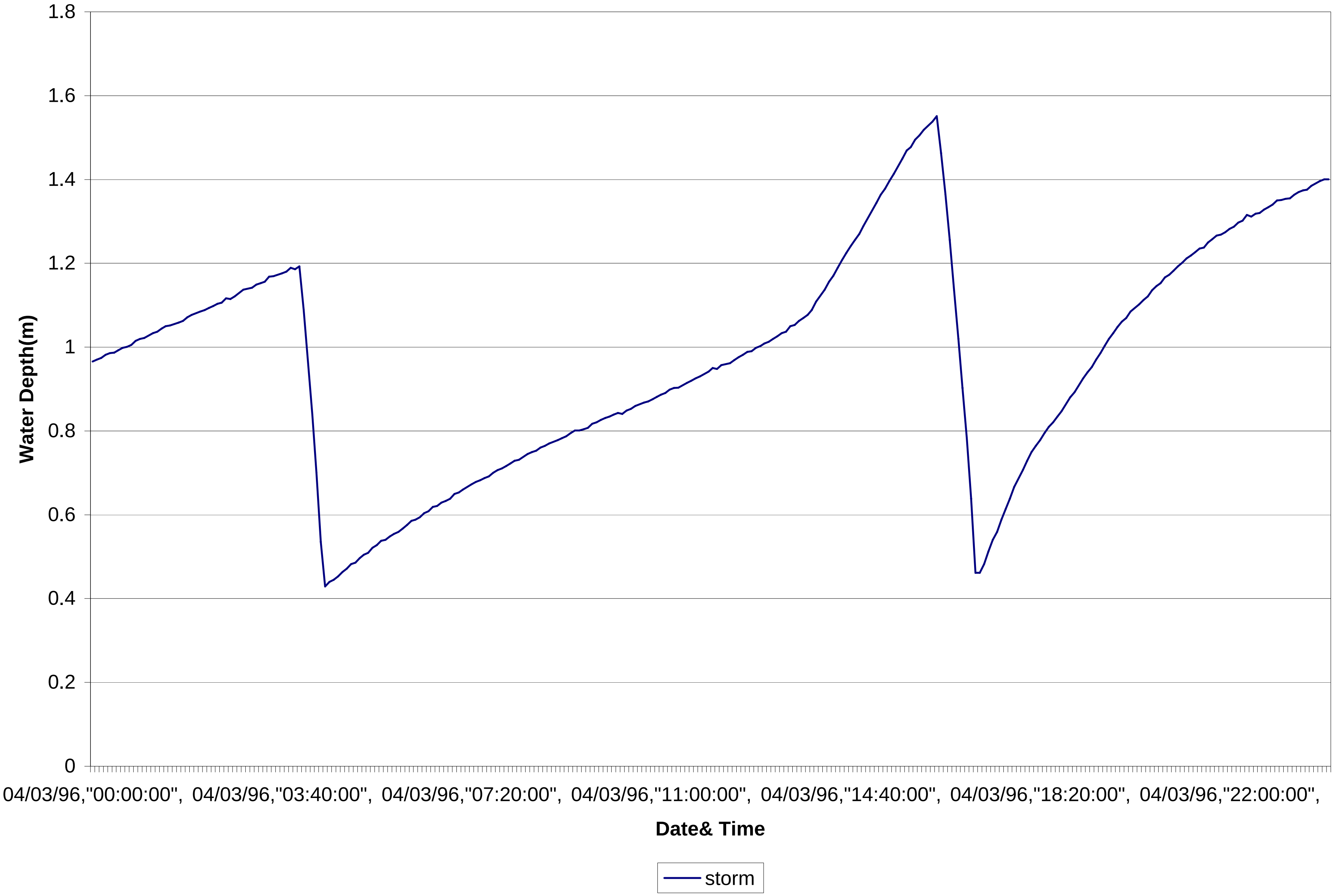

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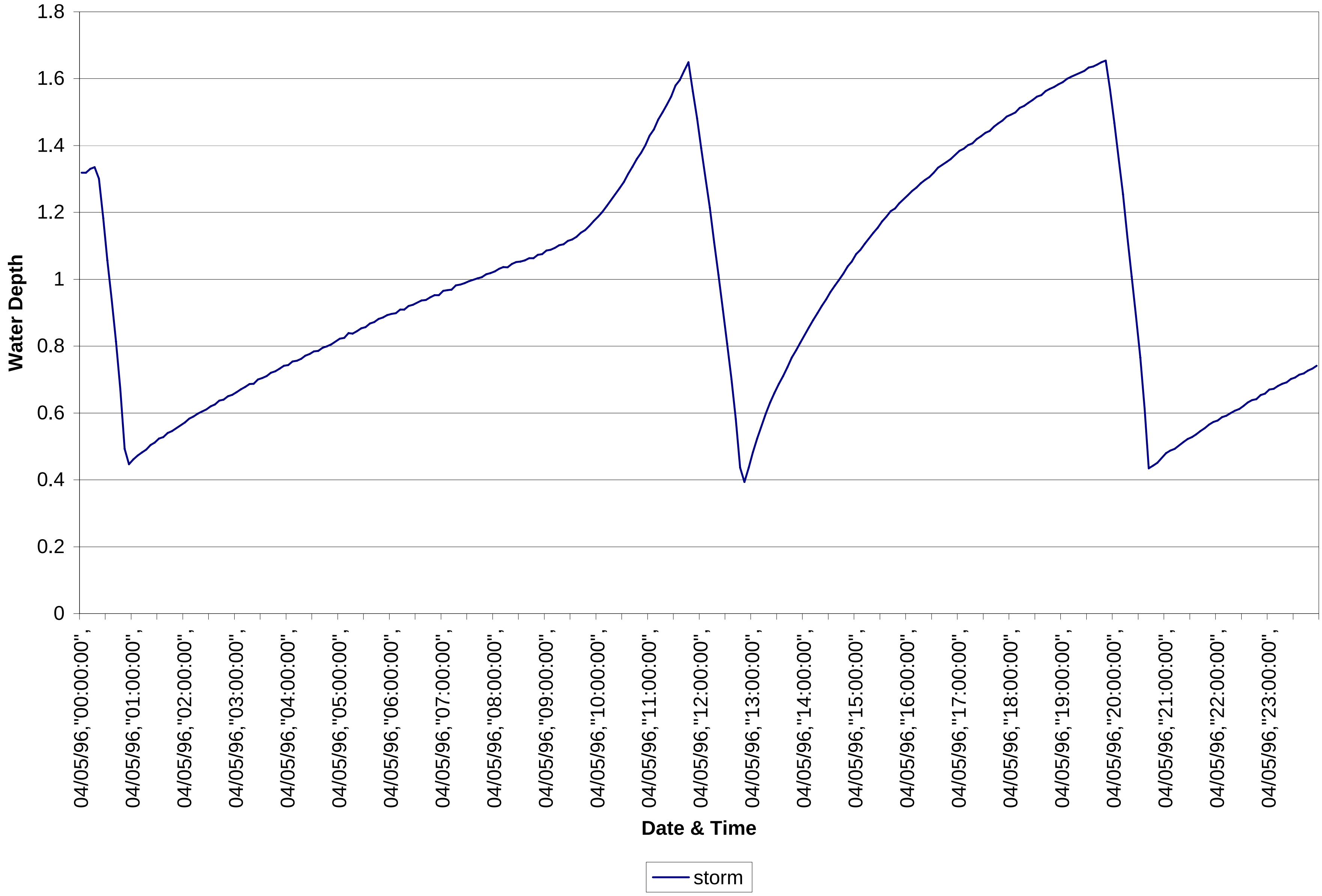

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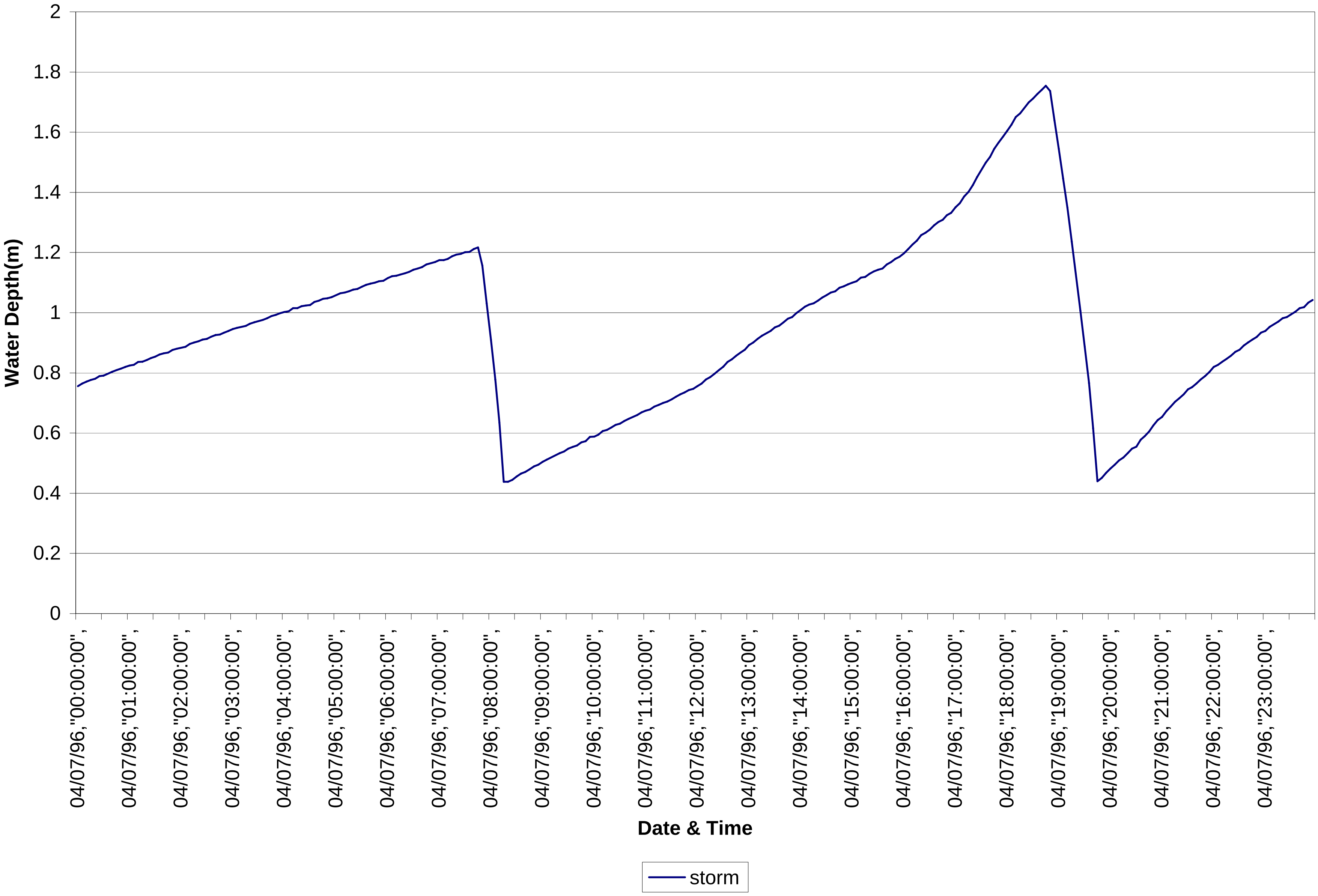

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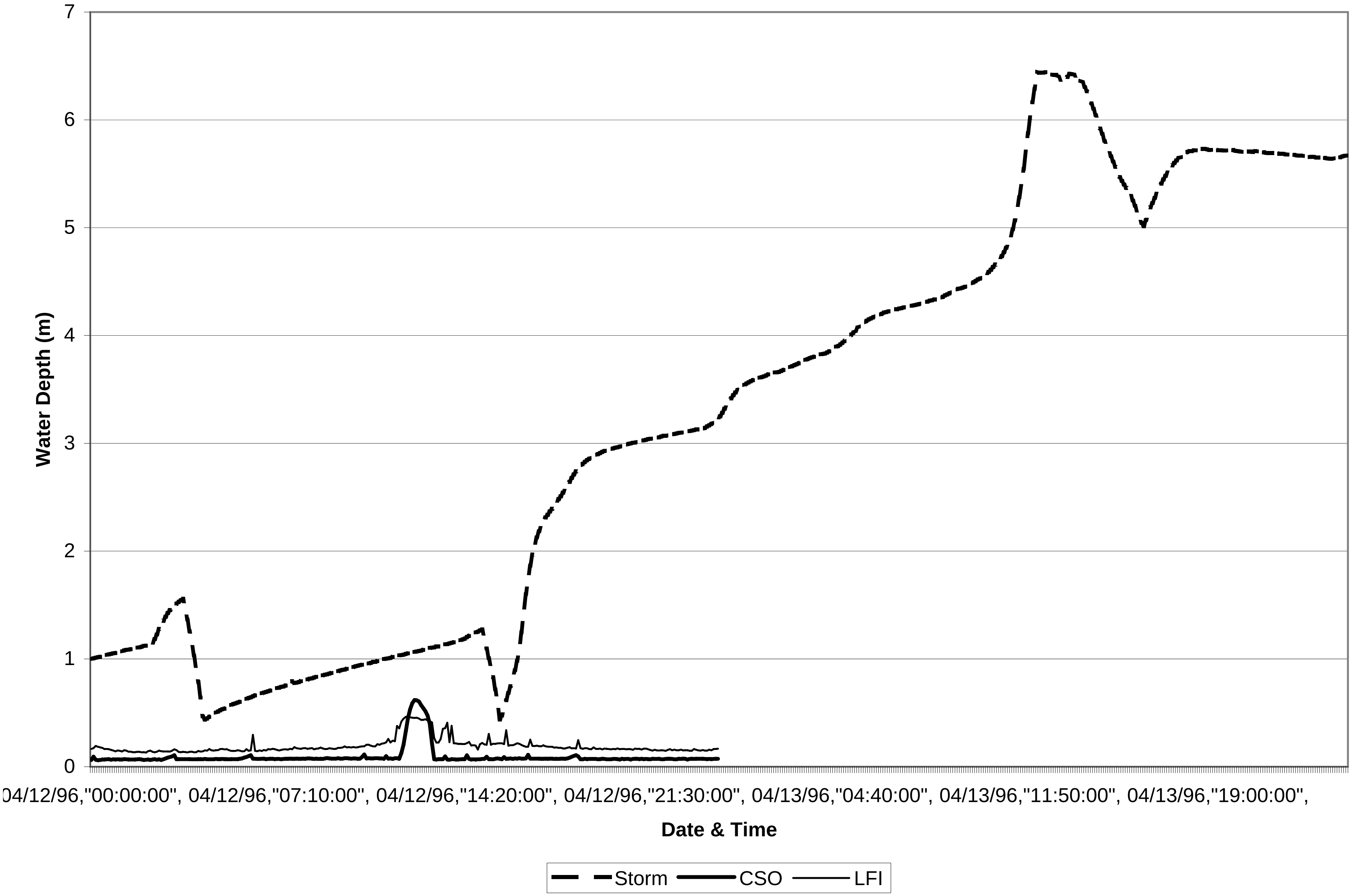
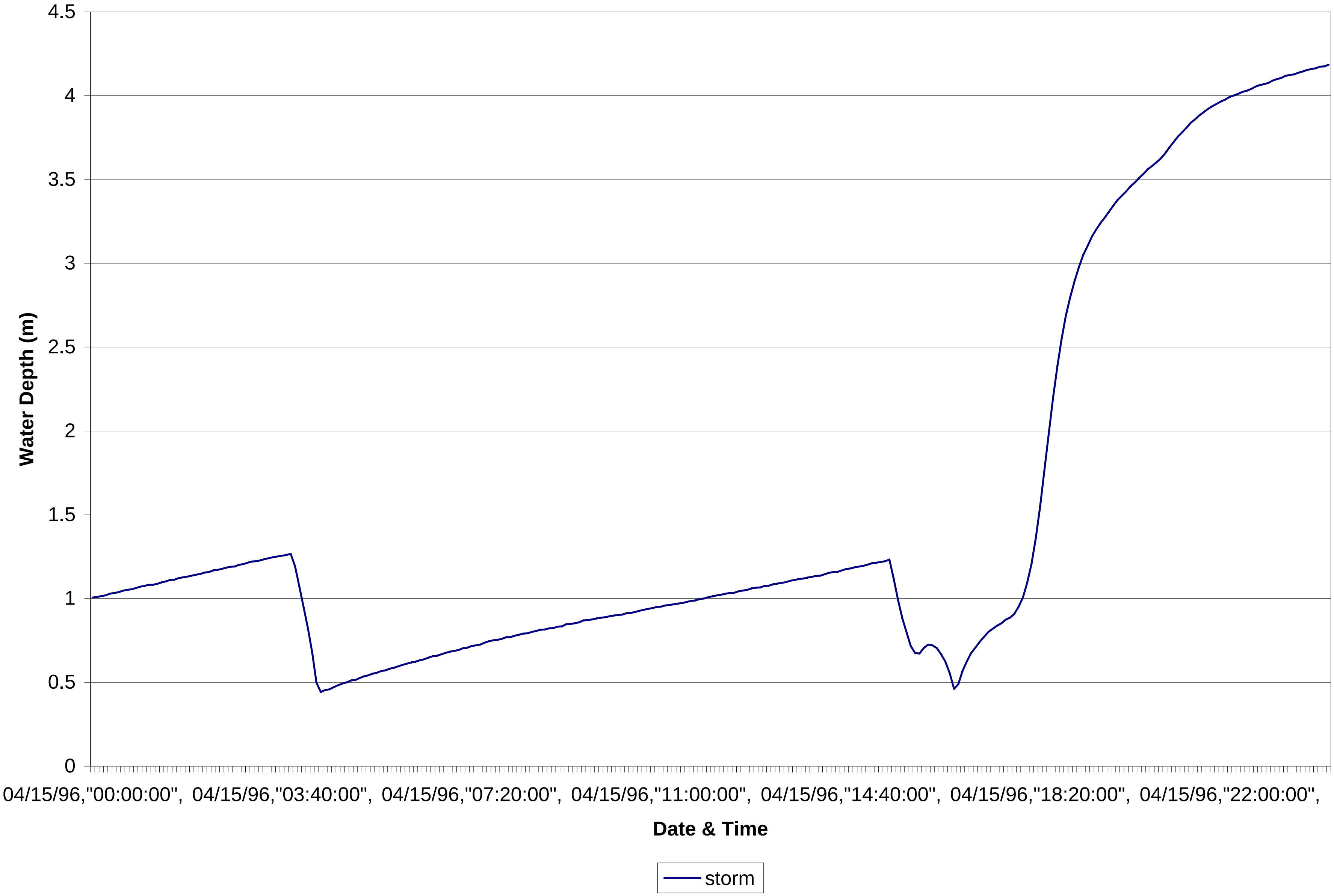
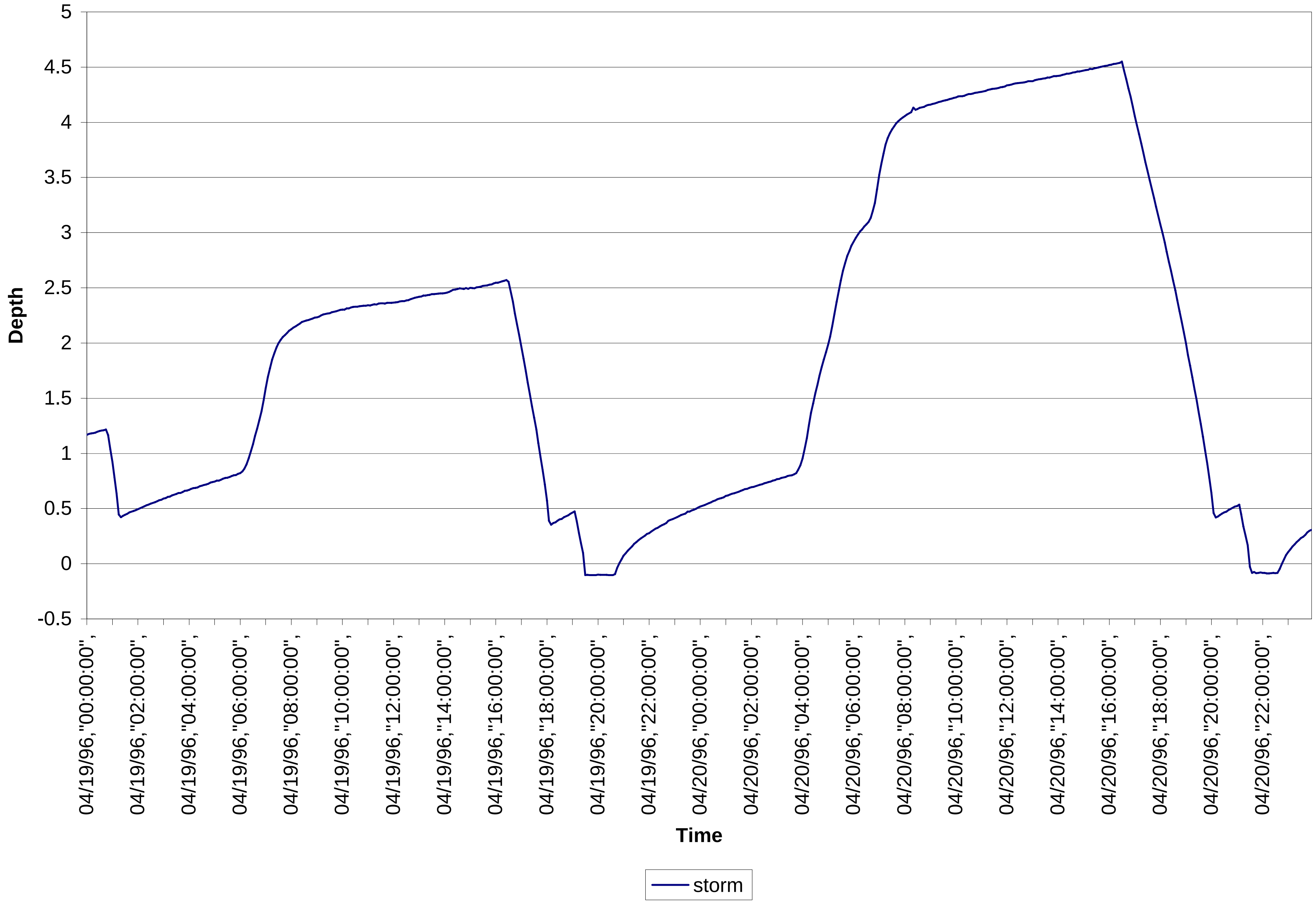
04/07/96,"14:00:00",
04/07/96,"15:00:00",
04/07/96,"16:00:00",
04/07/96,"17:00:00",
04/07/96,"18:00:00",
04/07/96,"19:00:00",
04/07/96,"20:00:00",
04/07/96,"21:00:00",
04/07/96,"22:00:00",
04/07/96,"23:00:00",
Date & Time
storm

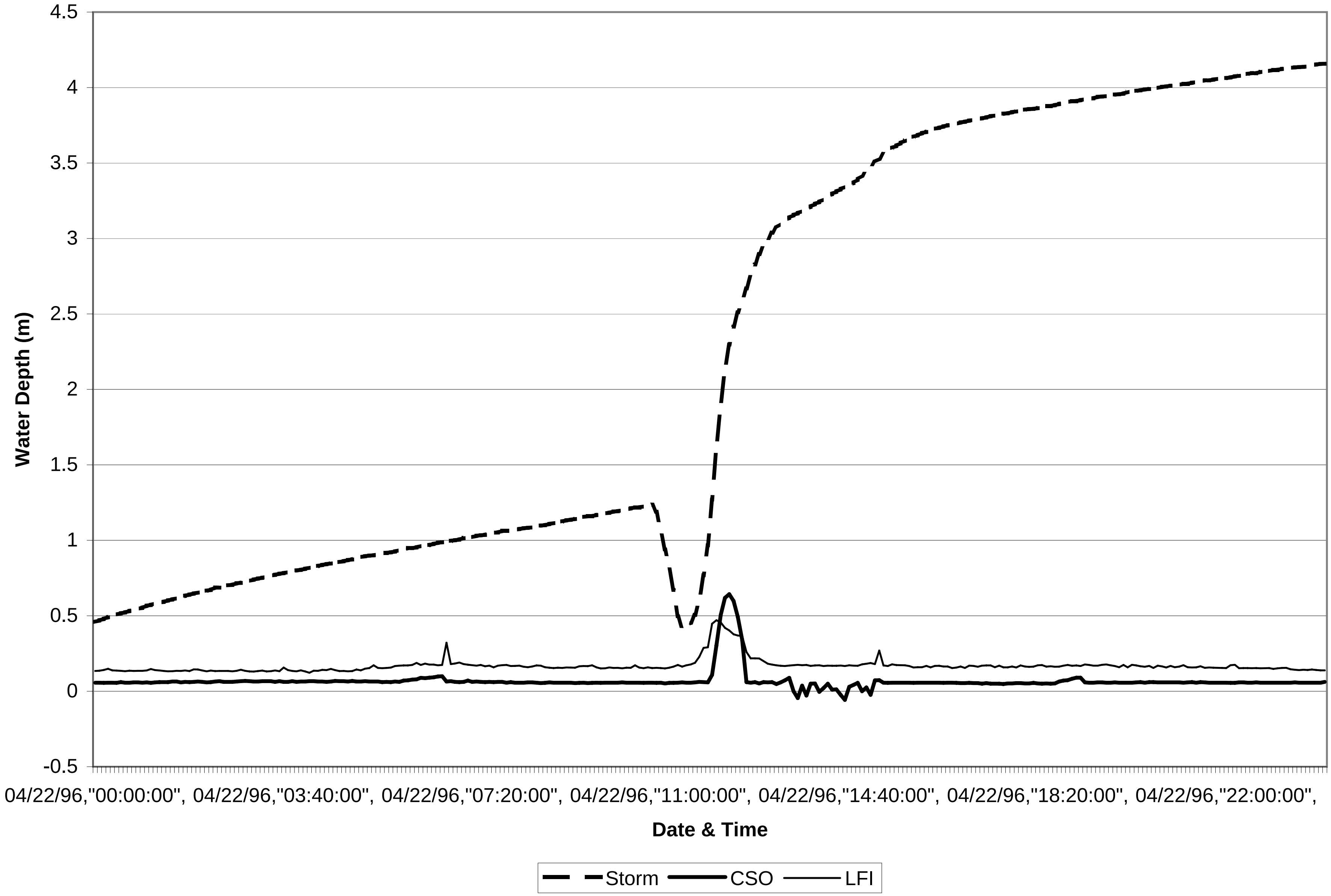


7
6
5
4
3
2
1
0
Water Depth (m)
04/12/96,"00:00:00", 04/12/96,"07:10:00", 04/12/96,"14:20:00", 04/12/96,"21:30:00", 04/13/96,"04:40:00", 04/13/96,"11:50:00", 04/13/96,"19:00:00",
Date & Time
Storm
CSO
LFI

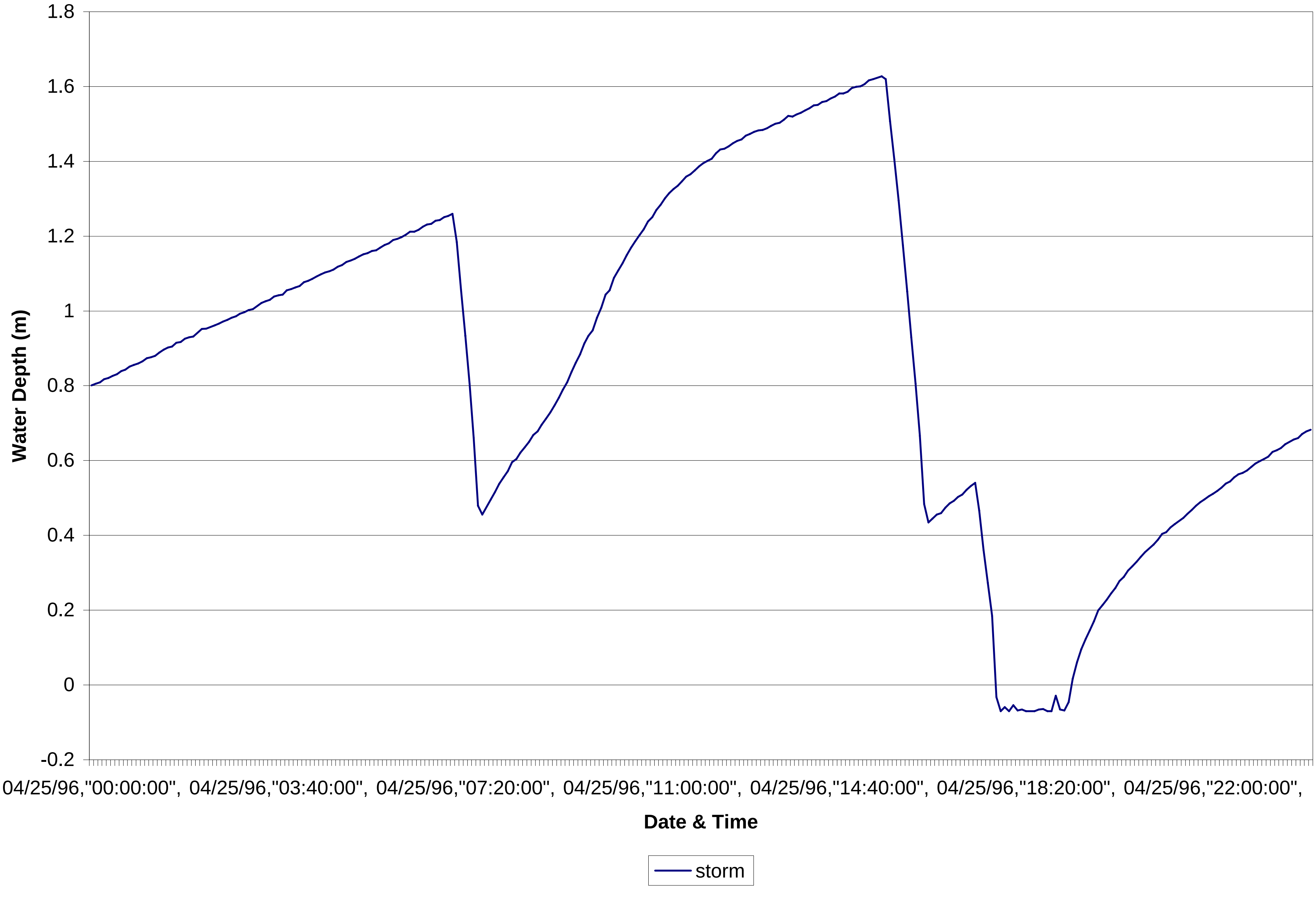


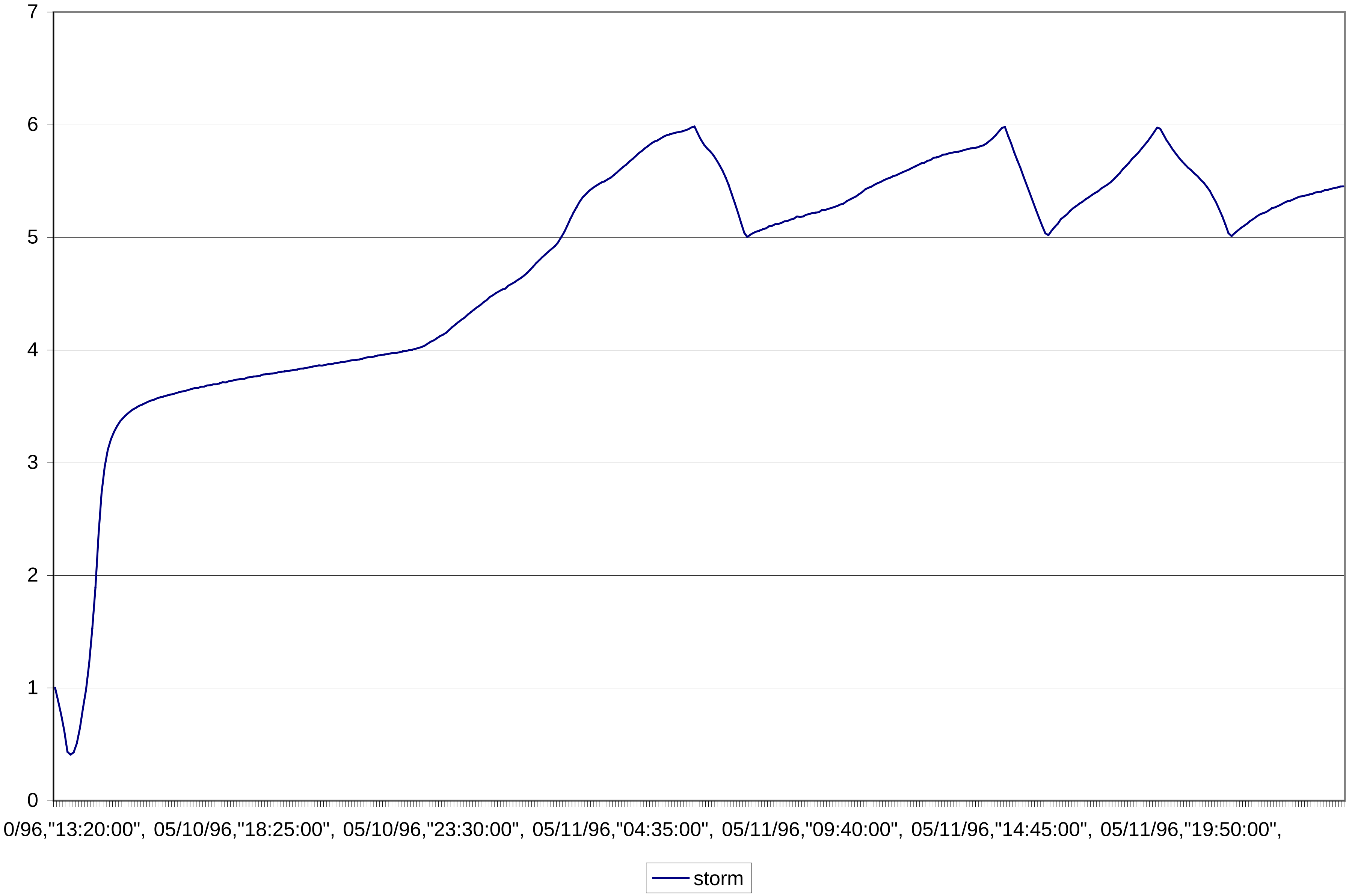
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Water Depth (m)
04/15/96,"00:00:00", 04/15/96,"03:40:00", 04/15/96,"07:20:00", 04/15/96,"11:00:00", 04/15/96,"14:40:00", 04/15/96,"18:20:00", 04/15/96,"22:00:00",
Date & Time
storm


Depth
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
04/19/96,"00:00:00",
04/19/96,"02:00:00",
04/19/96,"04:00:00",
04/19/96,"06:00:00",
04/19/96,"08:00:00",
04/19/96,"10:00:00",
04/19/96,"12:00:00",
04/19/96,"14:00:00",
04/19/96,"16:00:00",
04/19/96,"18:00:00",
04/19/96,"20:00:00",
04/19/96,"22:00:00",
04/20/96,"00:00:00",
04/20/96,"02:00:00",
04/20/96,"04:00:00",
04/20/96,"06:00:00",
04/20/96,"08:00:00",
04/20/96,"10:00:00",
04/20/96,"12:00:00",
04/20/96,"14:00:00",
04/20/96,"16:00:00",
04/20/96,"18:00:00",
04/20/96,"20:00:00",
04/20/96,"22:00:00",
Time
storm

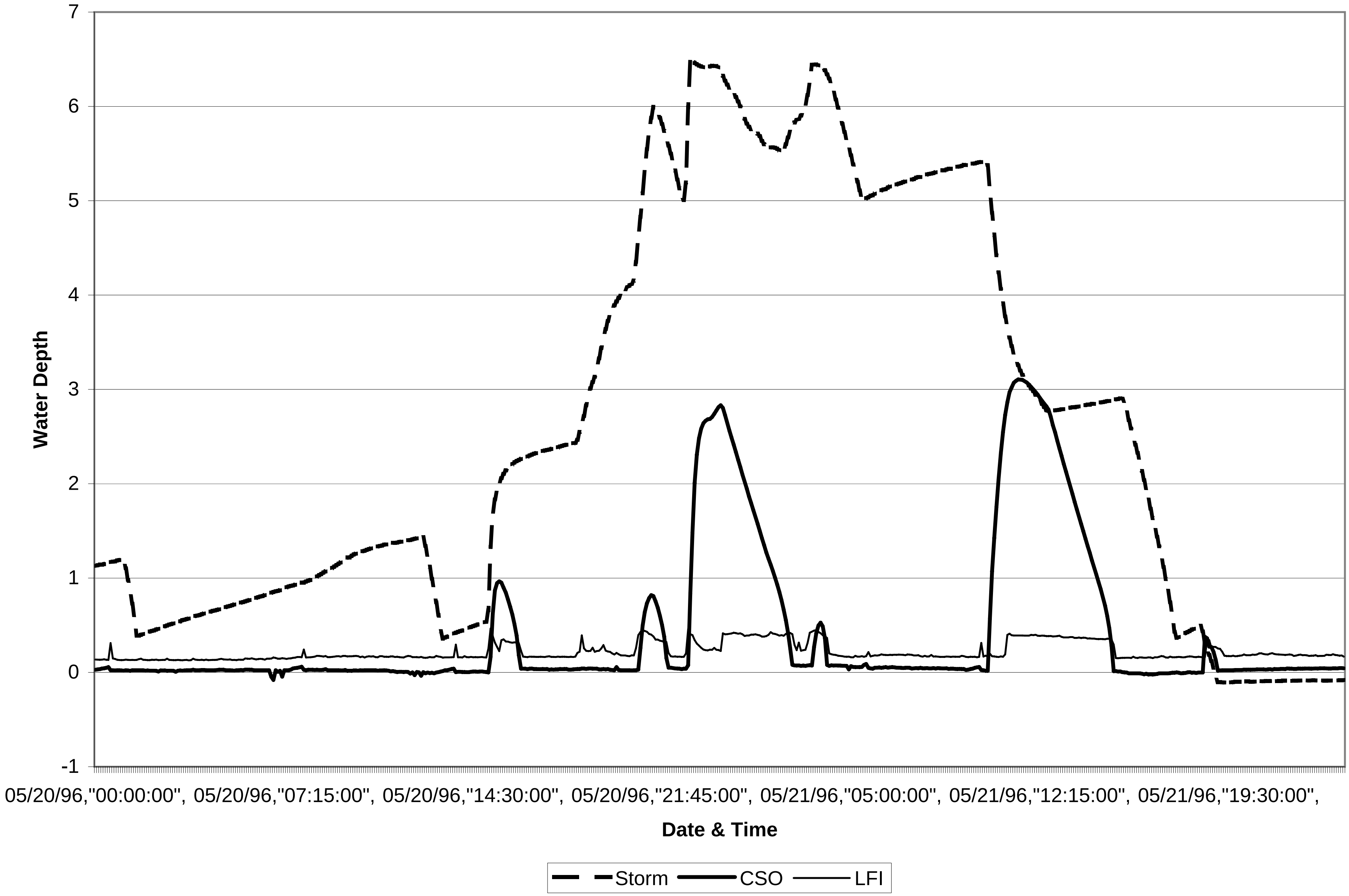


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Water Depth (m)
04/22/96,"00:00:00", 04/22/96,"03:40:00", 04/22/96,"07:20:00", 04/22/96,"11:00:00", 04/22/96,"14:40:00", 04/22/96,"18:20:00", 04/22/96,"22:00:00",
Date & Time
Storm
CSO
LFI

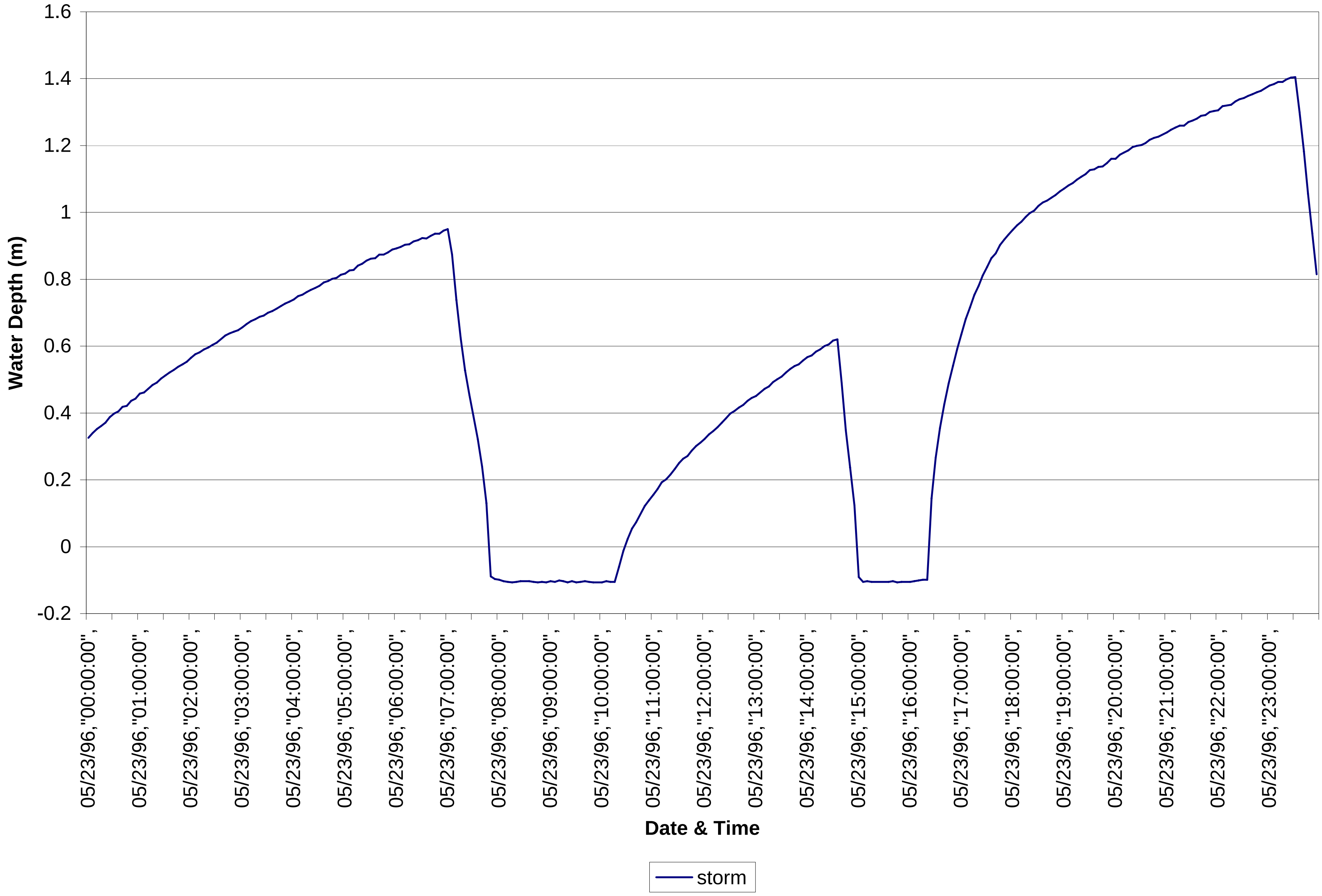

Water Depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
04/25/96,"00:00:00",
04/25/96,"03:40:00",
04/25/96,"07:20:00",
04/25/96,"11:00:00",
04/25/96,"14:40:00",
04/25/96,"18:20:00",
04/25/96,"22:00:00",
Date & Time
storm



7
6
5
4
3
2
1
0
0/96,"13:20:00",
05/10/96,"18:25:00",
05/10/96,"23:30:00",
05/11/96,"04:35:00",
05/11/96,"09:40:00",
05/11/96,"14:45:00",
05/11/96,"19:50:00",
storm



7
6
5
4
3
2
1
0
-1
Water Depth
05/20/96,"00:00:00", 05/20/96,"07:15:00", 05/20/96,"14:30:00", 05/20/96,"21:45:00", 05/21/96,"05:00:00", 05/21/96,"12:15:00", 05/21/96,"19:30:00",
Date & Time
Storm
CSO
LFI



Water Depth (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
05/23/96,"00:00:00",
05/23/96,"01:00:00",
05/23/96,"02:00:00",
05/23/96,"03:00:00",
05/23/96,"04:00:00",
05/23/96,"05:00:00",
05/23/96,"06:00:00",
05/23/96,"07:00:00",
05/23/96,"08:00:00",
05/23/96,"09:00:00",
05/23/96,"10:00:00",
05/23/96,"11:00:00",
05/23/96,"12:00:00",
05/23/96,"13:00:00",
05/23/96,"14:00:00",
05/23/96,"15:00:00",
05/23/96,"16:00:00",
05/23/96,"17:00:00",
05/23/96,"18:00:00",
05/23/96,"19:00:00",
05/23/96,"20:00:00",
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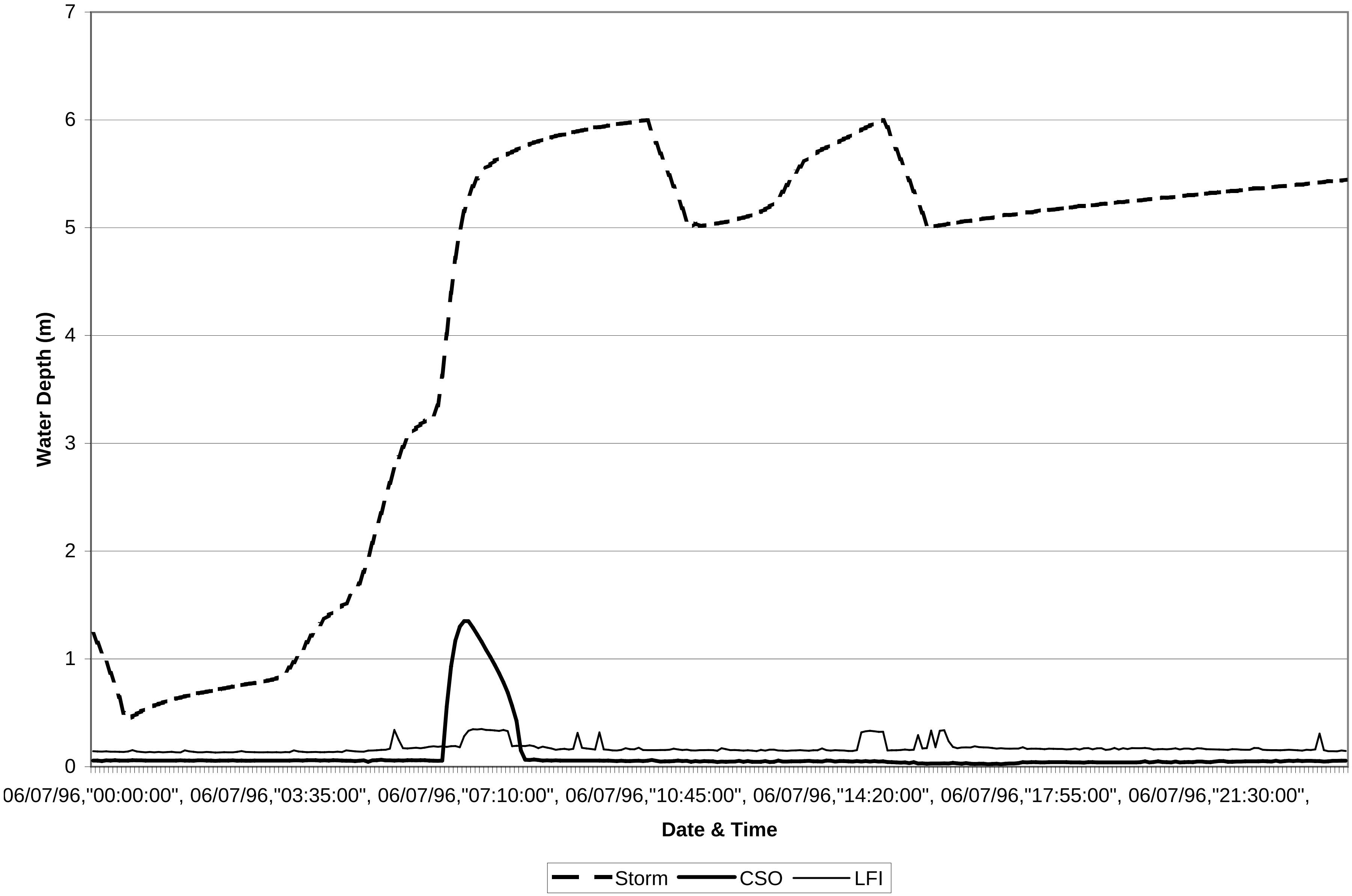
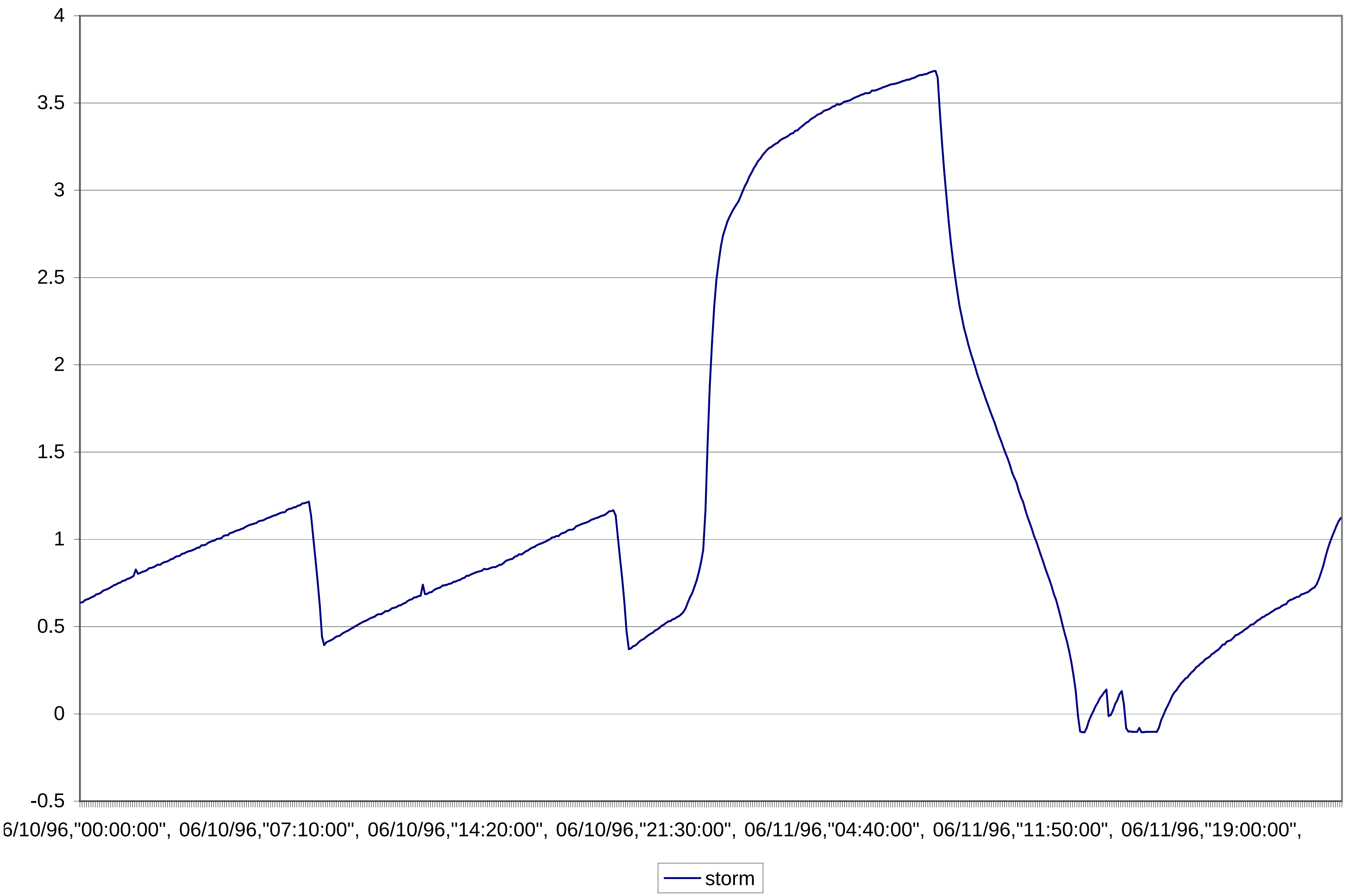
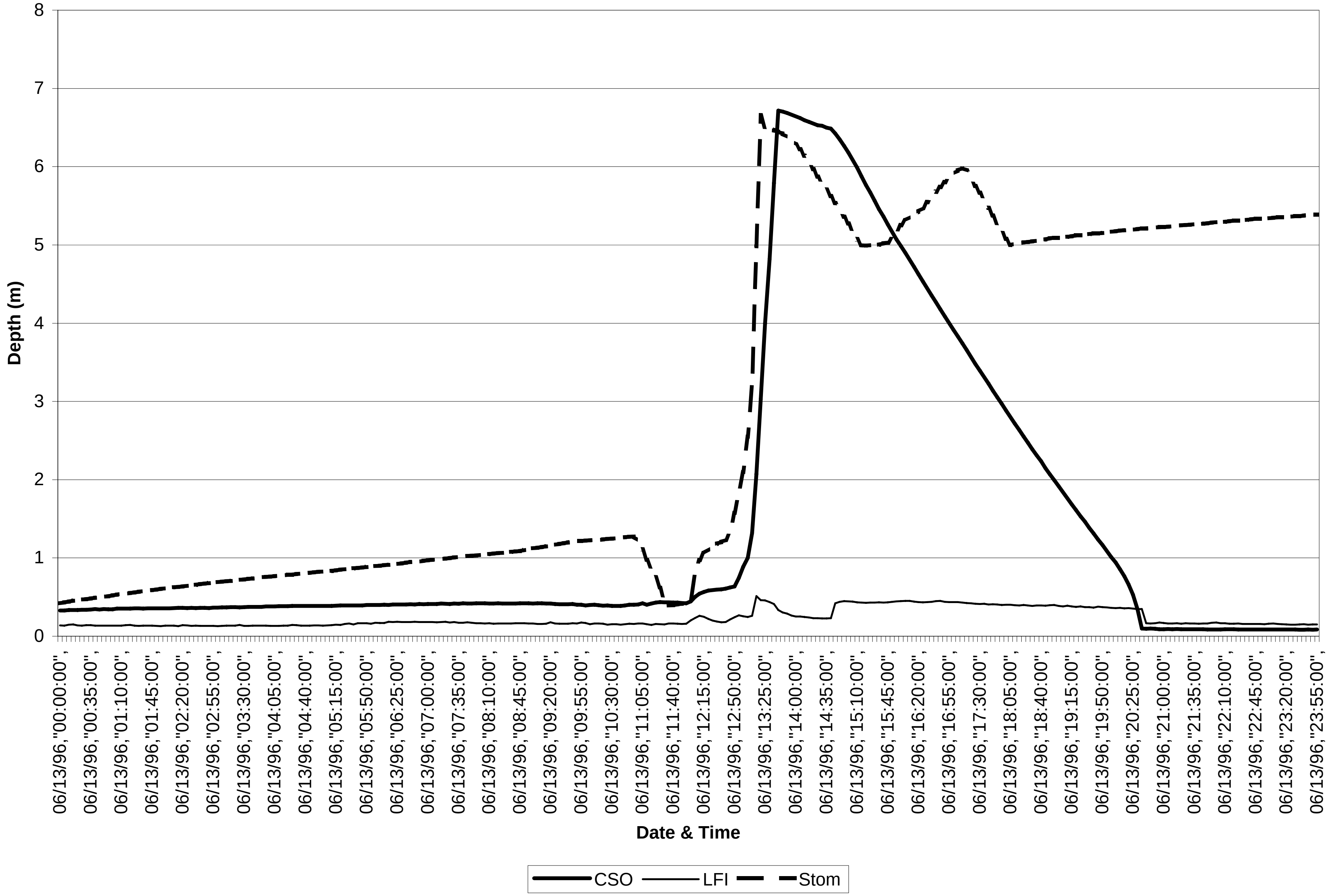
05/23/96,"22:00:00",
05/23/96,"23:00:00",
Date & Time
storm

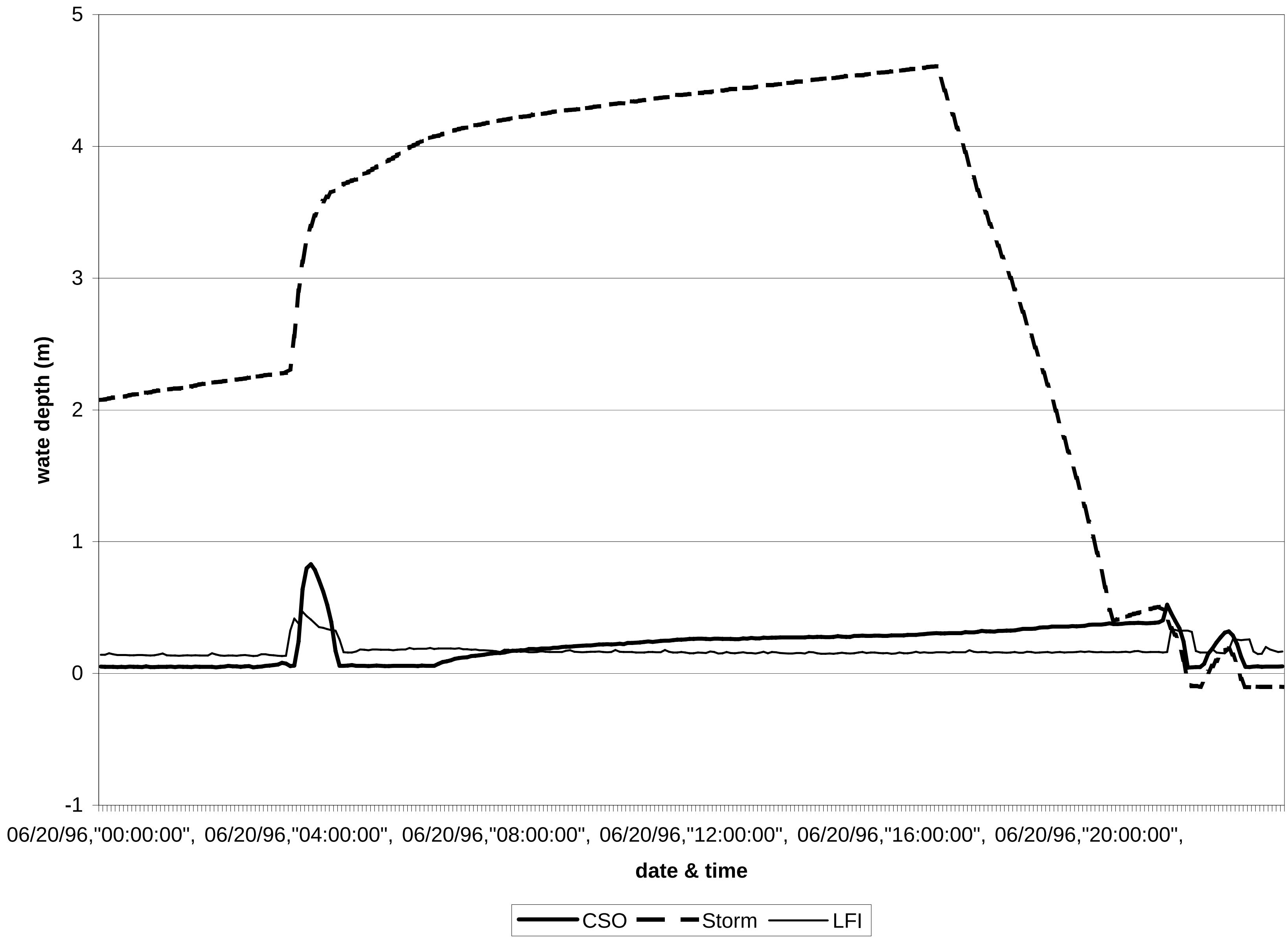


7
6
5
4
3
2
1
0
Water Depth (m)
06/07/96,"00:00:00", 06/07/96,"03:35:00", 06/07/96,"07:10:00", 06/07/96,"10:45:00", 06/07/96,"14:20:00", 06/07/96,"17:55:00", 06/07/96,"21:30:00",
Date & Time
Storm
CSO
LFI

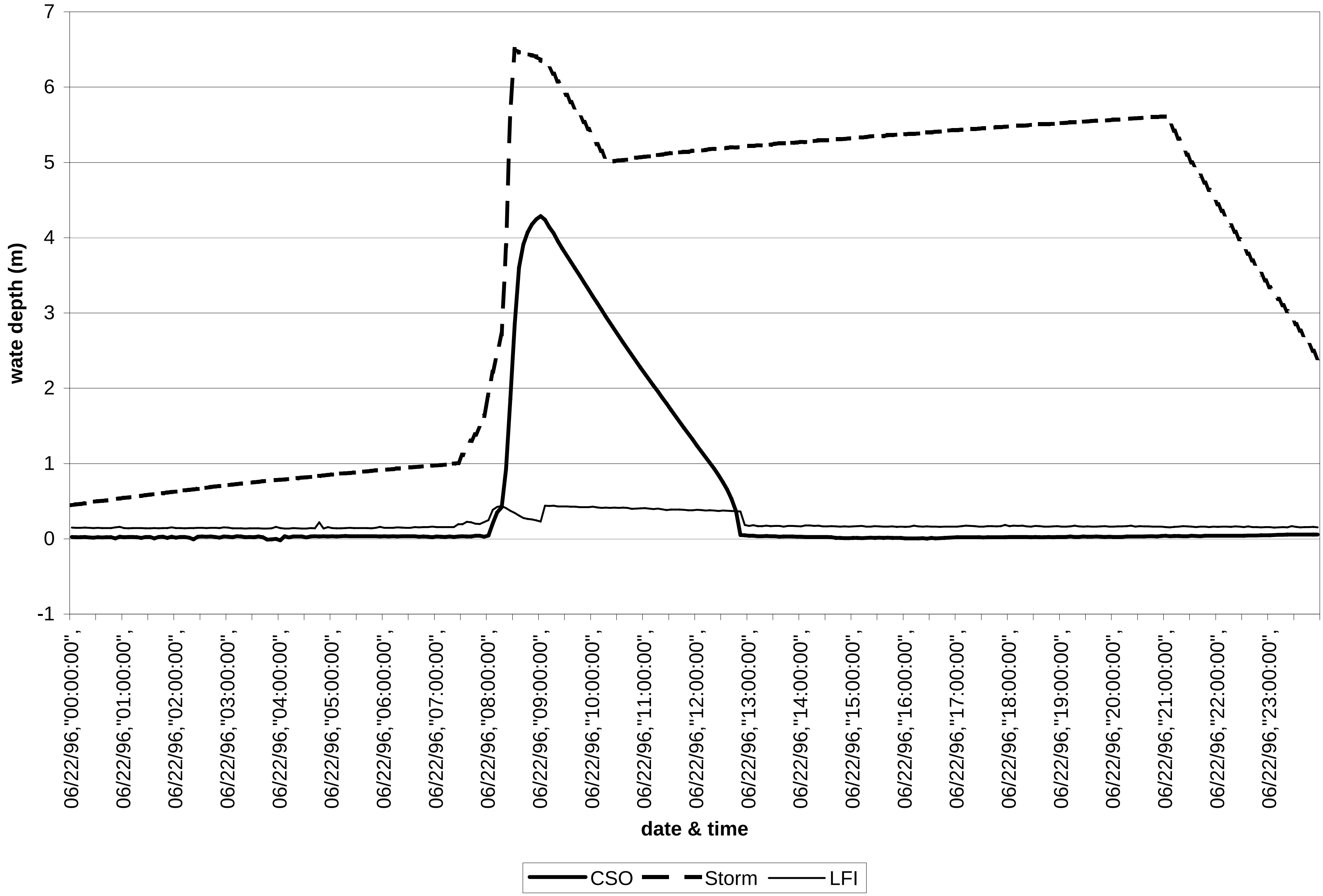


4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
6/10/96,"00:00:00", 06/10/96,"07:10:00", 06/10/96,"14:20:00", 06/10/96,"21:30:00", 06/11/96,"04:40:00", 06/11/96,"11:50:00", 06/11/96,"19:00:00",
storm


Depth (m)
0
1
2
3
4
5
6
7
8
Date & Time
CSO
LFI
Stom



5
4
3
2
1
0
-1
wate depth (m)
06/20/96,"00:00:00", 06/20/96,"04:00:00", 06/20/96,"08:00:00", 06/20/96,"12:00:00", 06/20/96,"16:00:00", 06/20/96,"20:00:00",
date & time
CSO
Storm
LFI



7
6
5
4
3
2
1
0
-1
wate depth (m)
06/22/96,"00:00:00",
06/22/96,"01:00:00",
06/22/96,"02:00:00",
06/22/96,"03:00:00",
06/22/96,"04:00:00",
06/22/96,"05:00:00",
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06/22/96,"07:00:00",
06/22/96,"08:00:00",
06/22/96,"09:00:00",
06/22/96,"10:00:00",
06/22/96,"11:00:00",
06/22/96,"12:00:00",
06/22/96,"13:00:00",
06/22/96,"14:00:00",
06/22/96,"15:00:00",
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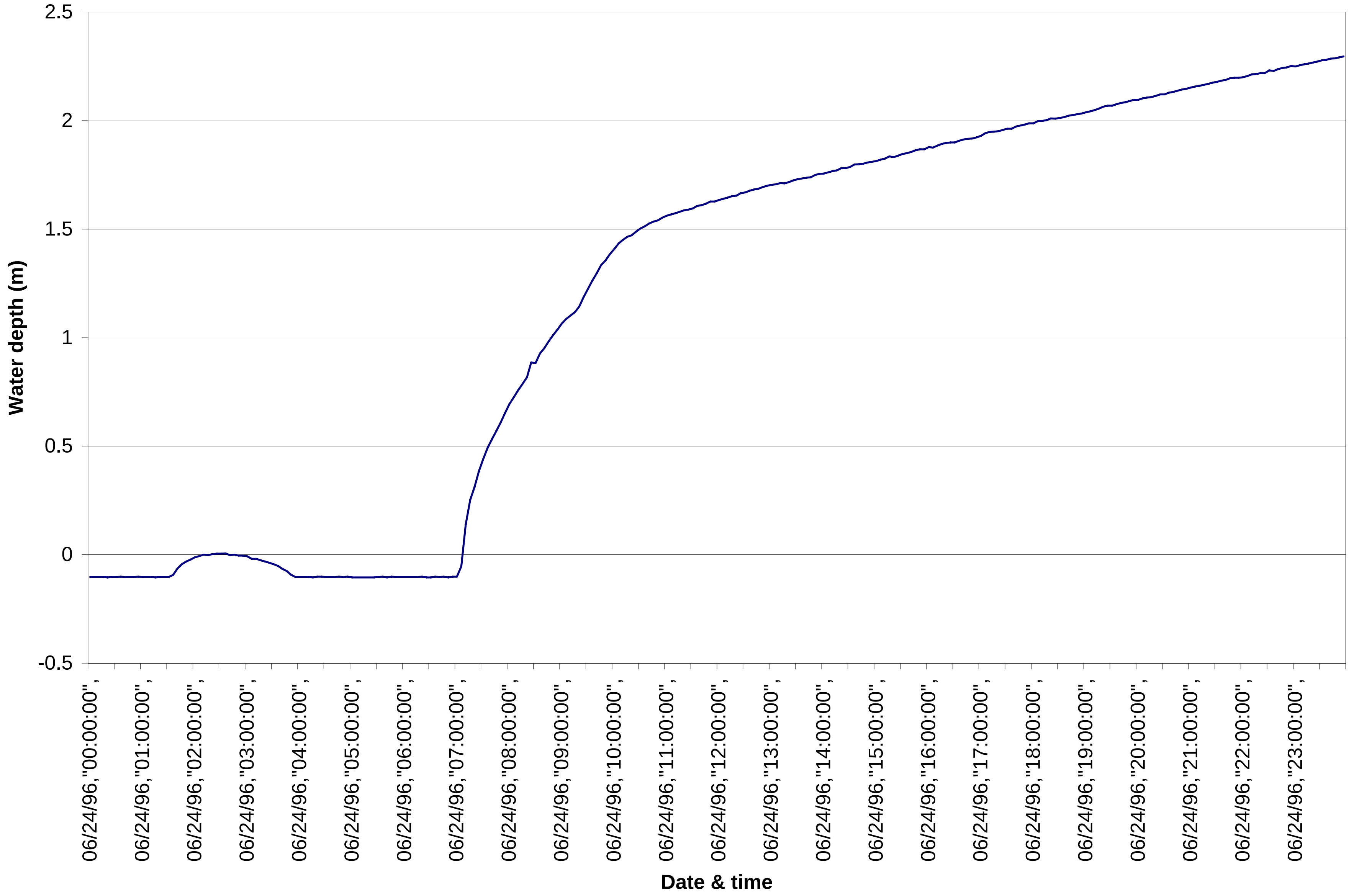
06/22/96,"19:00:00",
06/22/96,"20:00:00",
06/22/96,"21:00:00",
06/22/96,"22:00:00",
06/22/96,"23:00:00",
date & time
CSO
Storm
LFI



Water depth (m)
2.5
2
1.5
1
0.5
0
-0.5
06/24/96,"00:00:00",
06/24/96,"01:00:00",
06/24/96,"02:00:00",
06/24/96,"03:00:00",
06/24/96,"04:00:00",
06/24/96,"05:00:00",
06/24/96,"06:00:00",
06/24/96,"07:00:00",
06/24/96,"08:00:00",
06/24/96,"09:00:00",
06/24/96,"10:00:00",
06/24/96,"11:00:00",
06/24/96,"12:00:00",
06/24/96,"13:00:00",
06/24/96,"14:00:00",
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06/24/96,"16:00:00",
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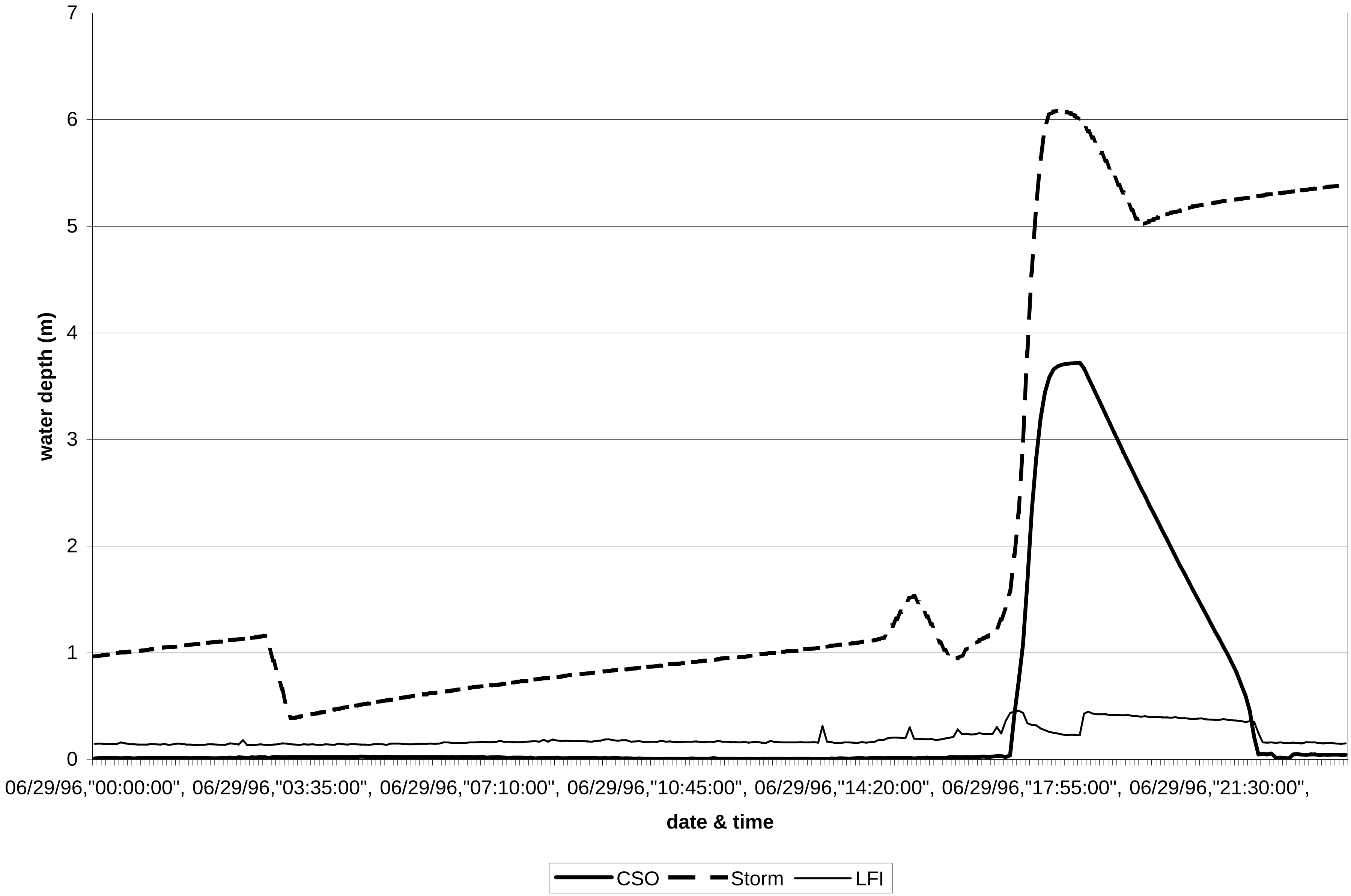
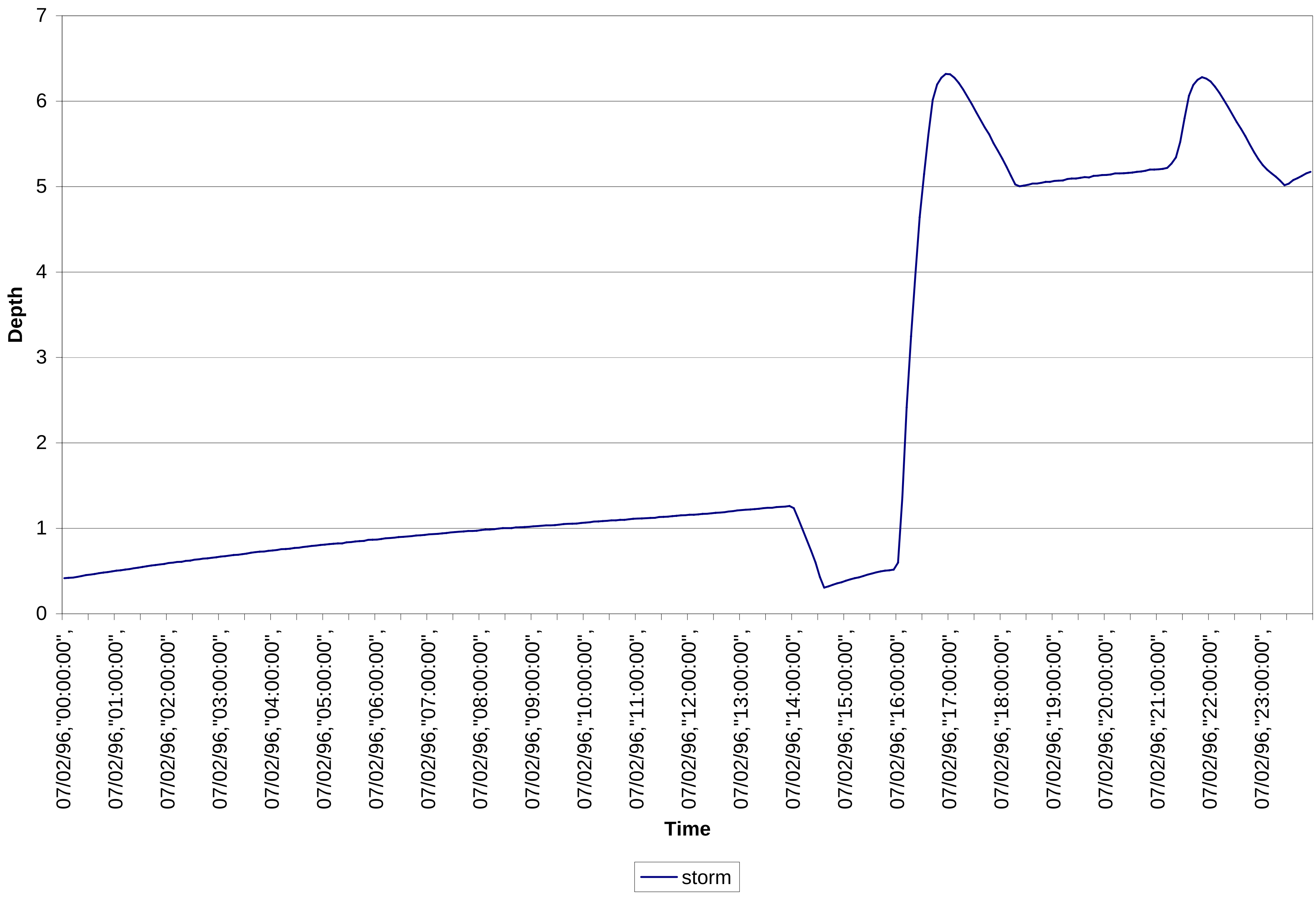
06/24/96,"18:00:00",
06/24/96,"19:00:00",
06/24/96,"20:00:00",
06/24/96,"21:00:00",
06/24/96,"22:00:00",
06/24/96,"23:00:00",
Date & time



7
6
5
4
3
2
1
0
water depth (m)
06/29/96,"00:00:00",
06/29/96,"03:35:00",
06/29/96,"07:10:00",
06/29/96,"10:45:00",
06/29/96,"14:20:00",
06/29/96,"17:55:00",
06/29/96,"21:30:00",
date & time
CSO
Storm
LFI



Depth
7
6
5
4
3
2
1
0
07/02/96,"00:00:00",
07/02/96,"01:00:00",
07/02/96,"02:00:00",
07/02/96,"03:00:00",
07/02/96,"04:00:00",
07/02/96,"05:00:00",
07/02/96,"06:00:00",
07/02/96,"07:00:00",
07/02/96,"08:00:00",
07/02/96,"09:00:00",
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07/02/96,"13:00:00",
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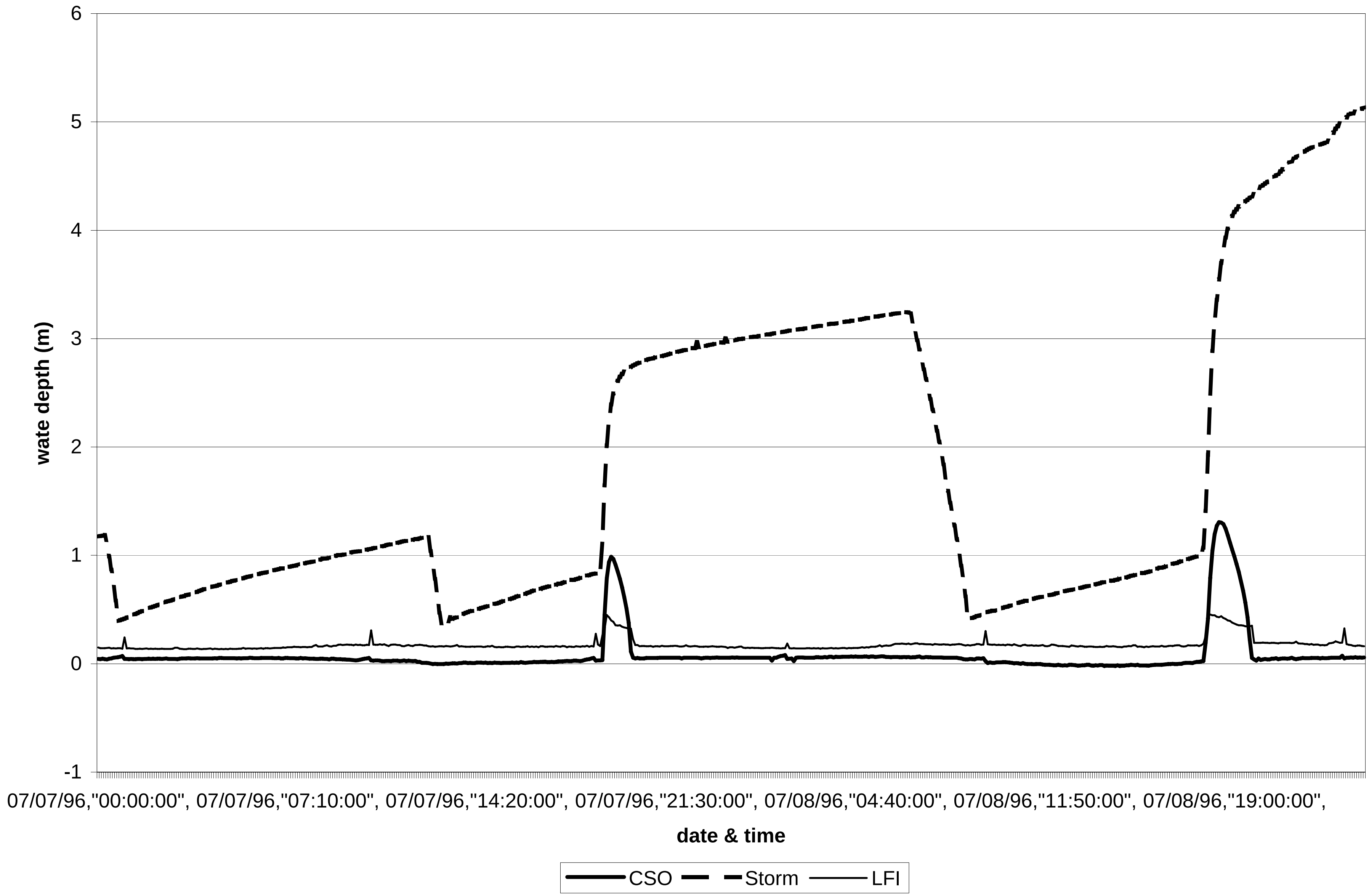
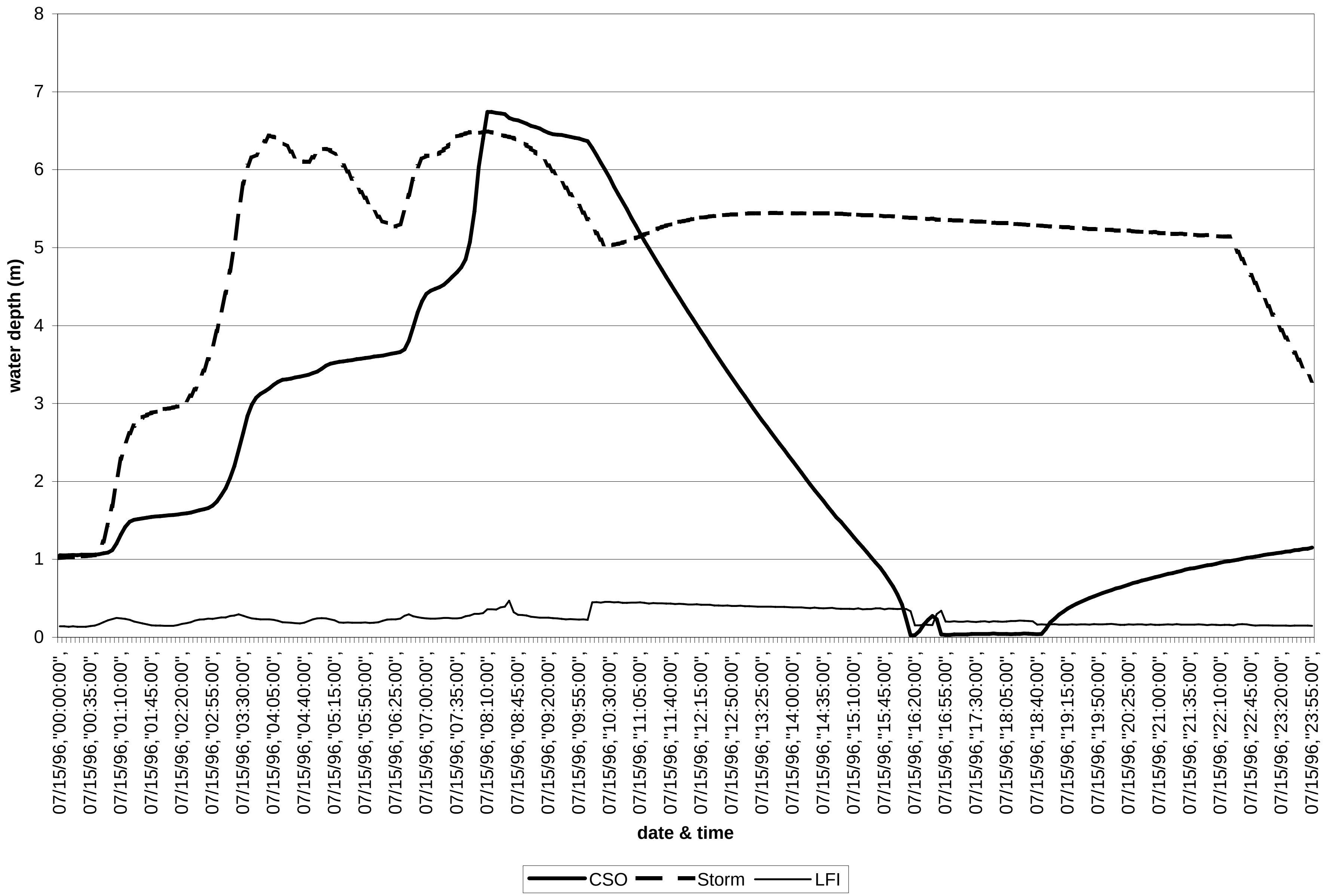
07/02/96,"17:00:00",
07/02/96,"18:00:00",
07/02/96,"19:00:00",
07/02/96,"20:00:00",
07/02/96,"21:00:00",
07/02/96,"22:00:00",
07/02/96,"23:00:00",
Time
storm



6
5
4
3
2
1
0
-1
wate depth (m)
07/07/96,"00:00:00", 07/07/96,"07:10:00", 07/07/96,"14:20:00", 07/07/96,"21:30:00", 07/08/96,"04:40:00", 07/08/96,"11:50:00", 07/08/96,"19:00:00",
date & time
CSO
Storm
LFI



water depth (m)
0
1
2
3
4
5
6
7
8
date & time
07/15/96,"00:00:00",
07/15/96,"00:35:00",
07/15/96,"01:10:00",
07/15/96,"01:45:00",
07/15/96,"02:20:00",
07/15/96,"02:55:00",
07/15/96,"03:30:00",
07/15/96,"04:05:00",
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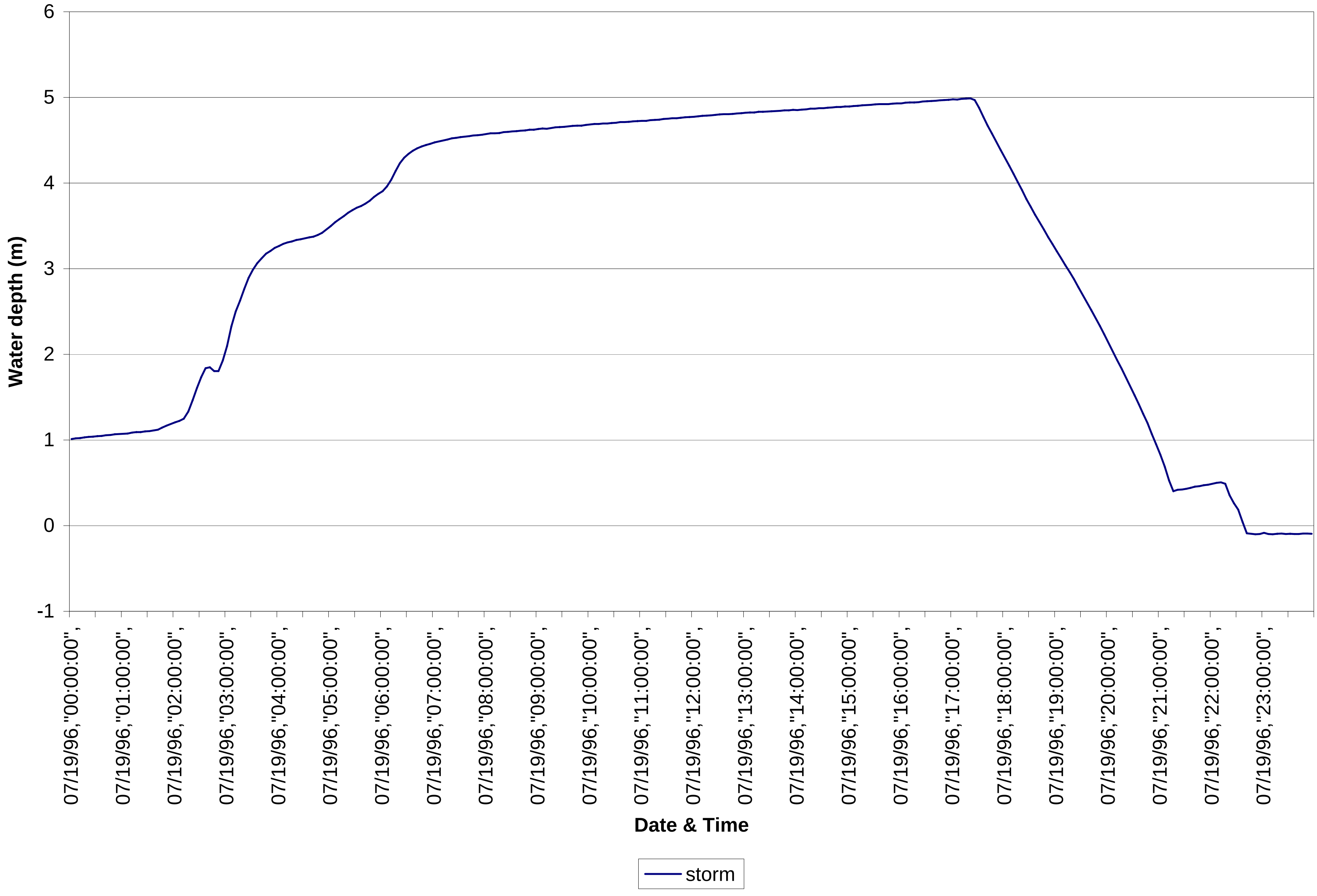
07/15/96,"22:10:00",
07/15/96,"22:45:00",
07/15/96,"23:20:00",
07/15/96,"23:55:00",
CSO
Storm
LFI



6
5
4
3
2
1
0
-1
Water depth (m)
07/19/96,"00:00:00",
07/19/96,"01:00:00",
07/19/96,"02:00:00",
07/19/96,"03:00:00",
07/19/96,"04:00:00",
07/19/96,"05:00:00",
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07/19/96,"07:00:00",
07/19/96,"08:00:00",
07/19/96,"09:00:00",
07/19/96,"10:00:00",
07/19/96,"11:00:00",
07/19/96,"12:00:00",
07/19/96,"13:00:00",
07/19/96,"14:00:00",
07/19/96,"15:00:00",
07/19/96,"16:00:00",
07/19/96,"17:00:00",
07/19/96,"18:00:00",
07/19/96,"19:00:00",
07/19/96,"20:00:00",
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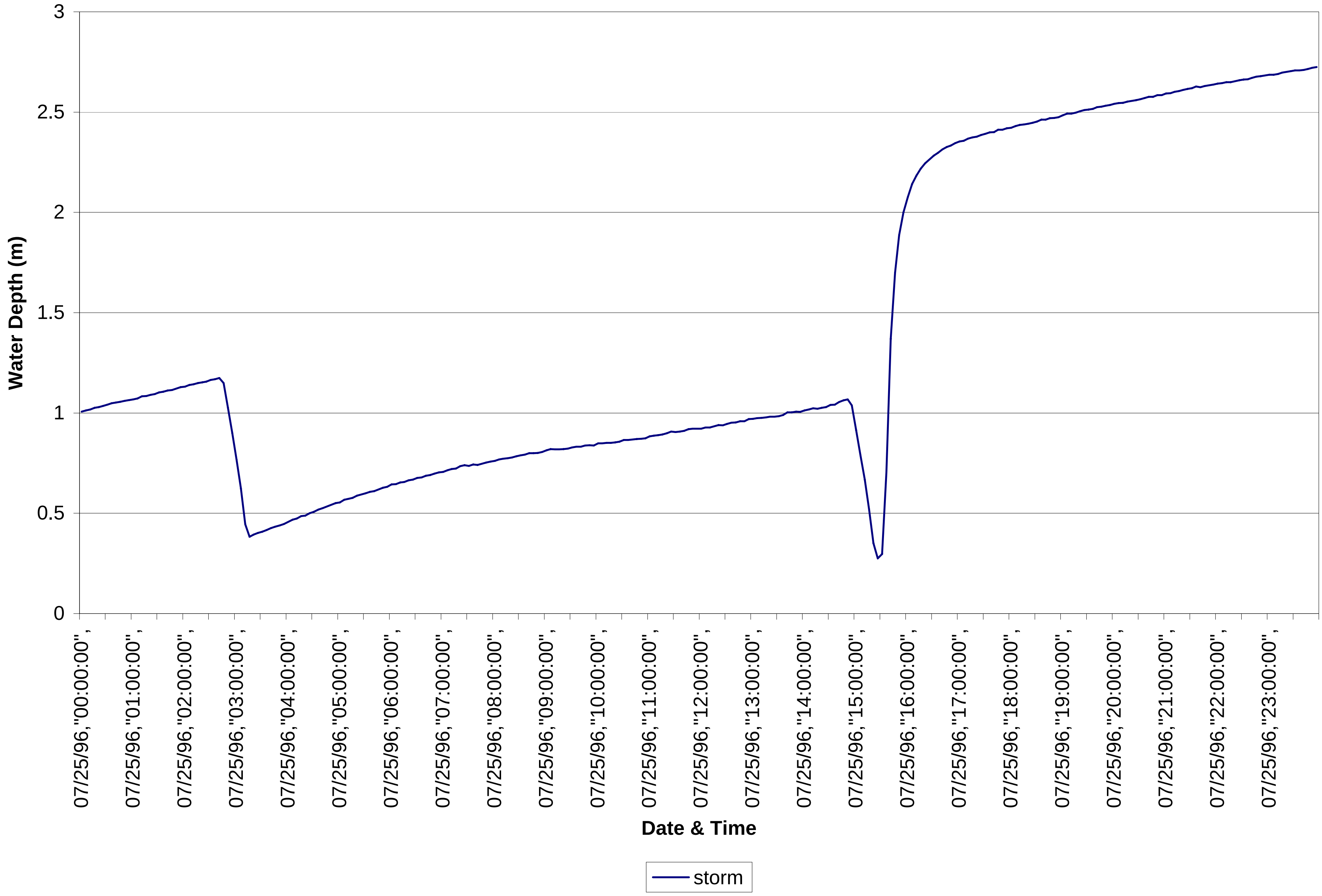
07/19/96,"22:00:00",
07/19/96,"23:00:00",
Date & Time
storm



Water Depth (m)
3
2.5
2
1.5
1
0.5
0
07/25/96,"00:00:00",
07/25/96,"01:00:00",
07/25/96,"02:00:00",
07/25/96,"03:00:00",
07/25/96,"04:00:00",
07/25/96,"05:00:00",
07/25/96,"06:00:00",
07/25/96,"07:00:00",
07/25/96,"08:00:00",
07/25/96,"09:00:00",
07/25/96,"10:00:00",
07/25/96,"11:00:00",
07/25/96,"12:00:00",
07/25/96,"13:00:00",
07/25/96,"14:00:00",
07/25/96,"15:00:00",
07/25/96,"16:00:00",
07/25/96,"17:00:00",
07/25/96,"18:00:00",
07/25/96,"19:00:00",
07/25/96,"20:00:00",
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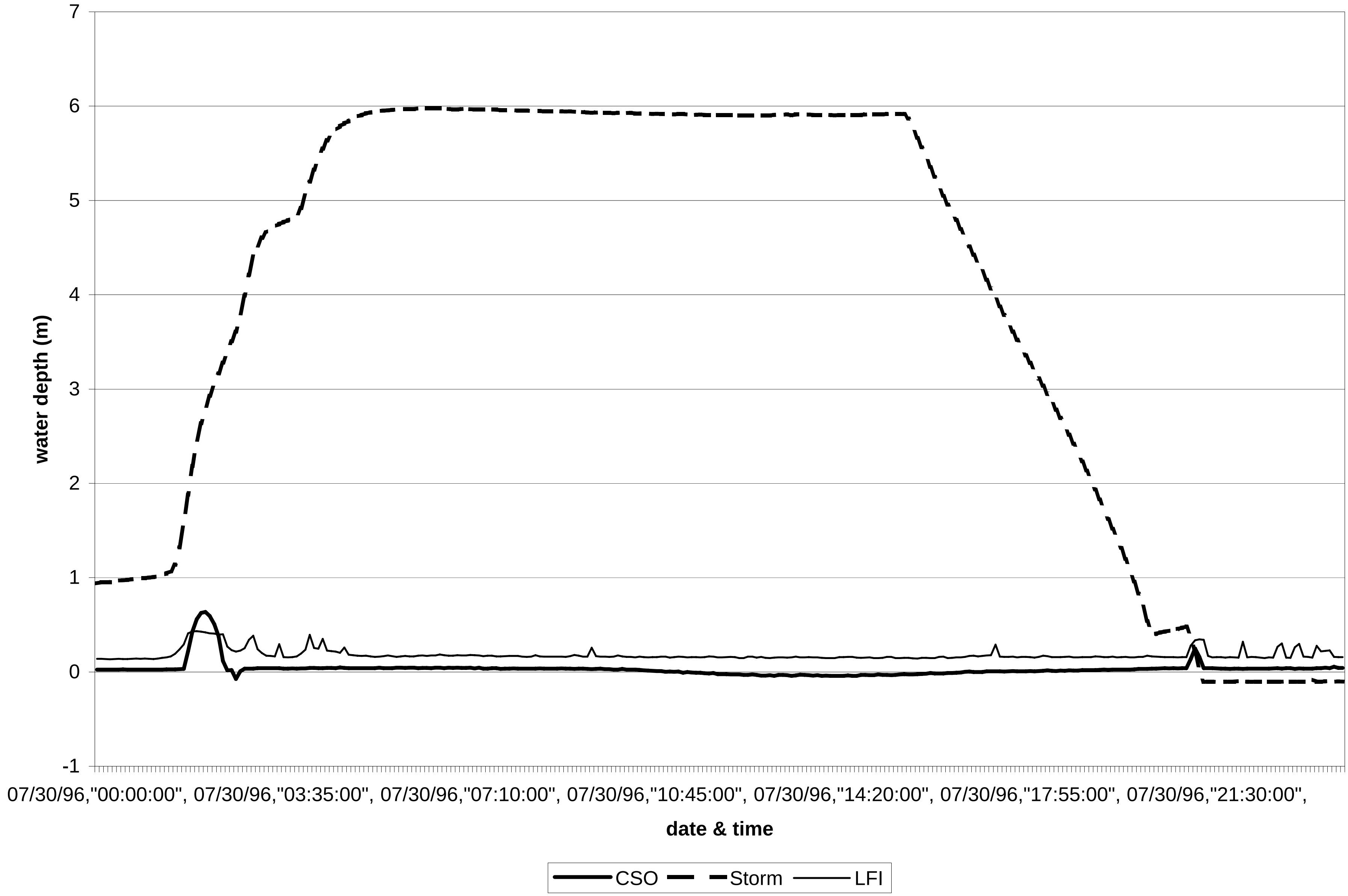
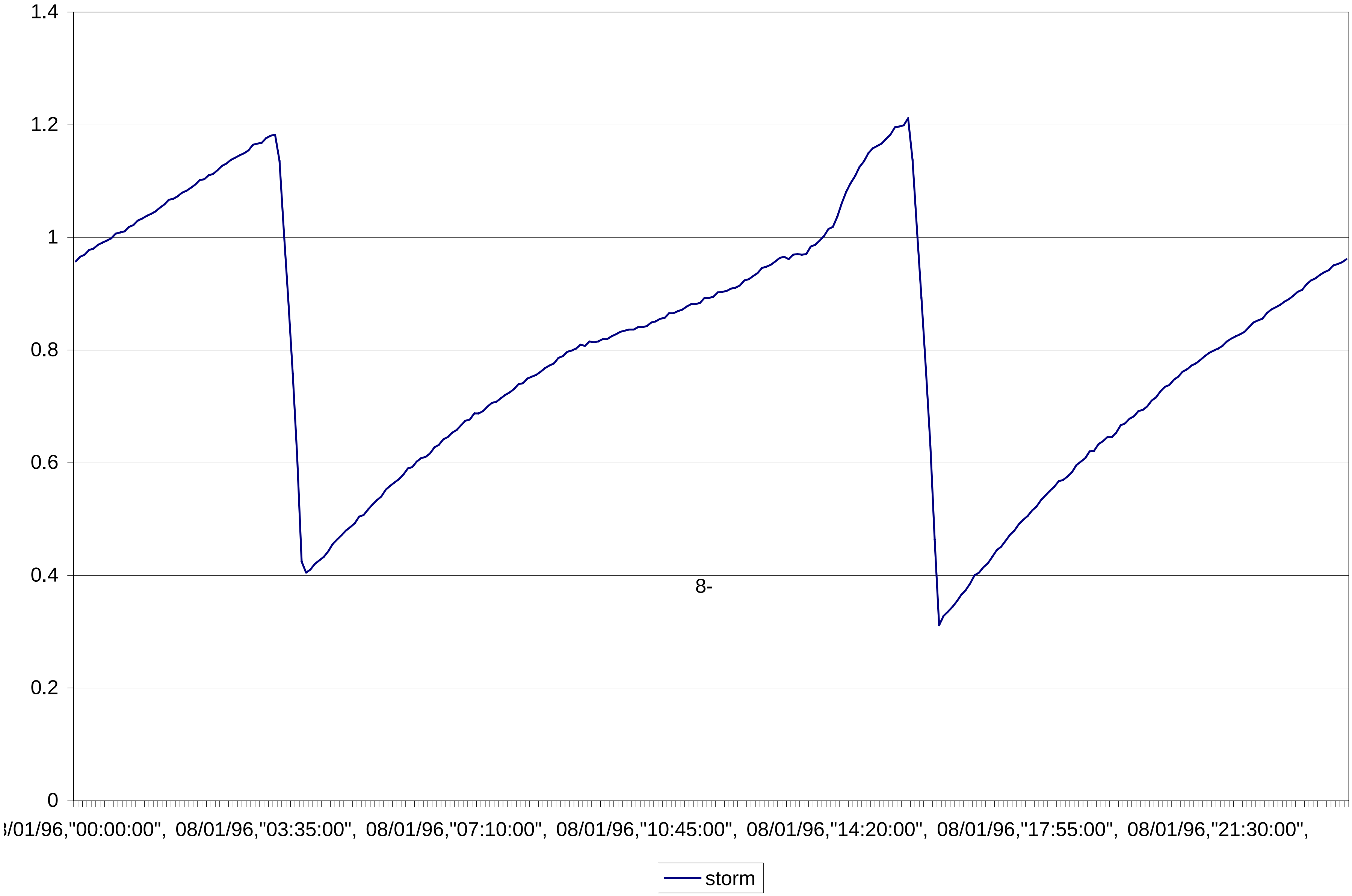
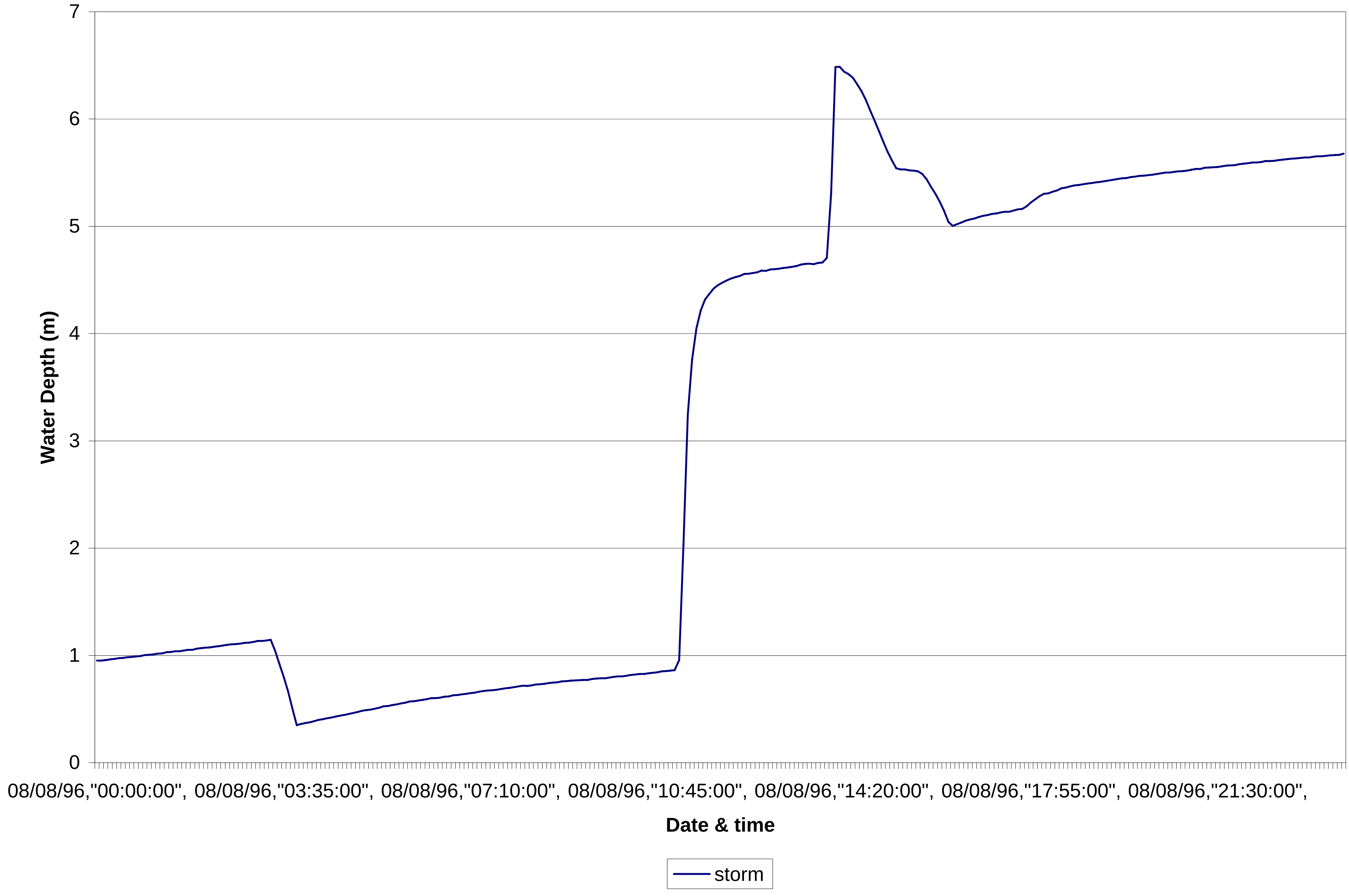
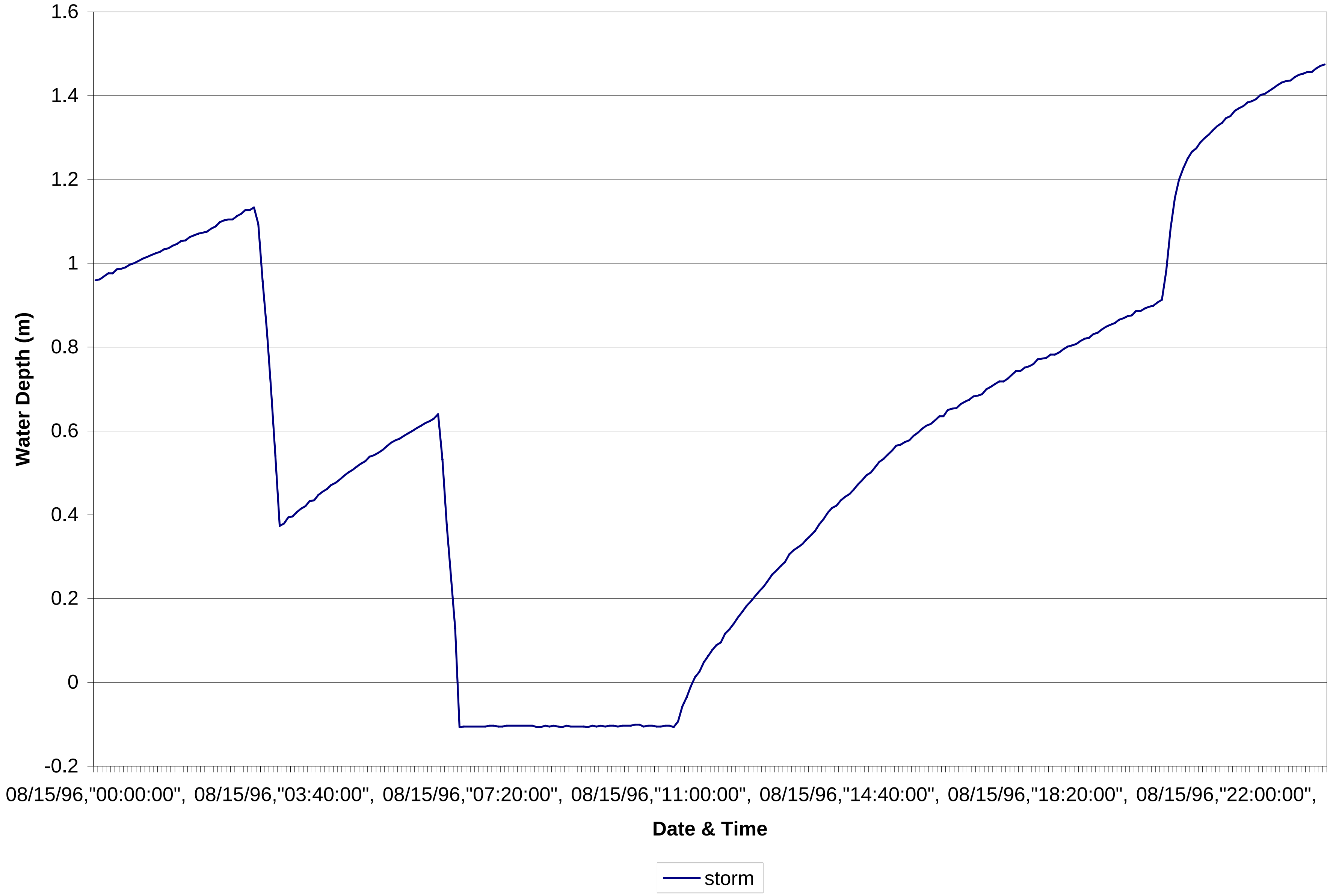
07/25/96,"22:00:00",
07/25/96,"23:00:00",
Date & Time
storm


7
6
5
4
3
2
1
0
-1
water depth (m)
07/30/96,"00:00:00", 07/30/96,"03:35:00", 07/30/96,"07:10:00", 07/30/96,"10:45:00", 07/30/96,"14:20:00", 07/30/96,"17:55:00", 07/30/96,"21:30:00",
date & time
CSO
Storm
LFI

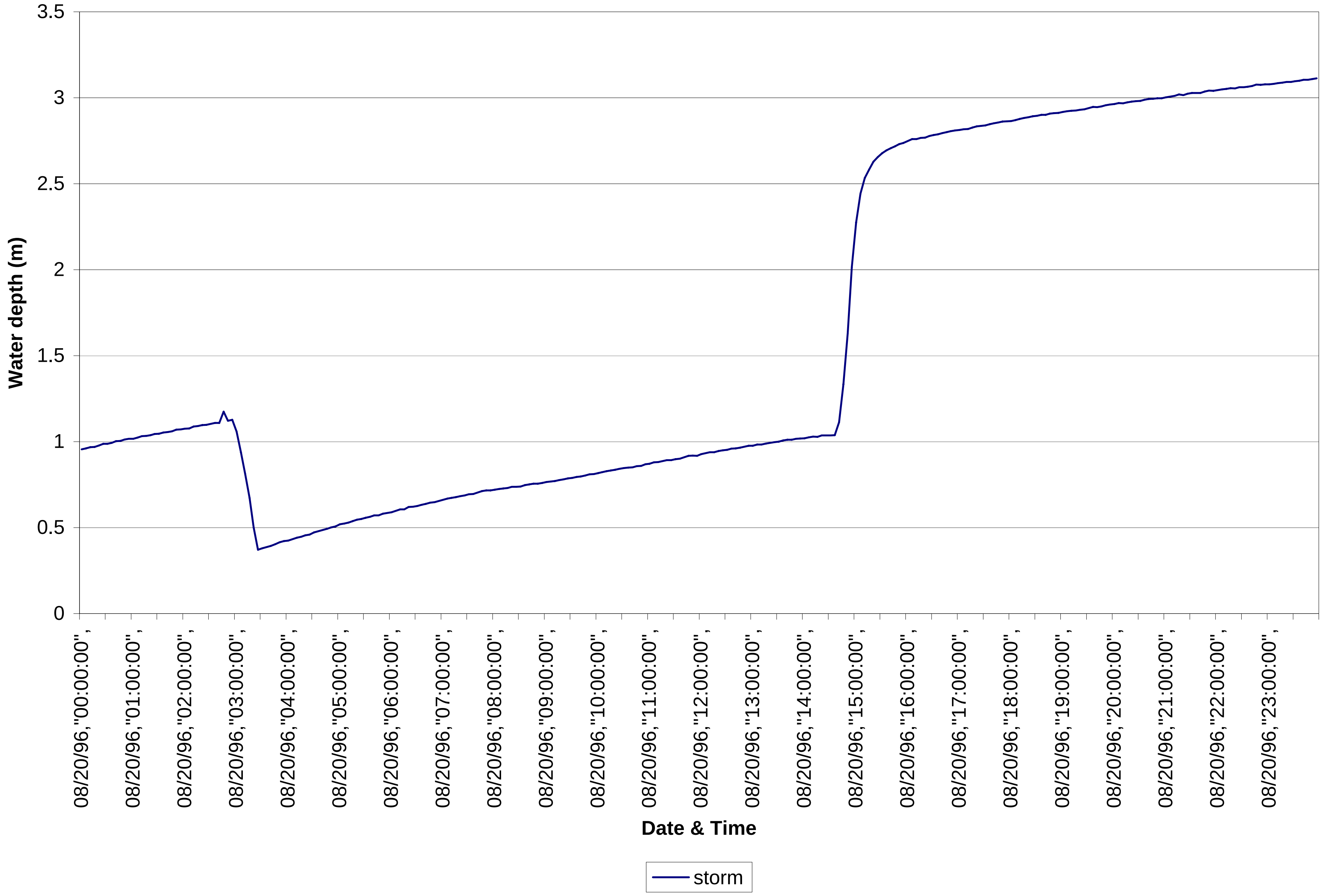


1.4
1.2
1
0.8
0.6
0.4
0.2
0
8-
/01/96,"00:00:00", 08/01/96,"03:35:00", 08/01/96,"07:10:00", 08/01/96,"10:45:00", 08/01/96,"14:20:00", 08/01/96,"17:55:00", 08/01/96,"21:30:00",
storm

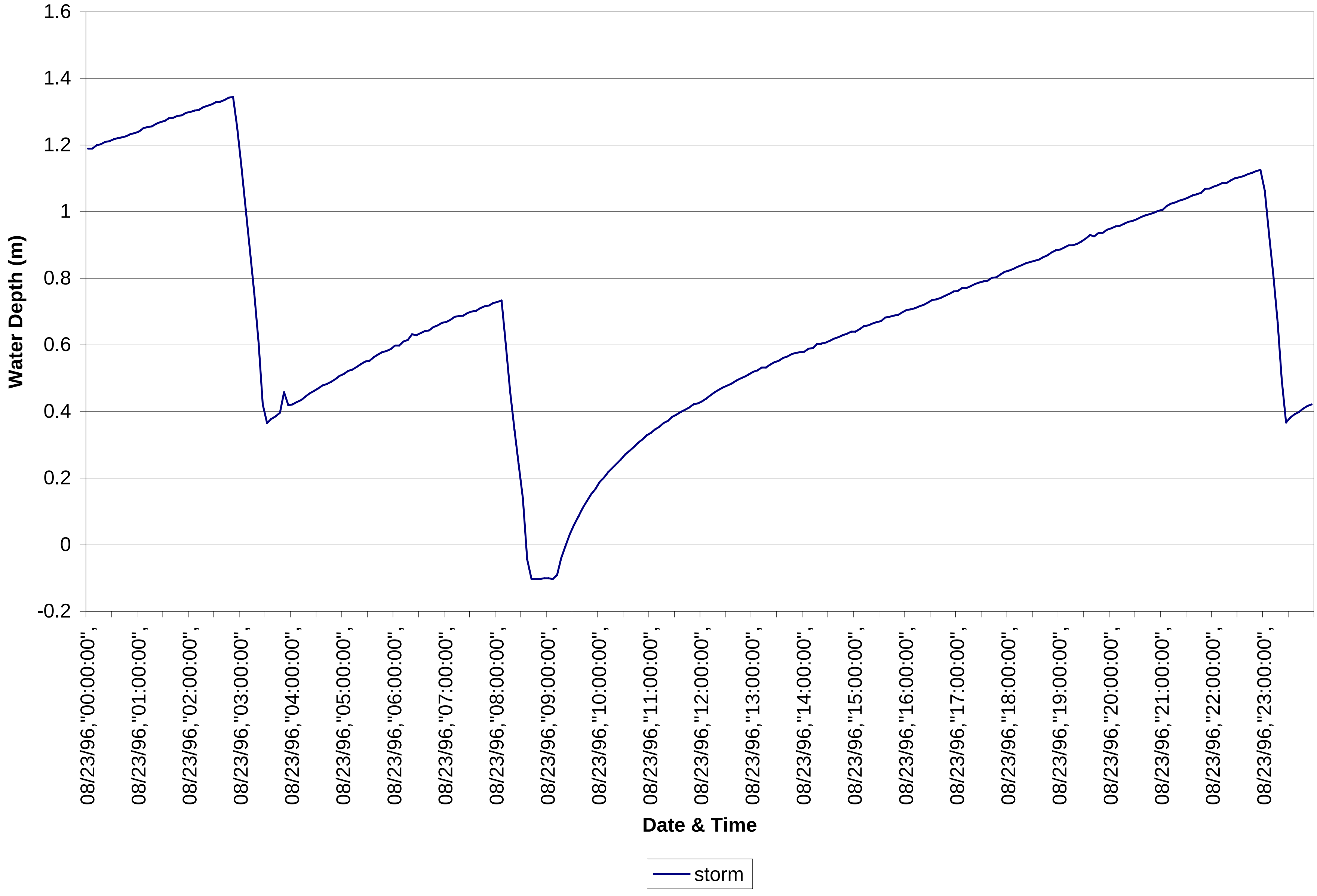

7
6
5
4
3
2
1
0
Water Depth (m)
08/08/96,"00:00:00",
08/08/96,"03:35:00",
08/08/96,"07:10:00",
08/08/96,"10:45:00",
08/08/96,"14:20:00",
08/08/96,"17:55:00",
08/08/96,"21:30:00",
Date & time
storm



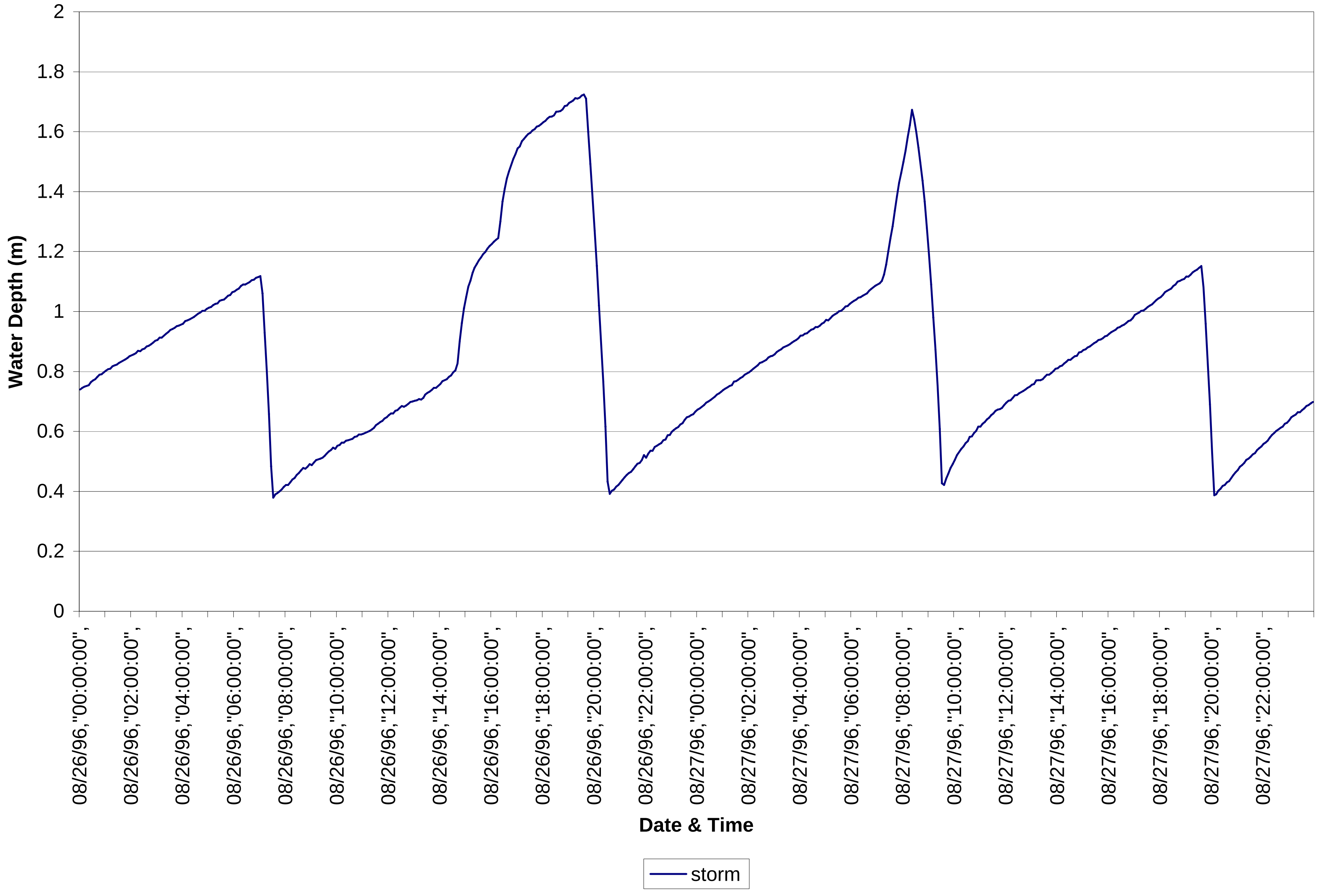
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Water Depth (m)
08/15/96,"00:00:00",
08/15/96,"03:40:00",
08/15/96,"07:20:00",
08/15/96,"11:00:00",
08/15/96,"14:40:00",
08/15/96,"18:20:00",
08/15/96,"22:00:00",
Date & Time
storm

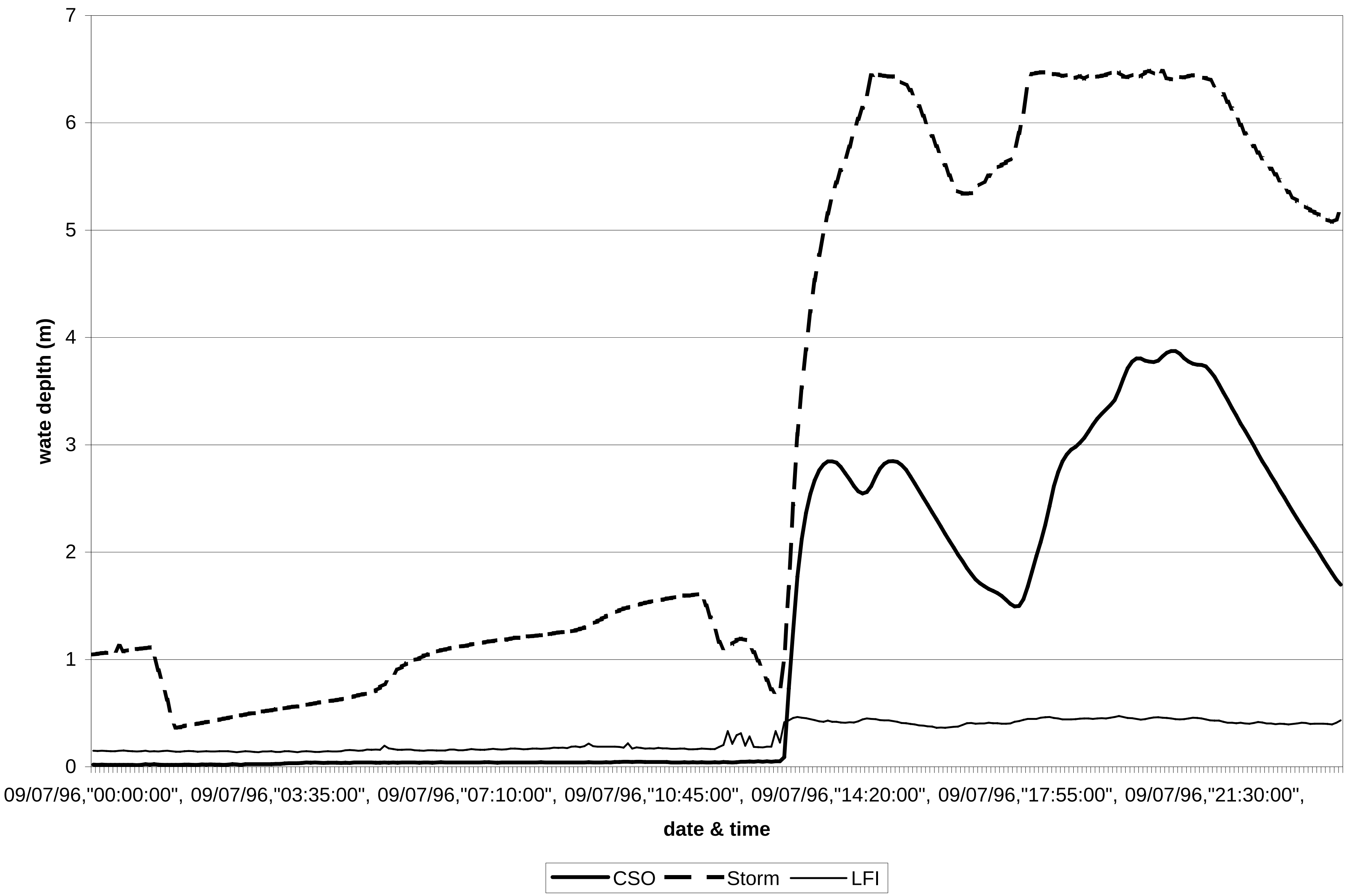


3.5
3
2.5
2
1.5
1
0.5
0
Water depth (m)
08/20/96,"00:00:00",
08/20/96,"01:00:00",
08/20/96,"02:00:00",
08/20/96,"03:00:00",
08/20/96,"04:00:00",
08/20/96,"05:00:00",
08/20/96,"06:00:00",
08/20/96,"07:00:00",
08/20/96,"08:00:00",
08/20/96,"09:00:00",
08/20/96,"10:00:00",
08/20/96,"11:00:00",
08/20/96,"12:00:00",
08/20/96,"13:00:00",
08/20/96,"14:00:00",
08/20/96,"15:00:00",
08/20/96,"16:00:00",
08/20/96,"17:00:00",
08/20/96,"18:00:00",
08/20/96,"19:00:00",
08/20/96,"20:00:00",
08/20/96,"21:00:00",
08/20/96,"22:00:00",
08/20/96,"23:00:00",
Date & Time
storm

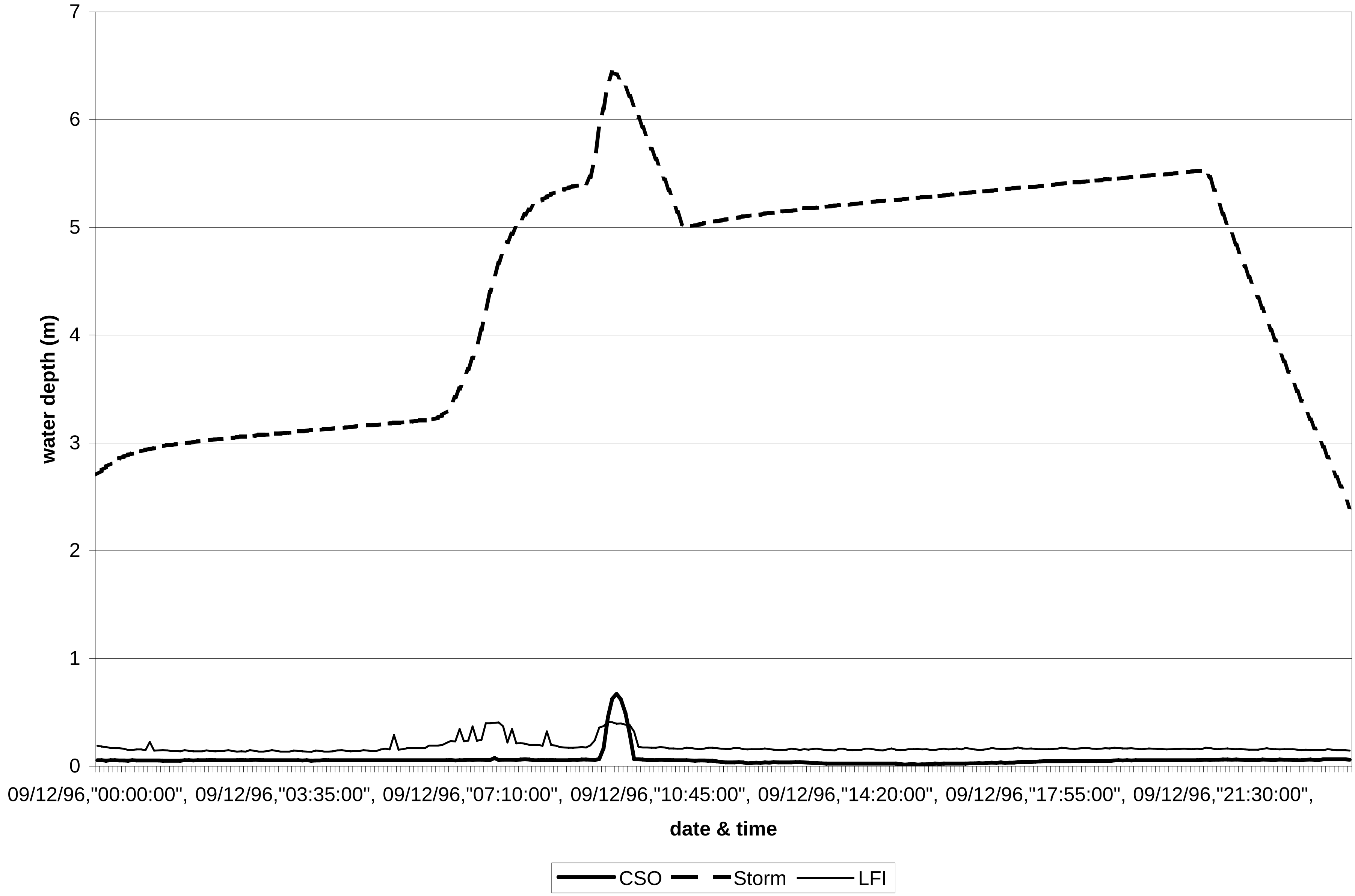


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Water Depth (m)
08/23/96,"00:00:00",
08/23/96,"01:00:00",
08/23/96,"02:00:00",
08/23/96,"03:00:00",
08/23/96,"04:00:00",
08/23/96,"05:00:00",
08/23/96,"06:00:00",
08/23/96,"07:00:00",
08/23/96,"08:00:00",
08/23/96,"09:00:00",
08/23/96,"10:00:00",
08/23/96,"11:00:00",
08/23/96,"12:00:00",
08/23/96,"13:00:00",
08/23/96,"14:00:00",
08/23/96,"15:00:00",
08/23/96,"16:00:00",
08/23/96,"17:00:00",
08/23/96,"18:00:00",
08/23/96,"19:00:00",
08/23/96,"20:00:00",
08/23/96,"21:00:00",
08/23/96,"22:00:00",
08/23/96,"23:00:00",
Date & Time
storm

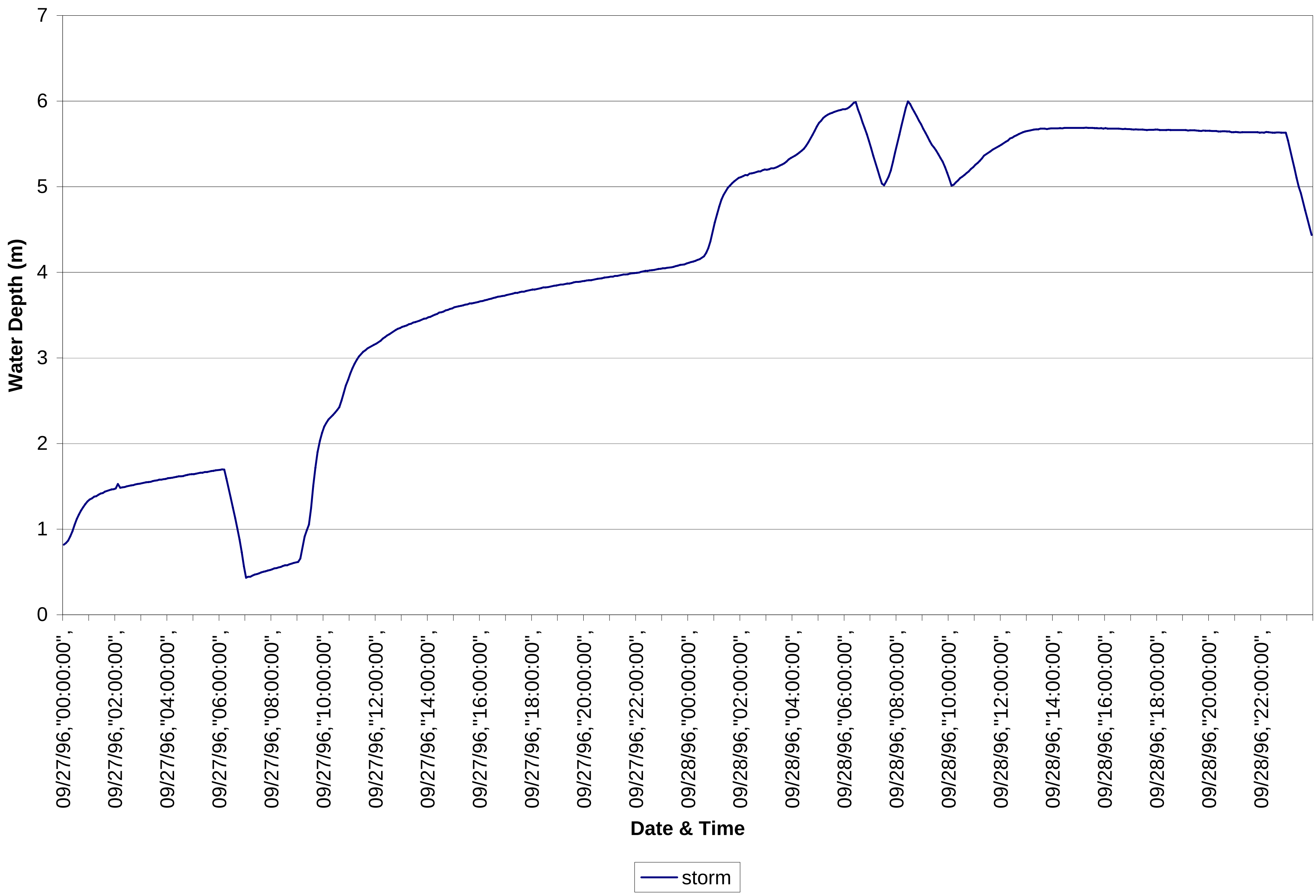

Water Depth (m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
08/26/96,"00:00:00",
08/26/96,"02:00:00",
08/26/96,"04:00:00",
08/26/96,"06:00:00",
08/26/96,"08:00:00",
08/26/96,"10:00:00",
08/26/96,"12:00:00",
08/26/96,"14:00:00",
08/26/96,"16:00:00",
08/26/96,"18:00:00",
08/26/96,"20:00:00",
08/26/96,"22:00:00",
08/27/96,"00:00:00",
08/27/96,"02:00:00",
08/27/96,"04:00:00",
08/27/96,"06:00:00",
08/27/96,"08:00:00",
08/27/96,"10:00:00",
08/27/96,"12:00:00",
08/27/96,"14:00:00",
08/27/96,"16:00:00",
08/27/96,"18:00:00",
08/27/96,"20:00:00",
08/27/96,"22:00:00",
Date & Time
storm



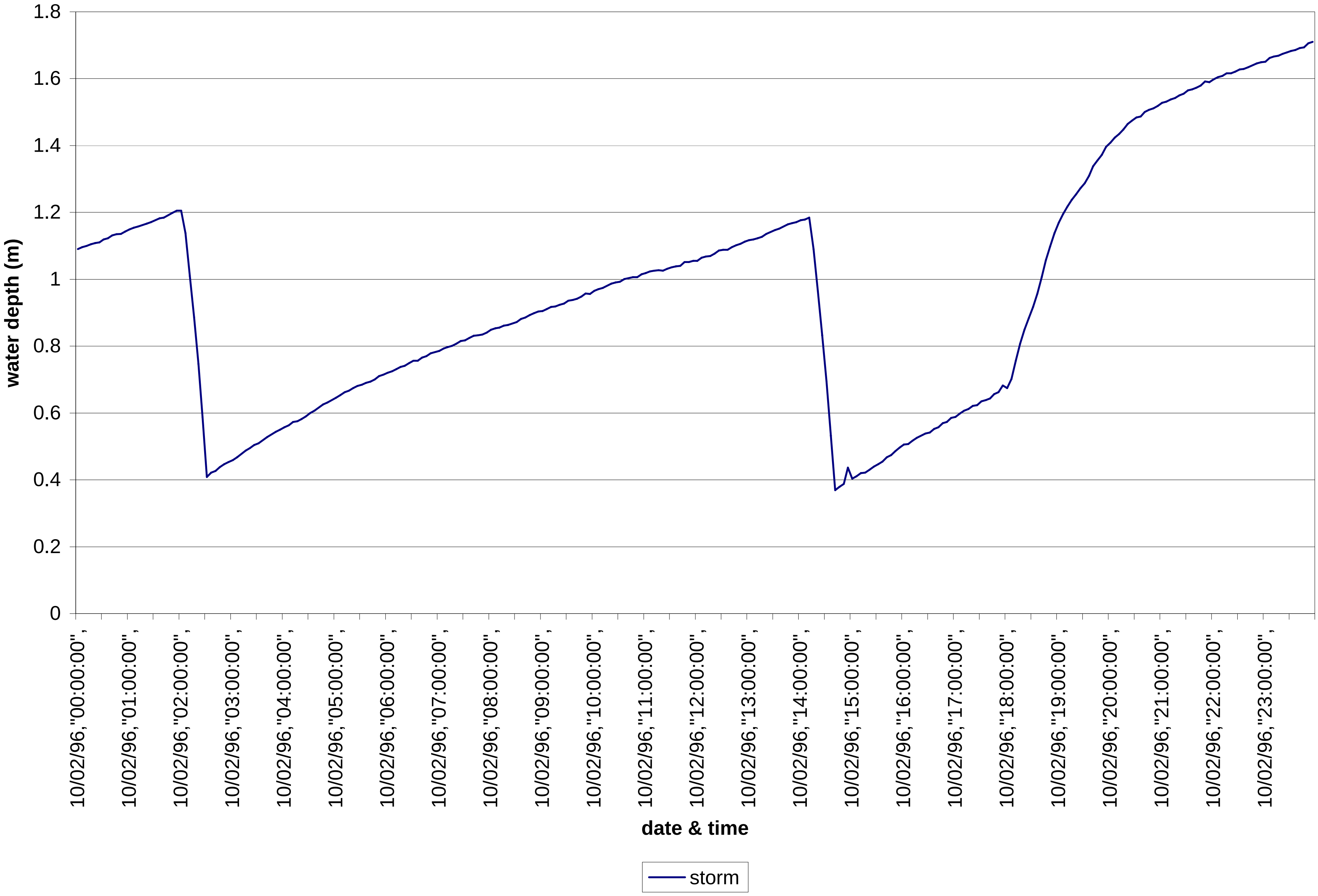
7
6
5
4
3
2
1
0
wate deplth (m)
09/07/96,"00:00:00",
09/07/96,"03:35:00",
09/07/96,"07:10:00",
09/07/96,"10:45:00",
09/07/96,"14:20:00",
09/07/96,"17:55:00",
09/07/96,"21:30:00",
date & time
CSO
Storm
LFI



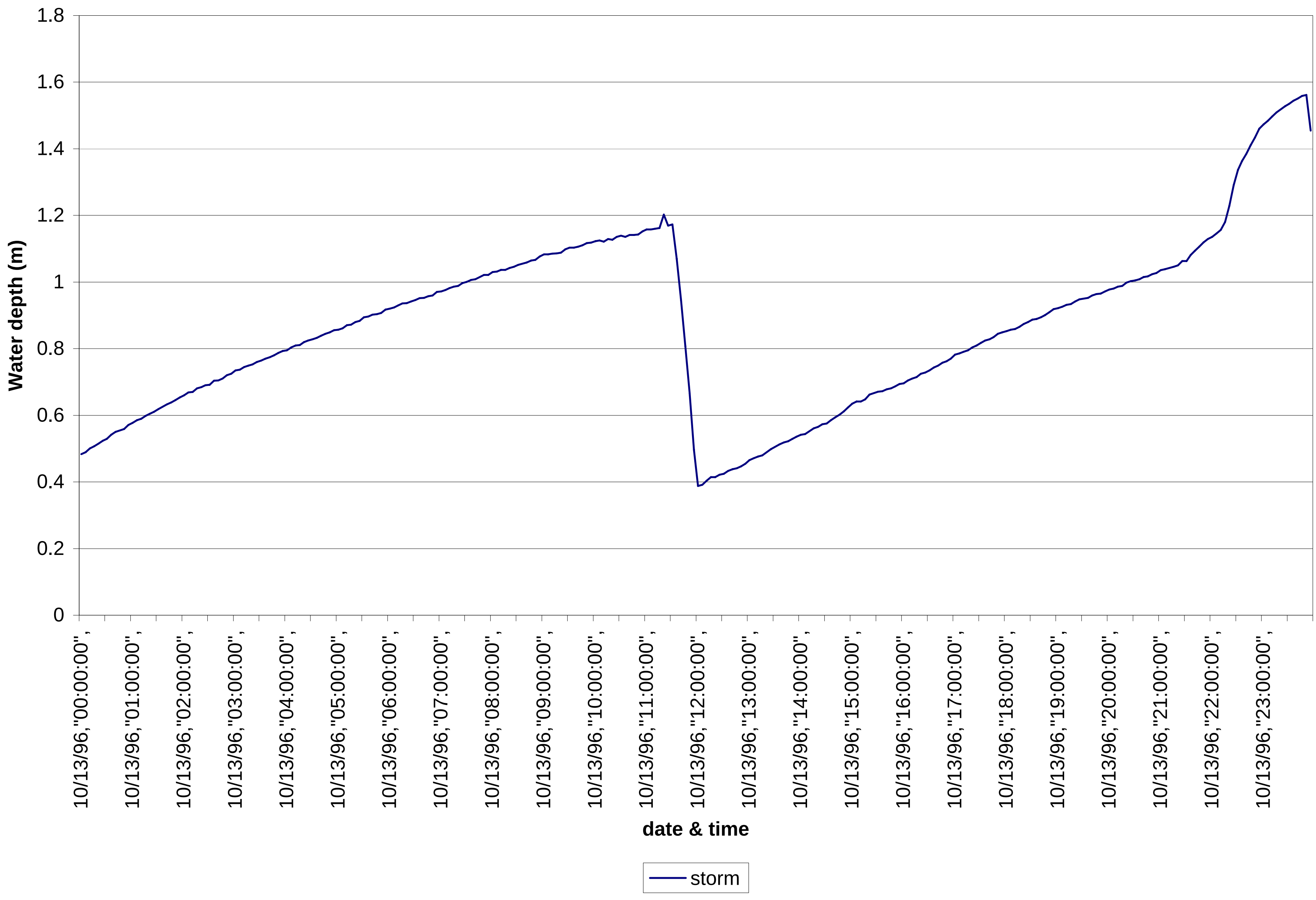
7
6
5
4
3
2
1
0
water depth (m)
09/12/96,"00:00:00",
09/12/96,"03:35:00",
09/12/96,"07:10:00",
09/12/96,"10:45:00",
09/12/96,"14:20:00",
09/12/96,"17:55:00",
09/12/96,"21:30:00",
date & time
CSO
Storm
LFI



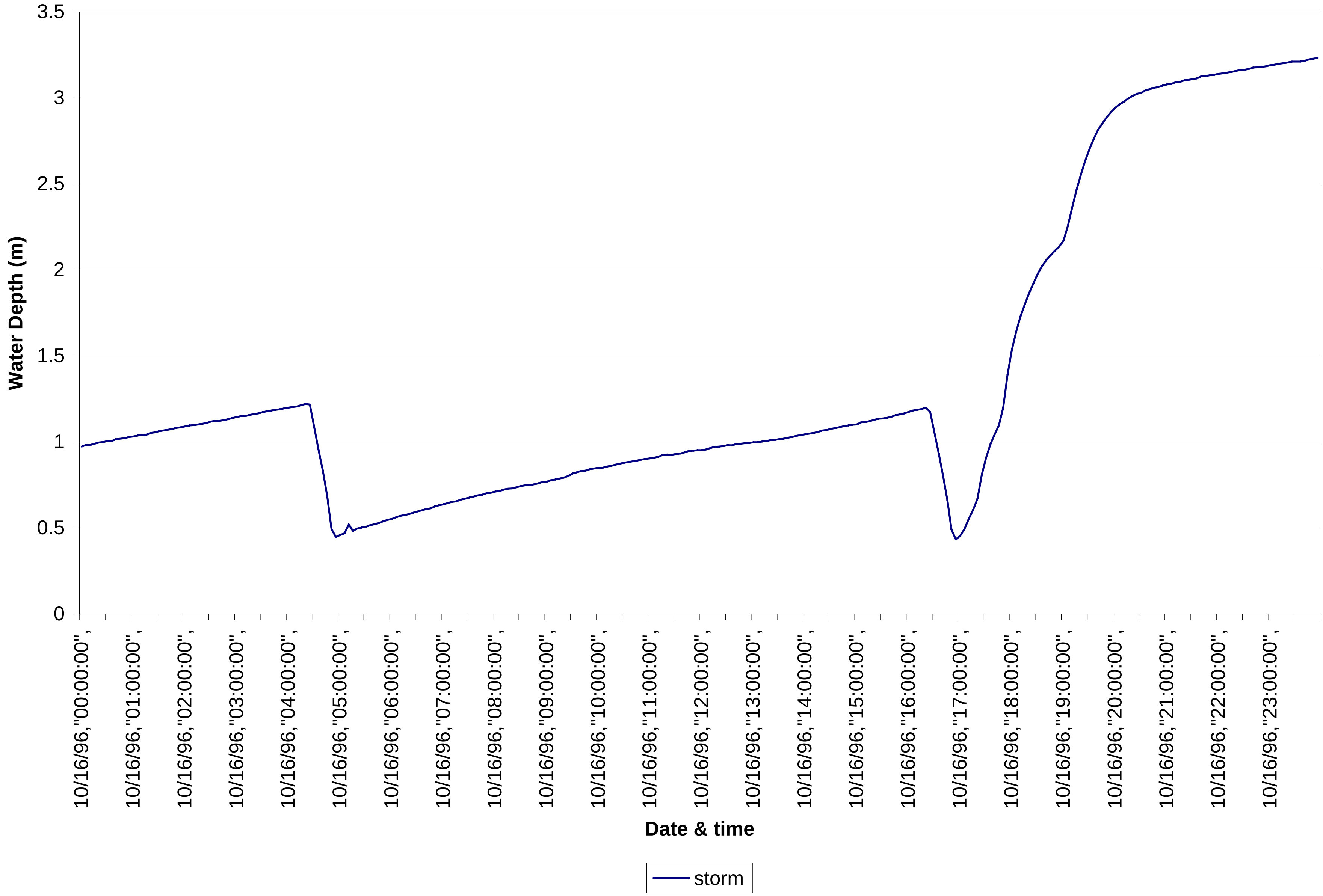
Water Depth (m)
0
1
2
3
4
5
6
7
09/27/96,"00:00:00",
09/27/96,"02:00:00",
09/27/96,"04:00:00",
09/27/96,"06:00:00",
09/27/96,"08:00:00",
09/27/96,"10:00:00",
09/27/96,"12:00:00",
09/27/96,"14:00:00",
09/27/96,"16:00:00",
09/27/96,"18:00:00",
09/27/96,"20:00:00",
09/27/96,"22:00:00",
09/28/96,"00:00:00",
09/28/96,"02:00:00",
09/28/96,"04:00:00",
09/28/96,"06:00:00",
09/28/96,"08:00:00",
09/28/96,"10:00:00",
09/28/96,"12:00:00",
09/28/96,"14:00:00",
09/28/96,"16:00:00",
09/28/96,"18:00:00",
09/28/96,"20:00:00",
09/28/96,"22:00:00",
Date & Time
storm



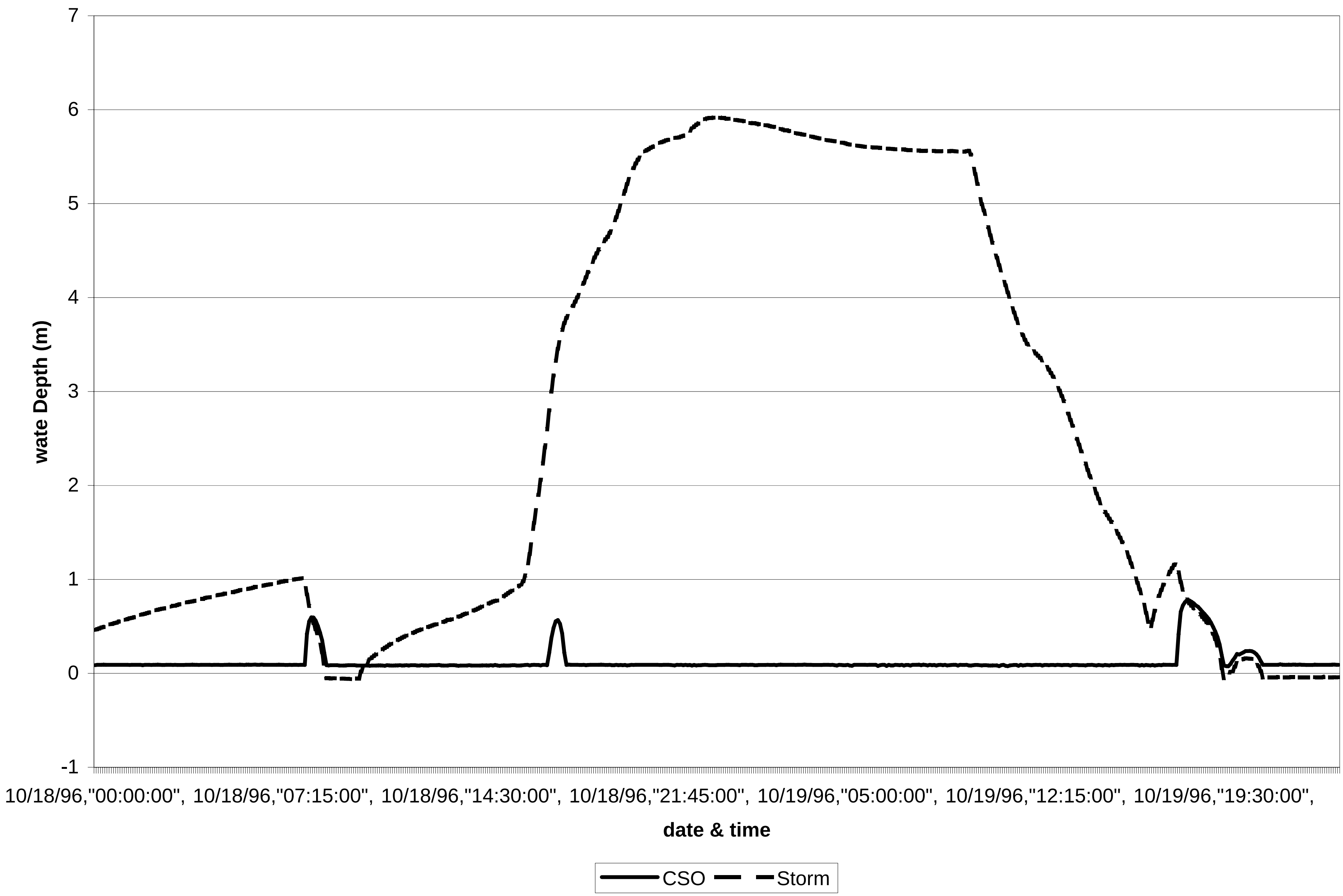
water depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/02/96,"00:00:00",
10/02/96,"01:00:00",
10/02/96,"02:00:00",
10/02/96,"03:00:00",
10/02/96,"04:00:00",
10/02/96,"05:00:00",
10/02/96,"06:00:00",
10/02/96,"07:00:00",
10/02/96,"08:00:00",
10/02/96,"09:00:00",
10/02/96,"10:00:00",
10/02/96,"11:00:00",
10/02/96,"12:00:00",
10/02/96,"13:00:00",
10/02/96,"14:00:00",
10/02/96,"15:00:00",
10/02/96,"16:00:00",
10/02/96,"17:00:00",
10/02/96,"18:00:00",
10/02/96,"19:00:00",
10/02/96,"20:00:00",
10/02/96,"21:00:00",
10/02/96,"22:00:00",
10/02/96,"23:00:00",
date & time
storm



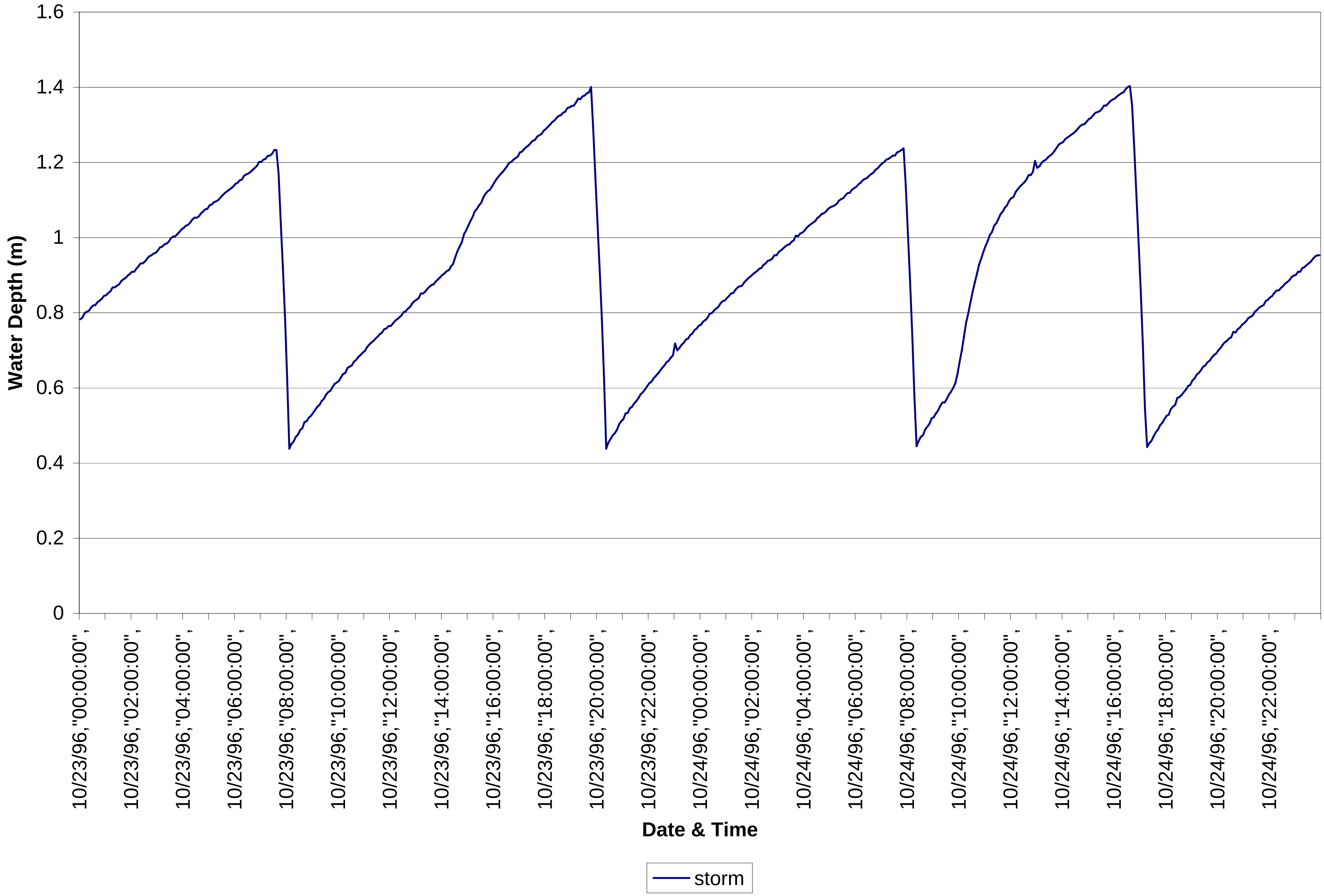
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Water depth (m)
10/13/96,"00:00:00",
10/13/96,"01:00:00",
10/13/96,"02:00:00",
10/13/96,"03:00:00",
10/13/96,"04:00:00",
10/13/96,"05:00:00",
10/13/96,"06:00:00",
10/13/96,"07:00:00",
10/13/96,"08:00:00",
10/13/96,"09:00:00",
10/13/96,"10:00:00",
10/13/96,"11:00:00",
10/13/96,"12:00:00",
10/13/96,"13:00:00",
10/13/96,"14:00:00",
10/13/96,"15:00:00",
10/13/96,"16:00:00",
10/13/96,"17:00:00",
10/13/96,"18:00:00",
10/13/96,"19:00:00",
10/13/96,"20:00:00",
10/13/96,"21:00:00",
10/13/96,"22:00:00",
10/13/96,"23:00:00",
date & time
storm



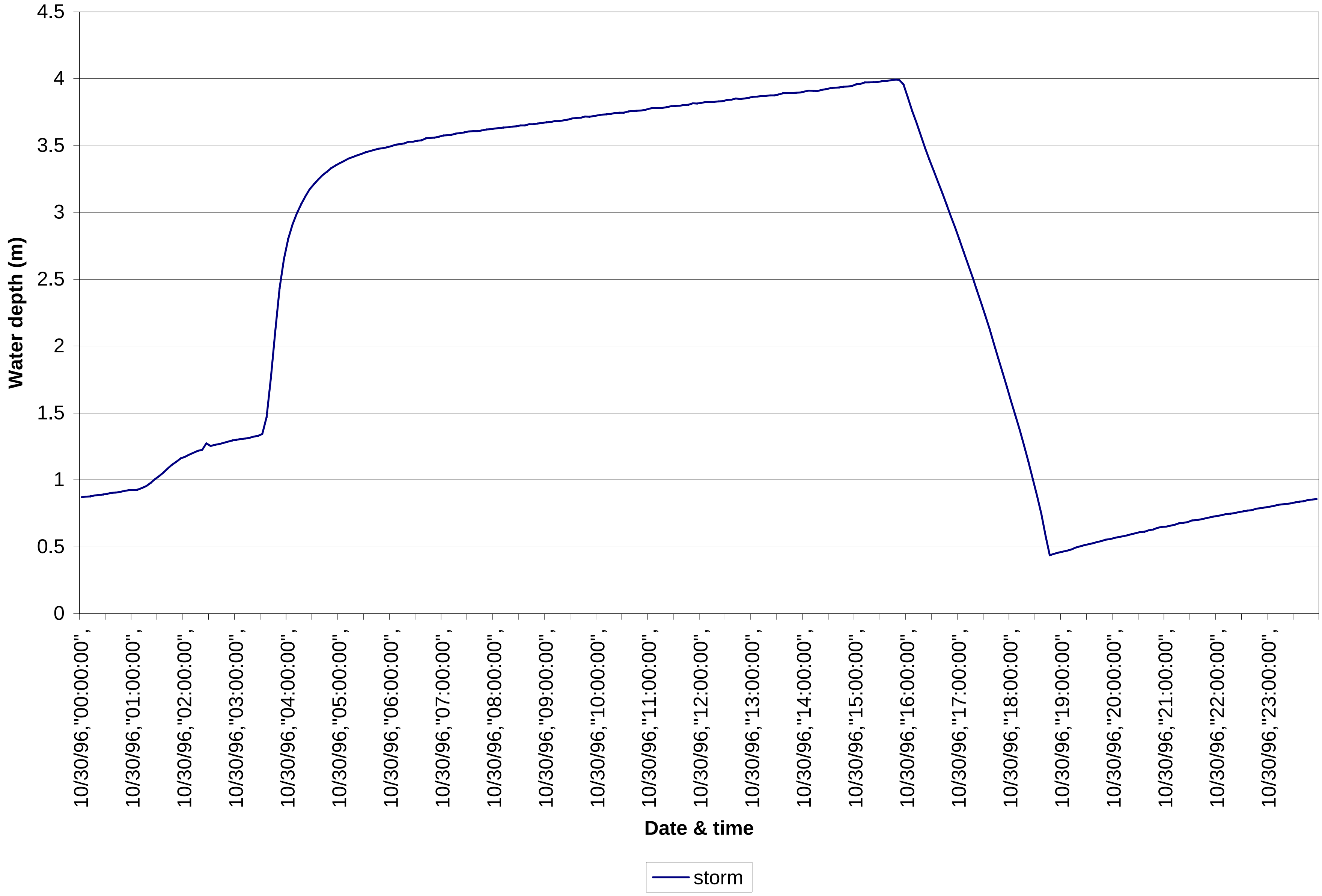
Water Depth (m)
3.5
3
2.5
2
1.5
1
0.5
0
10/16/96,"00:00:00",
10/16/96,"01:00:00",
10/16/96,"02:00:00",
10/16/96,"03:00:00",
10/16/96,"04:00:00",
10/16/96,"05:00:00",
10/16/96,"06:00:00",
10/16/96,"07:00:00",
10/16/96,"08:00:00",
10/16/96,"09:00:00",
10/16/96,"10:00:00",
10/16/96,"11:00:00",
10/16/96,"12:00:00",
10/16/96,"13:00:00",
10/16/96,"14:00:00",
10/16/96,"15:00:00",
10/16/96,"16:00:00",
10/16/96,"17:00:00",
10/16/96,"18:00:00",
10/16/96,"19:00:00",
10/16/96,"20:00:00",
10/16/96,"21:00:00",
10/16/96,"22:00:00",
10/16/96,"23:00:00",
Date & time
storm



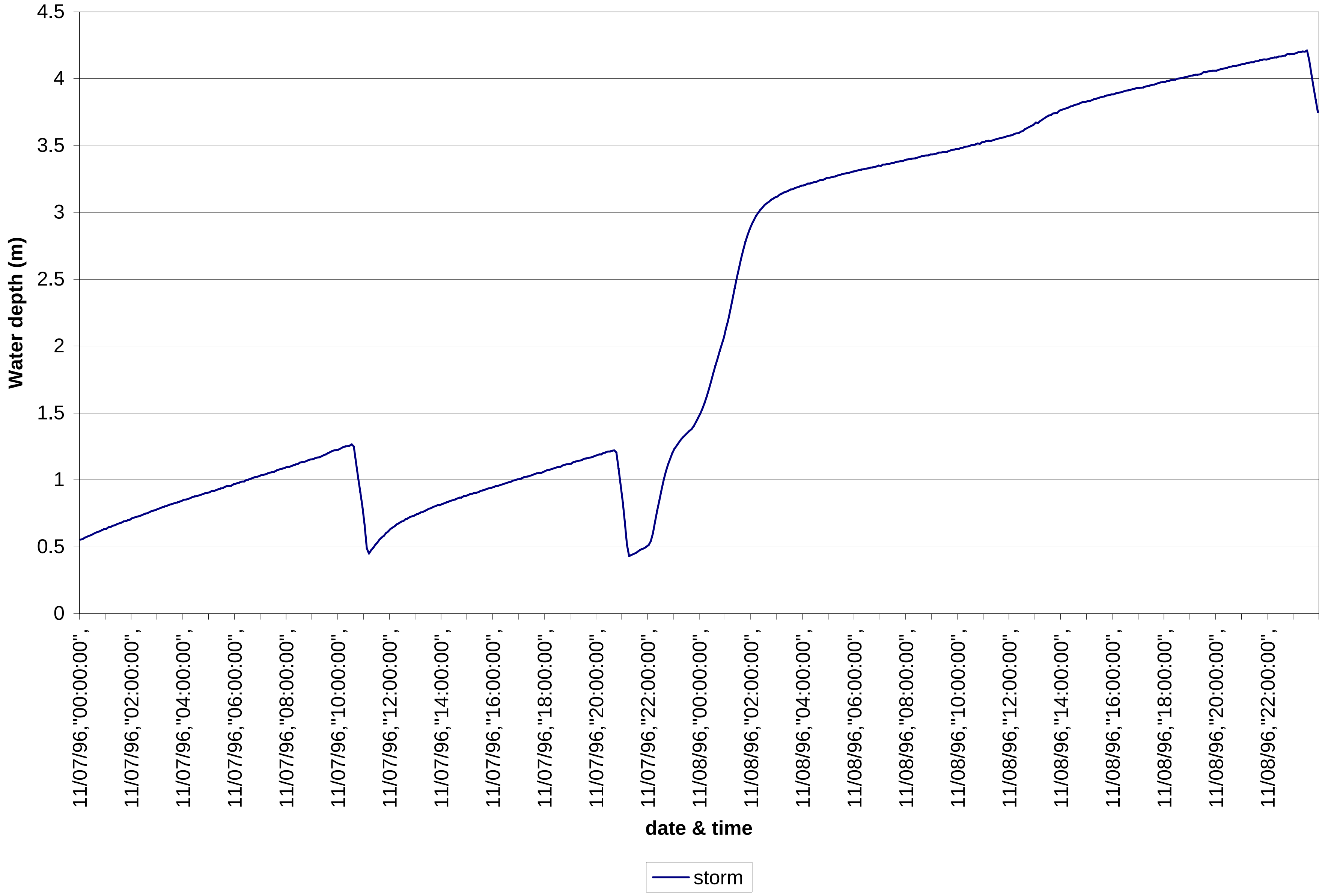
7
6
5
4
3
2
1
0
-1
wate Depth (m)
10/18/96,"00:00:00", 10/18/96,"07:15:00", 10/18/96,"14:30:00", 10/18/96,"21:45:00", 10/19/96,"05:00:00", 10/19/96,"12:15:00", 10/19/96,"19:30:00",
date & time
CSO
Storm

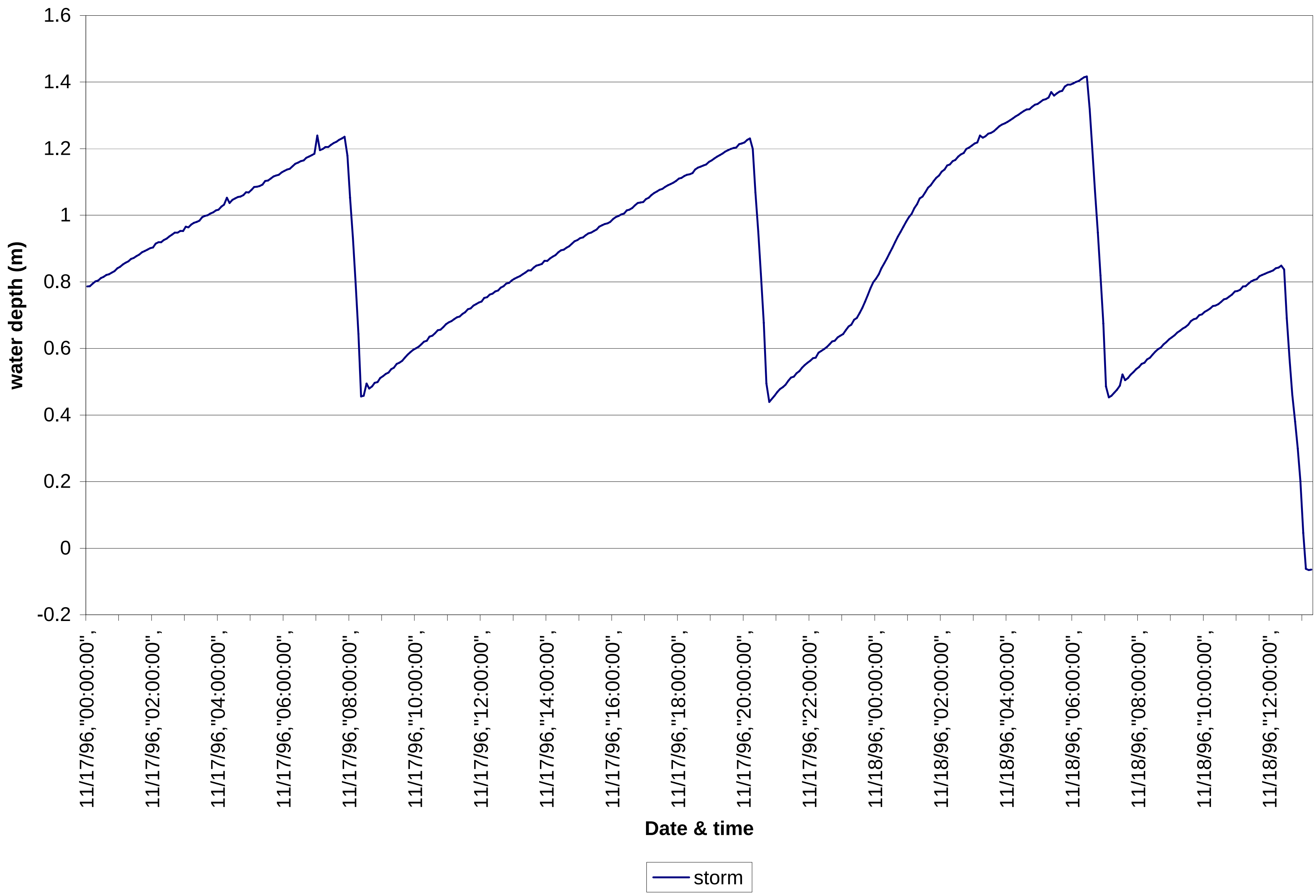


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Water Depth (m)
10/23/96,"00:00:00",
10/23/96,"02:00:00",
10/23/96,"04:00:00",
10/23/96,"06:00:00",
10/23/96,"08:00:00",
10/23/96,"10:00:00",
10/23/96,"12:00:00",
10/23/96,"14:00:00",
10/23/96,"16:00:00",
10/23/96,"18:00:00",
10/23/96,"20:00:00",
10/23/96,"22:00:00",
10/24/96,"00:00:00",
10/24/96,"02:00:00",
10/24/96,"04:00:00",
10/24/96,"06:00:00",
10/24/96,"08:00:00",
10/24/96,"10:00:00",
10/24/96,"12:00:00",
10/24/96,"14:00:00",
10/24/96,"16:00:00",
10/24/96,"18:00:00",
10/24/96,"20:00:00",
10/24/96,"22:00:00",
Date & Time
storm

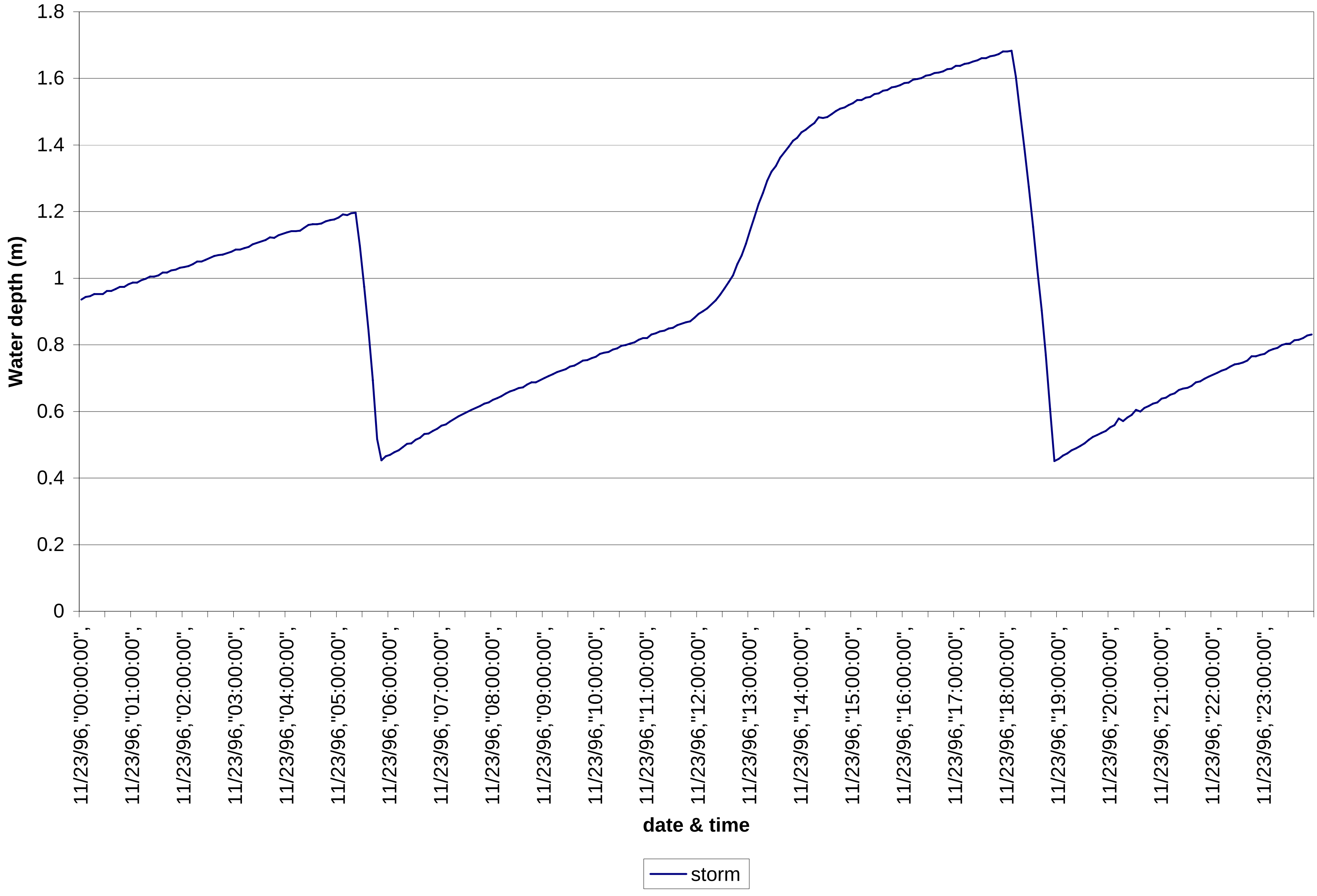


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Water depth (m)
10/30/96,"00:00:00",
10/30/96,"01:00:00",
10/30/96,"02:00:00",
10/30/96,"03:00:00",
10/30/96,"04:00:00",
10/30/96,"05:00:00",
10/30/96,"06:00:00",
10/30/96,"07:00:00",
10/30/96,"08:00:00",
10/30/96,"09:00:00",
10/30/96,"10:00:00",
10/30/96,"11:00:00",
10/30/96,"12:00:00",
10/30/96,"13:00:00",
10/30/96,"14:00:00",
10/30/96,"15:00:00",
10/30/96,"16:00:00",
10/30/96,"17:00:00",
10/30/96,"18:00:00",
10/30/96,"19:00:00",
10/30/96,"20:00:00",
10/30/96,"21:00:00",
10/30/96,"22:00:00",
10/30/96,"23:00:00",
Date & time
storm


Water depth (m)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
11/07/96,"00:00:00",
11/07/96,"02:00:00",
11/07/96,"04:00:00",
11/07/96,"06:00:00",
11/07/96,"08:00:00",
11/07/96,"10:00:00",
11/07/96,"12:00:00",
11/07/96,"14:00:00",
11/07/96,"16:00:00",
11/07/96,"18:00:00",
11/07/96,"20:00:00",
11/07/96,"22:00:00",
11/08/96,"00:00:00",
11/08/96,"02:00:00",
11/08/96,"04:00:00",
11/08/96,"06:00:00",
11/08/96,"08:00:00",
11/08/96,"10:00:00",
11/08/96,"12:00:00",
11/08/96,"14:00:00",
11/08/96,"16:00:00",
11/08/96,"18:00:00",
11/08/96,"20:00:00",
11/08/96,"22:00:00",
date & time
storm



1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
water depth (m)
11/17/96,"00:00:00",
11/17/96,"02:00:00",
11/17/96,"04:00:00",
11/17/96,"06:00:00",
11/17/96,"08:00:00",
11/17/96,"10:00:00",
11/17/96,"12:00:00",
11/17/96,"14:00:00",
11/17/96,"16:00:00",
11/17/96,"18:00:00",
11/17/96,"20:00:00",
11/17/96,"22:00:00",
11/18/96,"00:00:00",
11/18/96,"02:00:00",
11/18/96,"04:00:00",
11/18/96,"06:00:00",
11/18/96,"08:00:00",
11/18/96,"10:00:00",
11/18/96,"12:00:00",
Date & time
storm



1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Water depth (m)
11/23/96,"00:00:00",
11/23/96,"01:00:00",
11/23/96,"02:00:00",
11/23/96,"03:00:00",
11/23/96,"04:00:00",
11/23/96,"05:00:00",
11/23/96,"06:00:00",
11/23/96,"07:00:00",
11/23/96,"08:00:00",
11/23/96,"09:00:00",
11/23/96,"10:00:00",
11/23/96,"11:00:00",
11/23/96,"12:00:00",
11/23/96,"13:00:00",
11/23/96,"14:00:00",
11/23/96,"15:00:00",
11/23/96,"16:00:00",
11/23/96,"17:00:00",
11/23/96,"18:00:00",
11/23/96,"19:00:00",
11/23/96,"20:00:00",
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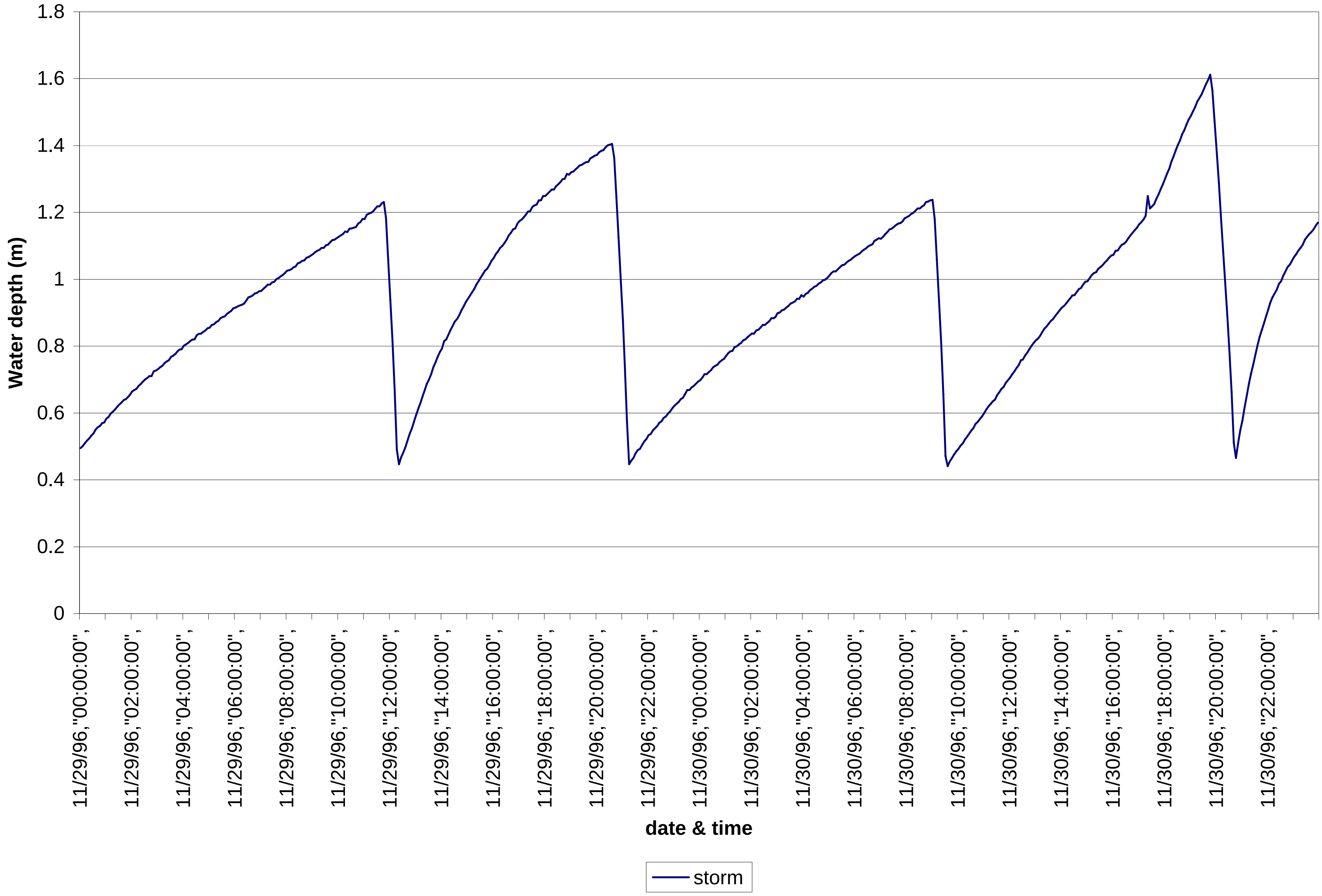
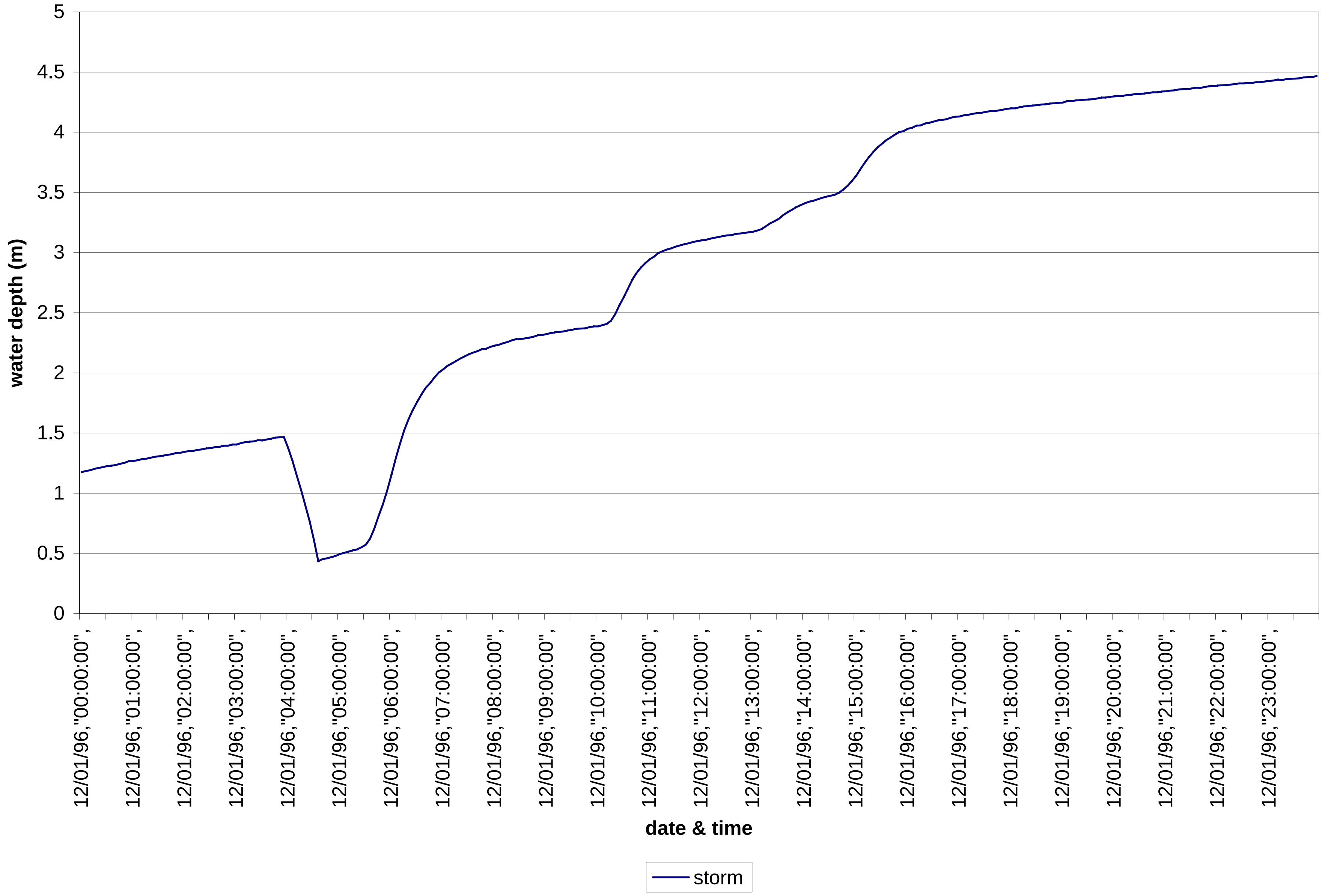
11/23/96,"22:00:00",
11/23/96,"23:00:00",
date & time
storm



Water depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
11/29/96,"00:00:00",
11/29/96,"02:00:00",
11/29/96,"04:00:00",
11/29/96,"06:00:00",
11/29/96,"08:00:00",
11/29/96,"10:00:00",
11/29/96,"12:00:00",
11/29/96,"14:00:00",
11/29/96,"16:00:00",
11/29/96,"18:00:00",
11/29/96,"20:00:00",
11/29/96,"22:00:00",
11/30/96,"00:00:00",
11/30/96,"02:00:00",
11/30/96,"04:00:00",
11/30/96,"06:00:00",
11/30/96,"08:00:00",
11/30/96,"10:00:00",
11/30/96,"12:00:00",
11/30/96,"14:00:00",
11/30/96,"16:00:00",
11/30/96,"18:00:00",
11/30/96,"20:00:00",
11/30/96,"22:00:00",
date & time
storm



5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
water depth (m)
12/01/96,"00:00:00",
12/01/96,"01:00:00",
12/01/96,"02:00:00",
12/01/96,"03:00:00",
12/01/96,"04:00:00",
12/01/96,"05:00:00",
12/01/96,"06:00:00",
12/01/96,"07:00:00",
12/01/96,"08:00:00",
12/01/96,"09:00:00",
12/01/96,"10:00:00",
12/01/96,"11:00:00",
12/01/96,"12:00:00",
12/01/96,"13:00:00",
12/01/96,"14:00:00",
12/01/96,"15:00:00",
12/01/96,"16:00:00",
12/01/96,"17:00:00",
12/01/96,"18:00:00",
12/01/96,"19:00:00",
12/01/96,"20:00:00",
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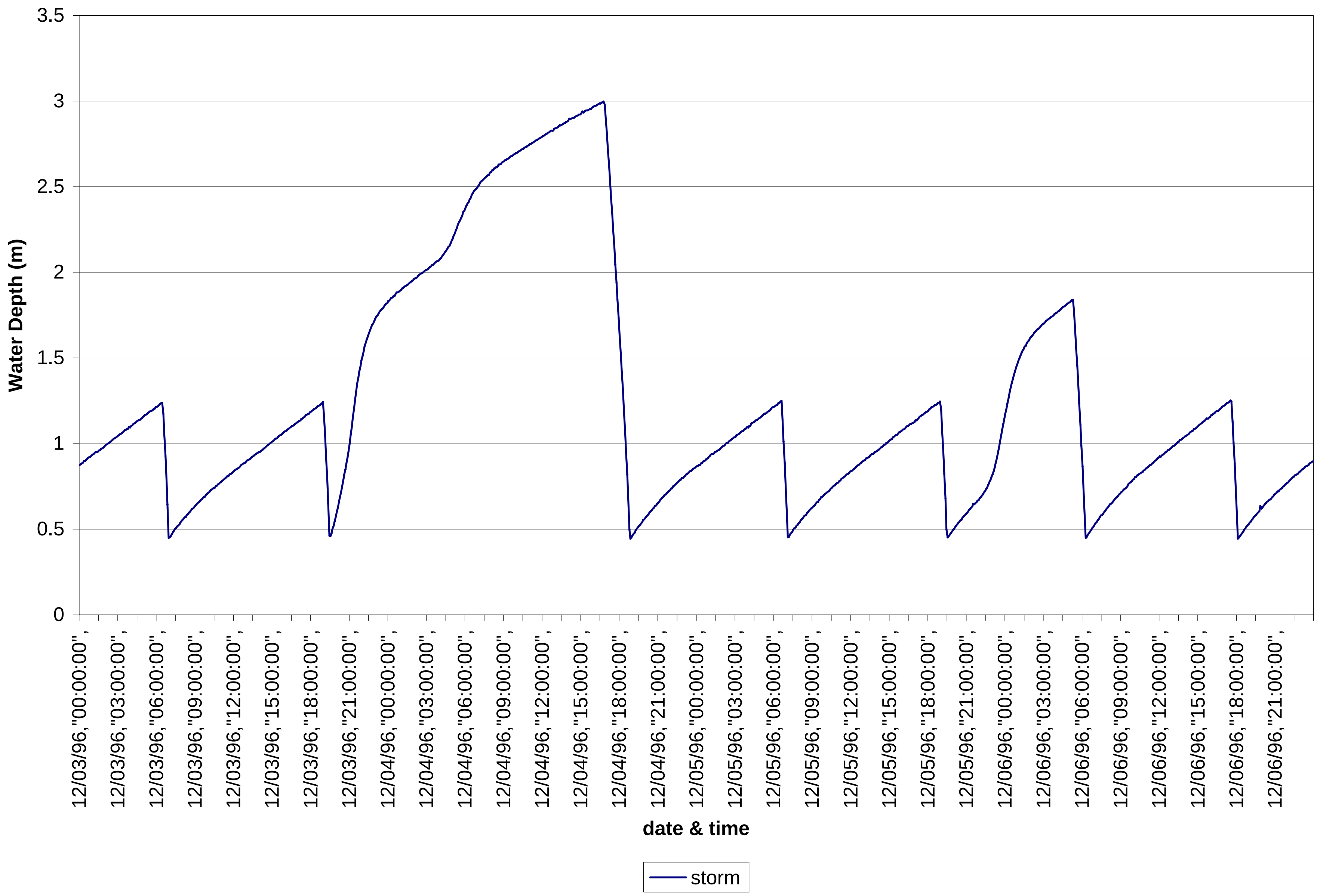
12/01/96,"22:00:00",
12/01/96,"23:00:00",
date & time
storm



3.5
3
2.5
2
1.5
1
0.5
0
Water Depth (m)
12/03/96,"00:00:00",
12/03/96,"03:00:00",
12/03/96,"06:00:00",
12/03/96,"09:00:00",
12/03/96,"12:00:00",
12/03/96,"15:00:00",
12/03/96,"18:00:00",
12/03/96,"21:00:00",
12/04/96,"00:00:00",
12/04/96,"03:00:00",
12/04/96,"06:00:00",
12/04/96,"09:00:00",
12/04/96,"12:00:00",
12/04/96,"15:00:00",
12/04/96,"18:00:00",
12/04/96,"21:00:00",
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12/05/96,"03:00:00",
12/05/96,"06:00:00",
12/05/96,"09:00:00",
12/05/96,"12:00:00",
12/05/96,"15:00:00",
12/05/96,"18:00:00",
12/05/96,"21:00:00",
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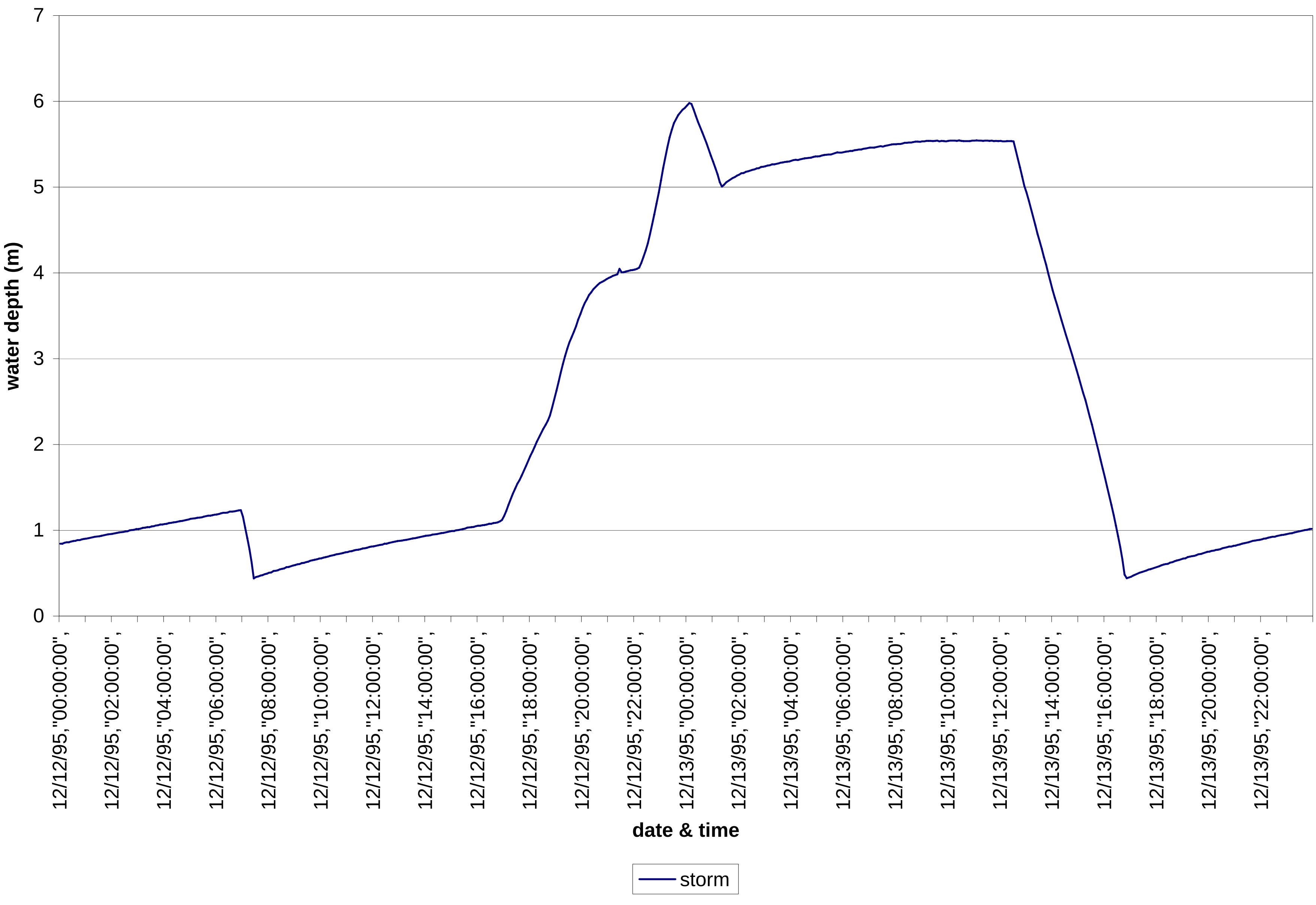
12/06/96,"03:00:00",
12/06/96,"06:00:00",
12/06/96,"09:00:00",
12/06/96,"12:00:00",
12/06/96,"15:00:00",
12/06/96,"18:00:00",
12/06/96,"21:00:00",
date & time
storm



7
6
5
4
3
2
1
0
water depth (m)
12/12/95,"00:00:00",
12/12/95,"02:00:00",
12/12/95,"04:00:00",
12/12/95,"06:00:00",
12/12/95,"08:00:00",
12/12/95,"10:00:00",
12/12/95,"12:00:00",
12/12/95,"14:00:00",
12/12/95,"16:00:00",
12/12/95,"18:00:00",
12/12/95,"20:00:00",
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12/13/95,"02:00:00",
12/13/95,"04:00:00",
12/13/95,"06:00:00",
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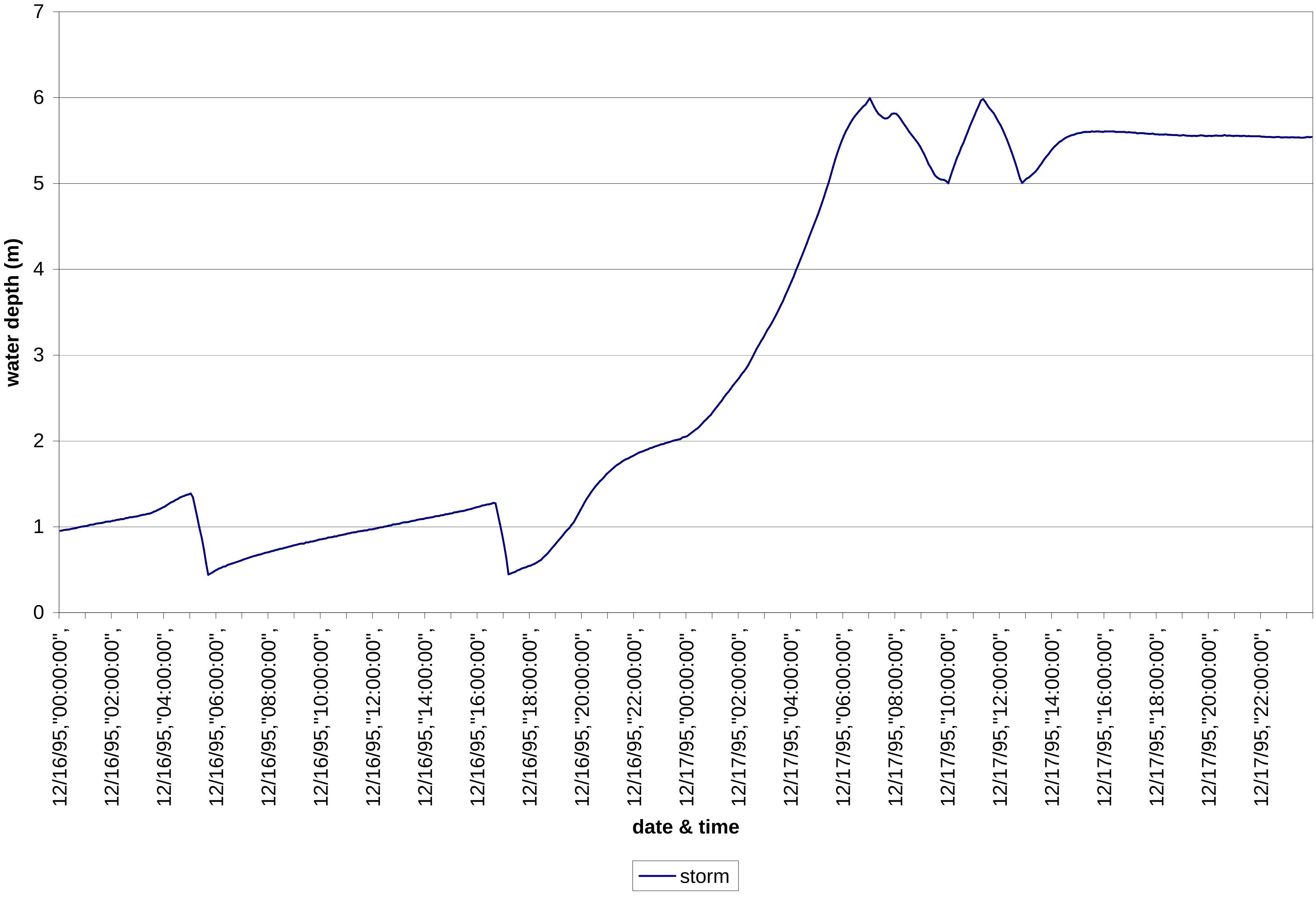
12/13/95,"16:00:00",
12/13/95,"18:00:00",
12/13/95,"20:00:00",
12/13/95,"22:00:00",
date & time
storm



water depth (m)
0
1
2
3
4
5
6
7
12/16/95,"00:00:00",
12/16/95,"02:00:00",
12/16/95,"04:00:00",
12/16/95,"06:00:00",
12/16/95,"08:00:00",
12/16/95,"10:00:00",
12/16/95,"12:00:00",
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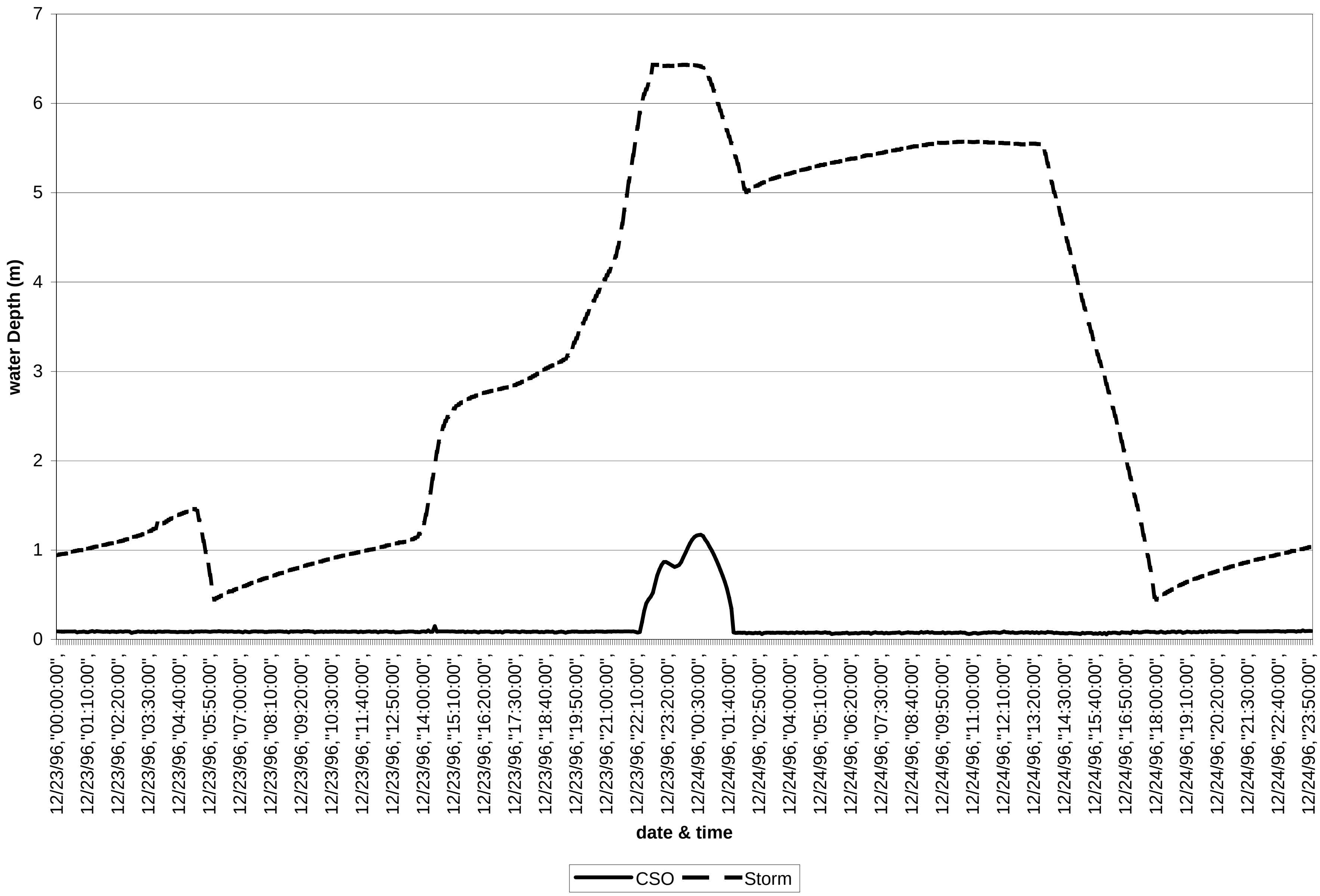
12/17/95,"14:00:00",
12/17/95,"16:00:00",
12/17/95,"18:00:00",
12/17/95,"20:00:00",
12/17/95,"22:00:00",
date & time
storm



water Depth (m)
0
1
2
3
4
5
6
7
date & time
CSO
Storm
12/23/96,"00:00:00",
12/23/96,"01:10:00",
12/23/96,"02:20:00",
12/23/96,"03:30:00",
12/23/96,"04:40:00",
12/23/96,"05:50:00",
12/23/96,"07:00:00",
12/23/96,"08:10:00",
12/23/96,"09:20:00",
12/23/96,"10:30:00",
12/23/96,"11:40:00",
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12/23/96,"16:20:00",
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12/23/96,"23:20:00",
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12/24/96,"05:10:00",
12/24/96,"06:20:00",
12/24/96,"07:30:00",
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12/24/96,"14:30:00",
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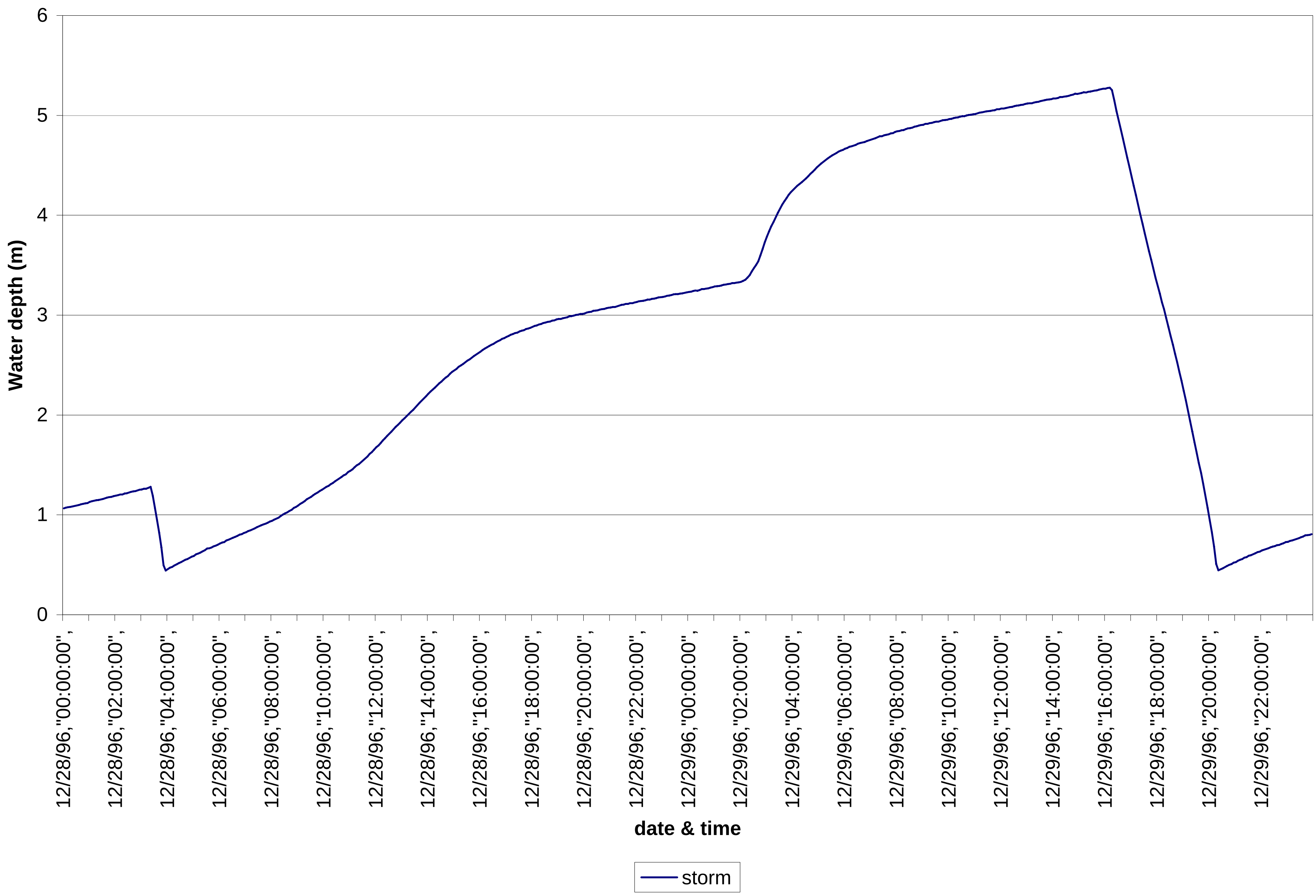
12/24/96,"23:50:00",



Water depth (m)
6
5
4
3
2
1
0
12/28/96,"00:00:00",
12/28/96,"02:00:00",
12/28/96,"04:00:00",
12/28/96,"06:00:00",
12/28/96,"08:00:00",
12/28/96,"10:00:00",
12/28/96,"12:00:00",
12/28/96,"14:00:00",
12/28/96,"16:00:00",
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12/28/96,"20:00:00",
12/28/96,"22:00:00",
12/29/96,"00:00:00",
12/29/96,"02:00:00",
12/29/96,"04:00:00",
12/29/96,"06:00:00",
12/29/96,"08:00:00",
12/29/96,"10:00:00",
12/29/96,"12:00:00",
12/29/96,"14:00:00",
12/29/96,"16:00:00",
12/29/96,"18:00:00",
12/29/96,"20:00:00",
12/29/96,"22:00:00",
date & time
storm