# STORMWATER EXFILTRATION STUDY

for the

City of Fond du Lac
First on the Lake

prepared by

HNTB

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## Introduction

Clearwater entry into sanitary sewers is a concern for many urban areas. Excess flow in a sanitary system during wet weather periods may result in bypasses within the system and at the wastewater treatment plant, which can have a detrimental effect on receiving water quality.

Under bypass conditions, untreated sanitary sewerage discharges directly into Lake Winnebago, either from the plant or by pumping to storm sewers. Over the years, the City of Fond du Lac has experienced both types of bypasses, causing concern about the sources of clearwater entry.

The City of Fond du Lac has many stormwater drainage basins which utilize lift stations to discharge stormwater into creeks and rivers tributary to Lake Winnebago. The purpose of this project was to study the First Street/Reserve Avenue and Taft Street/Bank Street stormwater drainage systems to identify potential sources of stormwater exfiltration from storm sewers to sanitary sewers systems in these areas. The exfiltration phenomenon occurs when stormwater from leaking storm sewers floods the trenches of non-watertight sanitary sewers. This report describes the methodologies used to evaluate these two storm sewer systems, presents the results of the study, and describes recommendations.

## Project Background and Recent Improvements

The City has been conducting flow monitoring in the sanitary sewers for the past 15 years. The results of the monitoring have guided the City's annual sewer replacement program, which is aimed in part at reducing the amount of clearwater entry into the system. In addition, the sanitary sewer interceptor passing through the study area was replaced between 1990 and 1995 in an effort to alleviate surcharging and basement backups. However, results of sanitary sewer monitoring following these improvements indicated that surcharging persisted in the Taft/Bank and First Street portions of the sanitary system during storm events. Furthermore, reports of basement flooding received following heavy rains in 1996 and 1997 were concentrated in areas coinciding with the Taft/Bank and First/Reserve storm sewer systems, suggesting there may be another source contributing to flow in the sanitary sewers. Because of this, the City began monitoring of certain storm sewers in 1998 for the purpose of comparing water surface elevations in the storm and sanitary systems.

As a result of separate investigations into collection system capacities, the City also completed construction of a new sanitary sewer interceptor within the project area in March of 2000. Computer simulation of sanitary collection system showed that this interceptor, the Mohawk Avenue Diversion, had the potential to relieve high wet weather flows that plagued the East Scott Street system (East Side Interceptor), by diverting the flow into the underutilized Harbor View Drive interceptor. The diversion extends from East Scott Street north to Harbor View Drive, interconnecting the two interceptor sewers.

## Drainage System Description

The First Street/Reserve Avenue system is approximately 293 acres in size and consists of a mix of residential, commercial, and institutional land uses. The subbasin is generally bounded by Merrill Avenue to the north, Eighth Street to the south, South Park Avenue to the west, and McDermott Creek to the east. DeNeveu Creek flows northwest through the basin, with approximately 2/3 of the subbasin drainage area on the west side of the Creek. The storm sewer systems on both sides of the creek flow by gravity to a stormwater lift station located on the east bank of the Creek. The pumping station has three pumps with space reserved for a fourth if needed in the future. Each pump has an independent discharge to the Creek. Pumps are called to start successively as the depth of water in the wet well increases, and all stop pumping at the same elevation.

The Taft Street/Bank Street system is approximately 41 acres and primarily consists of residential land use. The subbasin is generally bounded by East Scott Street to the north, Arndt Street to the south, Roosevelt Avenue to the west, and DeNeveu Creek to the east. The storm sewer flows by gravity to a stormwater pumping station located on the west bank of DeNeveu Creek. Two pumps discharge stormwater runoff into DeNeveu Creek.

## Data Collection

Extensive review of the available storm sewer system as-built plans was conducted to obtain pipe sizes, lengths and slopes for use in modeling. This information was added to the City's street map to create a comprehensive overview of the two storm sewer systems. These maps are included at the end of this report.

Because the City was reasonably confident of the completeness and accuracy of the as-built plans, it was not necessary to conduct field reconnaissance to verify any storm sewer information. The City conducted a limited storm sewer survey for a portion of the Taft/Bank system because some as-built plans were not found.

Rainfall information for specific storm events was obtained from gauges maintained by the City. The gauge located at Merrill Avenue at DeNeveu Creek was used in simulation of both the First/Reserve system and the Taft/Bank system. Additional rainfall data was taken from Bulletin 71, Rainfall Frequency Atlas of the Midwest by the Midwestern Climate Center and the Illinois State Water Survey.

Pumping station construction plans for the First/Reserve station were also reviewed. However, they contained little information on the operation of the pumps. The required pump information for modeling was obtained from past service records showing nameplate data and pump performance curves. Construction plans were not available for the Taft/Bank pump station.

According to the 1960 construction plans for the First/Reserve pump station, the "on" elevations for Pumps 1 and 2 were 750.1 and 750.6, respectively, and the "off" elevation for both pumps was 744.2. The storm sewer system plans show that the pump off elevation is the same as the lowest pipe invert at the pump station. However, the Pump 1 start elevation was nearly 6 feet higher than the invert elevation of the incoming storm sewer, causing standing water in the storm sewer system approximately 2700 feet west and 850 feet east of the pump station. It is likely that some frequent storm events do not produce enough runoff to turn a pump on but cause enough to accumulate and stand in the pipes, promoting exfiltration.

The City realized this situation and made adjustments to the pump starting elevations. Pump 1 now starts with only 3 feet of water above the invert elevation of the incoming storm sewer, Pump 2 with 3.3 feet of water, and Pump 3 with 4.6 feet of water. Although this configuration is an improvement over the original design, it still allows significant amount of standing water in the pipes at any time and reduces the capacity of the storm sewer system for a rainfall event.

The City records daily activity for each of the stormwater pumps. The records indicate the time each pump started, the number of times they started, and the run time of each start. This information is only kept for a short period of time before purging because of storage space limitations. Due to the timing of this study, pump records for the storms considered were no longer available.

Flow meters were installed at selected manholes in both drainage systems to record flow, velocity, and depth in incoming pipes every five minutes during storm events. Three meters were installed in the Taft/Bank system just upstream of the pump station. Six meters were installed in the First/Reserve system, three on each side of DeNeveu Creek. The locations of the meters are shown on the storm sewer system maps.

Cycling of the First/Reserve pump station is evident in the level data recorded by some of the flow meters in downstream portions of the storm sewer system. This is because the sewers enter the wet well below the pump start elevation, causing the stormwater to back up into the sewers. The longest observed interval between operating cycles was about 4 days, even during dry weather periods.

Sanitary flow meter data at sites tributary to the Mohawk Avenue relief sewer shows a dramatic improvement in hydraulic performance since the relief sewer was placed in service in March of 2000. In fact, for the first time since metering began in 1994, no surcharging was recorded in the East Side Interceptor in 2000. Flow data recorded in the 24-inch interceptor in First Street shows that, for a given depth of flow, flow rates since the March 2000 completion of the Mohawk Avenue relief sewer have increased by 30 to 60% over flows recorded in 1999. The difference is greatest at higher depths, reflecting the elimination of backwater effects in the East Side Interceptor system.

A review of the sanitary sewer system was also conducted to compare sanitary invert elevations to storm sewer inverts and pump operating levels. The as built plans show that there are scattered areas around the subbasin where sanitary sewers are below storm sewers. More importantly, it was found that there are several areas where the sanitary sewer inverts are below the pump start elevations. These areas are described as follows:

- Everett Street from First Street to the north
- Gillett Street west of Everett Street

These sanitary pipes are in the areas where the stormwater pump elevations allow up to 3 feet of standing water in the storm sewer.

## Hydrologic and Hydraulic Analyses

The XP-SWMM 2000 computer model by XP Software was used to calculate peak runoff rates and simulate storm sewer performance during storm events. A model of each system was created using the as-built storm sewer and pump information. Drainage areas to each pipe were delineated based on topography provided on the orthotopographic mapping. Hydrologic characteristics for each subbasin were input into the model and runoff hydrographs were computed. The hydrographs were then routed through the storm sewer system to simulate how the system functions and identify problem areas.

The models were calibrated by matching computed water surface elevations for gauged storm events with recorded water depths at meter locations. Flow meter data gathered from the August 3, 1999 storm was determined to be the best information of all the events metered and was used for calibration. Adjustments were made to the drainage area parameters (percent impervious, slope, subbasin width) to generate flows resulting in the observed depths. Once the models were calibrated, specific storm events were run to identify deficiencies and determine the capacity of each system. The results of the modeling are described below.

### *Taft/Bank System*

Because construction plans were not available for the Taft/Bank pump station, the performance of only the storm sewer system could be evaluated. The modeling results indicated that the storm sewer system could contain up to a 10-year event without street flooding. It is possible that the pump station may reduce this capacity, however it cannot be confirmed unless existing station and pump operation elevations become available. As previously noted, it appears that recent improvements to the sanitary sewer system, particularly the construction of the Mohawk Avenue Diversion, made a significant improvement in the capacity of the sanitary sewer in this area.

### *First/Reserve System*

Based on the modeling results, it was determined that the First/Reserve system has sufficient capacity to convey approximately a 2-year storm event without causing street flooding. However, many of the pipes not flooding are surcharged for this event. These frequent occurrences of standing or slow-moving water may promote exfiltration, particularly if the storm sewers in these areas are not in good condition. Because a system wide condition survey was not conducted as part of this study, it is difficult to determine if certain areas are more prone to exfiltration than others.

Most of the street flooding in this subbasin occurs at the upstream ends of storm sewer runs where pipes are relatively shallow and small in diameter. In these areas there are often several manholes close together with pipe size and direction changes, which add significantly to head losses in the system, leading to surcharging and/or flooding. There are also a few areas with reverse-sloped pipes. However, the depth of standing water anywhere is no greater than three inches and, consequently, this condition should not contribute significantly to the exfiltration potential.

Further modeling was conducted to determine if the pipes or the pump station controlled the capacity of the system. In the model without the pump station, there was a reduction in the number of manholes flooded as well as a reduction of surcharging in other manholes. This implies that the pump station somewhat limits the capacity of the storm sewer system.

## Evaluation of Alternatives

### *First/Reserve System*

The alternatives considered for the First/Reserve system involve adding capacity to the storm sewer system and/or the pump station. The alternatives are described in detail below.

Alternative 1: Storm Sewer System Improvements

As indicated by the modeling, the storm sewer system has capacity for less than a 2-year storm without causing surcharging or street flooding. Therefore, the storm sewer system frequently surcharges or has significant depths of flow.

To reduce the potential for exfiltration, the capacity of the storm sewer system would have to be increased throughout the subbasin. This could be achieved by replacing the existing pipes or by installing additional parallel pipes. This alternative could be implemented over a number of years to minimize disruption to residents and distribute the construction cost.

Alternative 2: Non-Structural Improvements

Another method to improve the performance of the storm sewers is to limit the amount of stormwater runoff that enters the storm sewer system. This can be accomplished by requiring roof downspouts discharge onto lawns rather than directly into the storm sewers or onto pavement. This can be accomplished with a stormwater ordinance and a public information and education program.

Alternative 3: Pump Station Improvements

It may be possible to improve the performance of the storm sewer system by lowering the pump start elevations. By lowering the start elevations, a greater system capacity could be achieved. In addition, this would reduce linear extent and duration of pipe surcharging. However, this may cause more frequent cycling of the pumps resulting in additional wear on the pumps and motors. Although there is little implementation cost, there may be increased costs for maintenance.

Another option is to add a fourth pump in the First/Reserve pump station. This pump could be similar in size to the three existing pumps and could be set to start pumping at an elevation below the incoming storm sewer invert. This may result in additional system capacity. However, starting this pump at a lower elevation may cause more frequent cycling of the pumps resulting in additional wear on the pumps and motors.

Adding a small pump or lowering one of the pump start elevations to eliminate standing water in the storm sewers during dry weather was also considered. However, because the flow monitoring data indicated that Pump 1 cycles frequently, even during dry weather, lowering the start elevation to eliminate standing water in the storm sewer would cause excessive wear on the pump and motor. Similarly, a smaller pump would run almost continuously and may need to be replaced frequently. It should be noted that it would be advantageous to add a similar size pump as described above rather than a small pump because all four pumps could be rotated as necessary to prevent excessive wear on one pump.

## *Taft/Bank System*

As noted above, no construction plans or as-built plans were available for the pump station of the Taft/Bank drainage basin. The impact of pump operating levels on storm sewer system capacity and the potential for standing water in the downstream storm sewer pipes could not be evaluated. However, it is very likely that the relationships of pumping capacity to pipe system capacity, and pump operating levels to pipe invert elevations, are the same as those of the First/Reserve system. Therefore, the same alternative improvement measures developed for that system would apply to the Taft/Bank system.

It should be noted that the pipe system capacity was determined to be greater than that of the First/Reserve system. The modeling results indicated that the storm sewer system can contain up to a 10-year event without street flooding and, therefore, the frequency of surcharging and significant pipe flow depths should be less than that in the First/Reserve system. However, as in the First/Reserve system, it is possible that the pump station operational scheme may reduce the overall system capacity. The impact of the pump station should be evaluated further if it is determined that measures to reduce exfiltration must be implemented.

## Summary and Recommendations

The City of Fond du Lac has experienced frequent sanitary sewer system bypassing in recent years. The three potential causes of bypassing are:

1. Inflow and infiltration
2. Stormwater exfiltration
3. Inadequate capacity

To reduce the frequency of sanitary sewer system bypassing, the City rehabilitates sewer mains on a yearly basis. In addition, the City constructed the Mohawk Avenue diversion sewer in March of 2000. Based on the results of sewer flow monitoring, these measures have greatly reduced sanitary sewer back-ups.

The results of this study indicate two potential causes of stormwater exfiltration:

1. Standing water in storm sewers upstream from the pumping stations due to operating levels.
2. Frequent storm sewer system surcharging and significant depths of flow due to limited capacity.

Measures to eliminate these potential causes of stormwater exfiltration would be costly. As described in the discussion of alternatives, pump station modifications would result in either significant capital costs or higher operation and maintenance costs. Increasing the capacity of the storm sewer systems would be costly because there are no isolated bottlenecks to eliminate. Capacity would have to be added system-wide. It should be noted however, that the City recently modified the pump operating levels at the First/Reserve pump station. This reduced the frequency of standing water in upstream storm sewer pipes.

Based on the beneficial impacts of the sanitary sewer system improvements noted above, and the costs associated with measures to reduce the potential for stormwater exfiltration, it is recommended that the City only continue its yearly sanitary sewer main rehabilitation program at this time. In addition, sewer system flow monitoring should continue to further evaluate impacts of the sanitary sewer system improvements, and the need for stormwater exfiltration prevention measures.