BAYBERRY FLOODING EVALUATION

Prepared for:
City of Wyoming
Kent County, Michigan

January 20, 2014
Revised April 3, 2014
Project No. G130701

fTC&h

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KENT COUNTY, MICHIGAN

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LIST OF ABBREVIATIONS/ACRONYMS

City	City of Wyoming
Condominiums	Bayberry Farms Condominiums
CPP	Corrugated Plastic Pipe
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FTCH	Fishbeck, Thompson, Carr & Huber, Inc.
GIS	Geographic Information System
GPS	Geographic Positioning System
KCDC	Kent County Drain Commissioner
NAVD 88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
PUD	Planned Unit Development
PVC	Polyvinyl Chloride (Pipe)
REGIS	Regional Geographic Information Services
RCP	Reinforced Concrete Pipe
Senior Apartments	Bayberry Farms Village Apartments
SWMM	Stormwater Management Model

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LIST OF UNITS

ac	acre
ac-ft	acre feet
cfs	cubic feet per second
cfs/ac	cubic feet per second per acre
cft	cubic feet
cy	cubic yards
ft	fee
in	inch

EXECUTIVE SUMMARY

Residents of the Bayberry Farms community located within the City of Wyoming (City), Michigan experienced significant flooding during the recent record rainfall on September 9, 2013 (Figure 3). Flood damage to structures and vehicles occurred. The City commissioned this engineering study to assist in fact-finding and determination of remedial action.

Key findings of the investigation and evaluation of the stormwater management system in the study area (Figure 2) are summarized below:

- The rainfall of September 9, 2013, was an extreme event and can be categorized as a 400-year storm. This event greatly exceeded the rainfall depths and intensities used for design of stormwater systems. City and private stormwater systems in the study area were taxed, but generally performed well when tested with an extreme rainfall event. Where flood damage occurred, it was in low areas without an adequate overland flow route.
- The Bayberry Farms and City storm sewer systems functioned satisfactorily for the 10-year and 25-year design storms. One exception is Byron Center Avenue, 200 feet south of 56th Street, which begins to discharge water through the Bayberry Market North commercial development.
- The Bayberry Market detention basin was found to have several maintenance and design deficiencies. The basin is undersized for the 25-year design storm. Most importantly, the berm on the west side of the basin is too low and overflows are directed to the Bayberry Farms Condominiums and Senior Apartments storm sewers, which were not designed for this additional water.
- Stormwater runoff from Health Drive tends to bypass storm sewer inlets during extreme rainfall events and flow across Byron Center Avenue into the Bayberry Market.

Recommendations for maintenance, capital improvements, and policy review are summarized below:

- Owners of the Bayberry Market detention basin should perform necessary maintenance and regrade the basin and overland flow path to bring it in compliance with design standards.
- The Bayberry Condominium Board should contract to reinstall the backflow preventers removed from the storm sewer system downstream of the swale behind the Condominiums.
- The City should include inspection of the backflow preventers as a critical area in their operation and maintenance plan.

- The City should consider taking ownership of the Bayberry Market detention basin, or at a minimum, participate financially and expand it to accommodate the additional stormwater contributions from Byron Center Avenue. The latter should include a maintenance agreement between the City and the private owner with provisions for regular inspection and reporting. The estimated project cost ranges from $60,000 to $200,000 depending on the amount of excavation needed to meet either 25-year or 100-year volume requirements within the basin.
- The City should investigate berming along the south side of 56th Street to reduce overflows to the Bayberry Village Senior Apartments. Because this action will raise flood water levels in 56th Street and the low areas to the north, the City should further investigate the need for stormwater detention at this location. At a minimum, an emergency action plan should be put in place for anticipated road closures in this location during large storm events.
- The City should consider additional high-efficiency inlets along Health Drive to intercept and route stormwater runoff from large storms (greater than the 25-year design) to the Metro Health Ponds as intended. The estimated project cost for storm sewer inlet improvements along Health Drive is $60,000.
- City stormwater policy for site plan reviews should re-emphasize the importance of adequate overland flow routes, the need for certified as-built drawings, and confirmation of minimum building openings. The latest rainfall data from NOAA Atlas 14 should be incorporated for use in City design standards to account for the larger magnitude rainfalls experienced with increasing frequency during the last 20 years. The City should determine whether design standards should be increased from 25-year to 100-year for overland flow routes.
- Individual property owners in identified floodprone locations should consider floodproofing of their structures if design standards do not provide the desired level of flood protection.

INTRODUCTION

Residents of the Bayberry Farms community located within the City of Wyoming (City), Michigan experienced significant flooding during the recent record rainfall on September 9, 2013. Flood damage to structures and vehicles occurred, and the City was contacted to assist in fact-finding and determination of remedial action.

The City commissioned this study to evaluate how the stormwater management system functioned during the rainfall event of September 9, 2013, identify any system deficiencies based on City design standards, and provide recommendations to mitigate the risk of flood damage from rainfall events that exceed the capacity of the existing stormwater and drainage system.

STUDY AREA

The Bayberry Farms Plat is located south of 56th Street and west of Byron Center Avenue in the Southeast Quarter of Section 33 (T6N, R12W). This section is located in the southwest side of the City generally referred to as the "panhandle." A location map is shown in Figure 1.

Bayberry Farms is a 133-acre Planned Unit Development (PUD) consisting of mixed land use built between 1996 and 2006. Specifically, the development includes apartments, village (senior living apartments and condominium units), site condominiums, single family homes, and a commercial center (Bayberry Market). Land use east of Byron Center Avenue consists of institutional (Metro Health Hospital) and commercial retail. A site map is shown in Figure 2.

The study area consists of the identified contributing drainage areas to the outlets of the Bayberry Farms storm sewer system and the City storm sewer in 56th Street (Figure 2). The area is approximately 250 acres, with 90 acres contributing to the 56th Street storm sewer (half of which passes through the regional detention pond along the north side of Gezon Parkway) and 160 acres contributing to the Bayberry Farms storm sewer system. Drainage patterns generally slope from east (higher elevation) to west (lower elevation) with as much as a 70-foot change in relief in less than a mile.

Surficial soils in the study area consist of a mixture of loams (Capac and Marlette) and loamy fine sands (Chelsea and Arkport). These types of soils are classified as Hydrologic Soil Groups B and C and have a moderate to slow infiltration rate when thoroughly wet.

The Bayberry Farms Development is served by both public and private stormwater infrastructure (Figure 2). The drainage and stormwater system consists of a series of storm sewers, detention basins, and overland flow paths. The City storm sewer in 56th Street discharges to a City regional detention basin north of 56th Street and east of the Kent Trails non-motorized trail. The public storm sewer located through the Bayberry Farms Development discharges to a City regional detention area west of Barcroft Drive and east of Kent Trails. Two 24-inch storm sewers under Byron Center Avenue convey stormwater from east of Byron Center Avenue, which outlets via two separate trunk sewers, one through the Bayberry Farms Condominiums and the other through the Bayberry Farms Apartments. Stormwater from Byron Center Avenue also outlets through the trunk sewer at Bayberry Farms Apartments.

The City widened Byron Center Avenue, adding two additional traffic lanes south of Health Drive in 2004. The private storm sewers from Metro Health Hospital and the commercial retail east of Byron Center Avenue are routed through privately-owned onsite stormwater detention ponds on the east side of Byron Center Avenue before discharging to the storm sewer in Byron Center Avenue.

The Bayberry Farms Development is located within the Behan-Foley Drainage District, and stormwater is ultimately discharged to the Behan-Foley Drain located between Kent Trails and Ivanrest Avenue. The Behan-Foley Drain is a tributary to Buck Creek, which outlets to the Grand River (Figure 1). The Behan-Foley Drain is also an established county drain under the jurisdiction of the Kent County Drain Commissioner (KCDC).

PROBLEM STATEMENT

Unusually intense rainfall occurred in southwestern Kent County on September 9, 2013, resulting in numerous occurrences of flooding in roadways and depression areas throughout the City panhandle. The Behan-Foley Drain overtopped 56th Street and the City temporarily closed the road, which was one of several locations with road closures that day. Although the duration of the most intense rainfall was short-lived and many flooded areas receded quickly, high water levels caused flood damage in the Bayberry Farms Development. A map of related flooding areas is shown in Figure 3. Photographs are included in Appendix 1.

According to reports from City staff and local residents, the rain started at about 7 a.m. Cars were stranded in 56th Street just west of Byron Center Avenue due to floodwaters that peaked and quickly receded. Some of the ponded water spilled over the slope on the south side of the road to enter the parking lot of the Bayberry Farms Village Apartments (Senior Apartments). Stormwater also reportedly flowed westward down 56th Street and then down the driveway of the Senior Apartments. At the same time, surface water from the Metro Health Hospital flowed across Byron Center Avenue and through the Bayberry Market parking lot. Byron Center Avenue also flooded just south of 56th Street.

The stormwater detention basin at Bayberry Market overtopped. Discharge water flowed overland in three directions: around the back drive of the Senior Apartments, across the greenspace between the Senior Apartments and the Bayberry Farms Condominiums (Condominiums), and along the swale behind the Condominiums.

The Senior Apartments experienced flooding of the parking lot and damage to numerous parked vehicles. Water levels rose to above the top of curb and into lawn areas, but did not enter the first floors of any of the apartments. It reportedly took only 20 minutes from the time the rain started for the water in the parking lot to overtop the curb.

The Condominiums experienced flood damage due to water ponding up to 2-foot deep against the entrances to walk-out basements in the lowest of the units and also flooding into the living spaces.

Further to the west, surface water runoff from the Senior Apartments and Bayberry Market Detention Basin overflow combined with localized runoff to flood the in-ground pool and basement of houses on Bayberry Farms Drive (#5660, and #5678). A house on Thackery Drive (#2614) also experienced a wet basement.

STORMWATER DESIGN STANDARDS

The City completed a *Storm Water Management Study* in 1988 (McNamee, Porter & Seeley, 1988) and a *Storm Water Management Master Plan of Sections 28 – 35* in 1996 (FTCH, 1996) when the panhandle was beginning to undergo rapid development. The master plans provided the City with planning-level drainage areas, design flows, storm sewer and regional detention basin sizes, and recommendations for stormwater design standards.

The stormwater design standards adopted by the City in 1997 followed the KCDC *Development Drainage Rules* published at that time. These standards have been used by the City for both private developments and public infrastructure for the past 20 years and are summarized in Table 1.

Table 1 - Stormwater Design Standards

Description	Standard
Tributary Storm Sewers with overland flow paths	5-year peak discharge[1]
Trunk Storm Sewers	10-year peak discharge *100-year if no floodway*
Open Channels	10-year peak discharge; 25-year if no floodway *100-year if no floodway*
Open Channels (greater than 800 acres) *(greater than 1,280 acres or 2 square miles)*	100-year floodplain and floodway determined; no damage to structures; lowest level including basement at least 1-foot above 100-year flood level *Lowest level including basement at or above 100-year flood level*
Bridges for Major Roads	100-year; no backwater
Culverts	10-year peak discharge; no head
Detention Basins	25-year volume
Controlled Outlet	0.13 cfs/ac maximum discharge
Overflow Spillway	10-year peak discharge into facility
Water Quality Volume	First 0.5-inch of runoff held for minimum 24 hours[2] *First 0.5-inch of runoff held for not less than 12 nor more than 24 hours*
Retention Basins (no positive outlet; water infiltrates into soil)	100-year; Back-to-back 100-year if no floodway

[1]City standard only (McNamee, Porter & Seeley, 1988).
[2]Recommendation (FTCH, 1996); not in KCDC rules at the time.
Differences in KCDC rules dated January 1, 2013, are shown in *italics*.

Selection of the design storm used for flood control is a question of risk versus economics. The 100-year flood, or base flood, is the standard used by the Federal Emergency Management Agency (FEMA) for the National Flood Insurance Program (NFIP).

It should be noted the reference to storm recurrence interval in years (10-, 25-, 100-year), while standard practice is often misunderstood. Storm recurrence interval (frequency) is really a probability that a given amount of rain falling in a specified duration of time will be equaled or exceeded in any given year. The recurrence interval or frequency (*f*) is obtained by taking the inverse of the probability (*P*), expressed in an equation as:

$$f = \frac{1}{P}$$

A 100-year storm has an annual probability of occurrence of 0.01 (or 1 percent). Another way of saying this is the 100-year storm has a 1 percent chance of being equaled or exceeded in any given year. Similarly, a 25-year storm is also referred to as the 4 percent annual chance storm, and a 10-year storm is the 10 percent annual chance storm.

Local agencies have relied on engineering studies to guide the selection of stormwater design standards. For Kent County, one such study is the *Buck Creek and Plaster Creek Storm Water Management Master Plan* prepared for the KCDC in 1991 (Camp Dresser & Mckee, 1991). This study recommended the KCDC "not rely upon a 100-year design storm as a performance standard," but "runoff control facilities designed for less extreme rainstorms be tested with the 100-year design storm to ensure the recommended runoff control plan does not aggravate 100-year flood conditions."

The study goes on to recommend the 25-year design storm be used for flood control, as it is "more conservative than the 10-year design storm typically used for local storm sewer design, but less conservative than the 50- and 100-year events which would require more expensive runoff control measures." As justification, the study cites a United States Army Corps of Engineers study (Johnson, 1985), which looked at nationwide flood damage data compiled by the Federal Insurance Administration. The data showed "the average annual flood damages within the 25-year floodplain are very high, up to ten times greater than the damages associated with the incremental area between the 25-year and 100-year floodplains."

Finally, the report recommends a maximum allowable release rate for stormwater detention. The allowable release rate was determined through hydrologic and hydraulic modeling and averaged 0.13 cubic feet per second per acre (cfs/ac) for the Buck and Plaster Creek watersheds. This release rate was quite restrictive at the time since prior release rates were on the order of 0.33 cfs/ac or higher. It was necessary to set the release rate much lower than the undeveloped runoff rate for the 25-year storm (and lesser storms for that matter) due to the increased volumes of runoff associated with development otherwise combined in ways to cause a rise in the 25- and 100-year floodplains.

Updates to the KCDC *Development Drainage Rules* have included several changes to the design standards (italicized text in Table 1). Most significant is the requirements for trunk storm sewers and open channels to be sized for the 100-year storm if the floodway is unavailable.

Every design has a probability of exceedance, which underscores the importance of evaluating the overland flow routes for extreme rainfall events.

DESIGN REVIEW

A review of the stormwater system design and an as-built survey was conducted as a part of this study. Design drawings and stormwater calculations were obtained from the City. FTCH surveyors obtained as-built elevations in November and December 2013.

Vertical datum was obtained with a Geographic Positioning System (GPS) from the Michigan CORS using the Geoid 12A Model. Elevations are referenced to North American Vertical Datum of 1988 (NAVD 88). Benchmarks from design drawings were located, where possible, to rectify any differences in elevations used for design by other firms. One benchmark recorded on the Bayberry Farms Village drawings dated 2003 was found. This benchmark is located in a power pole on the south side of 56th Street with a plan elevation of 725.84 feet. FTCH surveyors shot the elevation at 725.32 feet. GPS elevations were adjusted up by 0.5 feet to obtain comparable elevations for the Bayberry Farms Village as-built survey. It is not known if the same difference in elevation holds true for the benchmarks used for the Bayberry Farms Condominiums and Bayberry Market design drawings, since benchmarks were either not provided or unable to be found. It appears GPS as-built elevations are on the order of 0.5-foot low in comparison to design elevations. All as-built elevations were adjusted by adding 0.5 foot based on the benchmark from the Bayberry Farms Village drawings.

BAYBERRY MARKET DETENTION BASIN

The stormwater detention basin at Bayberry Market overtopped during the rainfall event of September 9, 2013. A review of the basin was conducted as part of this study to determine compliance with the approved design drawings and assess the current condition of the basin. Results are summarized in Table 2 and shown graphically in Figure 4.

Table 2 - Bayberry Market Detention Basin Design Comparison

Description	2006 Design	2013 As-built
Drainage Area (ac)	5.59	5.1
Runoff Coefficient	0.8	0.7
25-year Storage Volume Required (cft)	38,068	
Storage Volume Provided (cft)	47,967 (720-726)	36,110 (720.5-725.9)
Bottom Elevation (ft)	720	720.8-723.2
Outlet Pipe	4-inch orifice on 6-inch PVC; 15-inch CPP	orifice end BURIED; 6-inch PVC; 15-inch CPP
Top of Outlet Catch basin in Bottom of Basin (ft)	719.8	720.0 (ground)
Top of the Overflow Catch basin[1] (ft)	725.7	725.52
Emergency Overflow Spillway Elevation (ft)	726.0	725.9
Top of Berm Elevation (ft)	727	725.9-727.4
Inlet Pipe from North	18-inch CPP	18-inch CPP
Inlet Pipe from East	15-inch CPP	15-inch CPP
Inlet Pipe from Southeast	18-inch CPP	24-inch CPP

[1]The spillway crest must be topped (design elevation 726 ft) before water will flow into the catch basin.
As-built elevations have been adjusted by adding 0.5 foot for comparison with design elevations.

Results of the as-built survey indicate several deficiencies with the existing detention basin. Most notable are the top-of-berm elevations along the west side of the basin, which are at the same elevation as the overflow spillway crest and up to 1 foot lower than the design elevation of 727 feet. This means the basin will overflow to the west at the same time the overflow spillway engages. Water discharged over the top of the detention basin can flow three ways: south along the pedestrian path to the back of the Condominiums and into a swale with a projecting 24-inch reinforced concrete pipe (RCP) inlet, west across an open area and into a catch basin inlet, or north in back of the Senior Apartments and into a catch basin inlet (Figure 3). None of these inlets were designed to take additional water from the detention basin.

The route from the overflow spillway also has some design deficiencies. The overflow spillway was designed to route flows to the south, first through a 15-inch pipe connected to the 30-inch storm sewer system at the Condominiums, and second over the top of the concrete spillway to a grassed swale (upper swale). While the concrete spillway is adequately sized to convey the 10-year peak inflow (18 cfs) into the detention basin in accordance with City standards, the catch basin inlet at the top of the spillway does not have adequate inlet capacity for the design discharge without a large amount of head (ponded water). The catch basin at the top of the spillway was designed only 0.3 feet lower than the

outflow side of the spillway. This does not provide the needed inlet capacity for the 14 cfs assumed to enter the 15-inch pipe (13 cfs from catch basin and 1 cfs from the 4-inch orifice). It is also evident any reduction in inlet capacity due to debris would quickly result in high water levels that would overtop the spillway. This results in more water flowing over the detention basin spillway and less water flowing through the outlet pipe. Downstream of the spillway, the grassed swale has only 0.5 foot of depth before water spills over to the west and runs down the slope to the grassed swale (lower swale) in back of the Condominiums.

A second important observation is the low-flow outlet is buried, which can significantly reduce the outlet capacity, although water was heard flowing in the structure below grade at the time of the as-built survey. A buried outlet would lead to the basin filling faster with a higher probability of overflow.

Overall, the bottom of the basin is higher than designed and the top of berm is lower than designed. The storage volume at the low berm elevation is less than the required 25-year volume.

Design assumptions made regarding the amount of runoff entering the basin (as reflected by the drainage area and runoff coefficient) are consistent with FTCH calculations. The diameter of the inlet pipe from the southeast, although larger than called for on the design drawings, does not affect the peak inflow as pipe capacity was not included as a limiting factor in either the original design calculations or the FTCH model.

BAYBERRY FARMS CONDOMINIUMS

The walk-out basements of several units of the Condominiums experienced flooding up to 2 feet deep during the rainfall event of September 9, 2013. A review of the lowest floor openings, grassed swale, and storm sewer inlet pipes was conducted as part of this study to determine compliance with the approved design. Results are summarized in Table 3 and shown graphically in Figure 5.

Table 3 - Bayberry Farms Condominiums Design Comparison

Location	Depth Below Finished Floor	
	1995 Design [ft]	2013 As-built [ft]
Invert 24-inch Inlet Pipe at North End	3.4	3.5
Bottom of Swale in Back of Units 25 through 27	2 - 3	1
Bottom of Swale in Back of Units 22 through 24	1.3 – 2.3	0.6 – 1.6
Bottom of Swale in Back of Units 18 through 21	2.9 – 3.9	2.2 – 3.2
Invert 12-inch Inlet Pipe at Manhole (from North)	3.9	4.1
Invert 12-inch Inlet Pipe at Manhole (from South)	3.6	3.9
Bottom of Swale in Back of Units 14 - 17	2.6 – 3.6	1.7 – 2.7
"1995 Design" pipe invert elevations taken from REGIS. Red shading indicates as-built elevations with less depth than design conditions.		

The differences in elevations between design and as-built conditions show 9 to 12 inches less depth between the bottom of the swale and finished floor. This seems to indicate the swale may have filled in over time, which reduces the allowable depth of water conveyed or stored in the swale before flooding of walk-outs occurs. Water can pond 3.5- to 4-foot deep before reaching the lowest opening. A minimum of 1 foot of freeboard should be provided between the design high water elevation and the lowest opening. Design standards specify the 25-year storm should be used to determine the design high water elevation because a floodway is not available.

Additional information received from the Bayberry Condominium Board after publication of this report revealed the two backflow preventers installed in the discharge pipes from the swale behind the Condominiums were not in place during the rainfall event of September 9, 2013. The Board had them removed in the spring of 2013 at the recommendation of a local contractor who believed they were preventing water from draining the swale because they were clogged with debris.

The need for backflow preventers is critical at this location to prevent a large volume of water from the storm sewer from discharging into and filling up the drainage swale. The type of backflow preventers (Tideflex check valves) approved by the City and installed at this location typically do not get plugged shut and provide a nearly ideal system to prevent flow back up the pipe even when clogged with debris. The check valves remain shut until opened by the pressure of the stormwater from the lower drainage swale once the back pressure in the downstream pipe has dissipated.

BAYBERRY FARMS VILLAGE

Vehicles located in the parking lot of the Senior Apartments experienced flooding during the rainfall event of September 9, 2013. A review of the Senior Apartments grading plan was conducted as part of this study to determine compliance with the approved design. A copy of the site plan with key as-built elevations is shown in Figure 6.

A review of the elevations shows water needs only to pond 9 inches deep in 56th Street before it will spill over the berm and into the parking lot of the Senior Apartments.

A review of the contours around the Senior Apartments indicates the critical overflow elevation for water ponded in the parking lot is governed by the elevation of the drive between the Senior Apartments and Condominiums. The driveway elevation is 718.5 feet. Water that crests this elevation will flow down the drive to the catch basin and swale between the two southerly condominium units. The grade of the drainage divides between the catch basins encircling the apartments is also at an elevation of approximately 718.5 feet, or 1 foot lower than the finished floor elevations. These over land flow routes prevented the water from ponding any higher during the rainfall event of September 9, 2013.

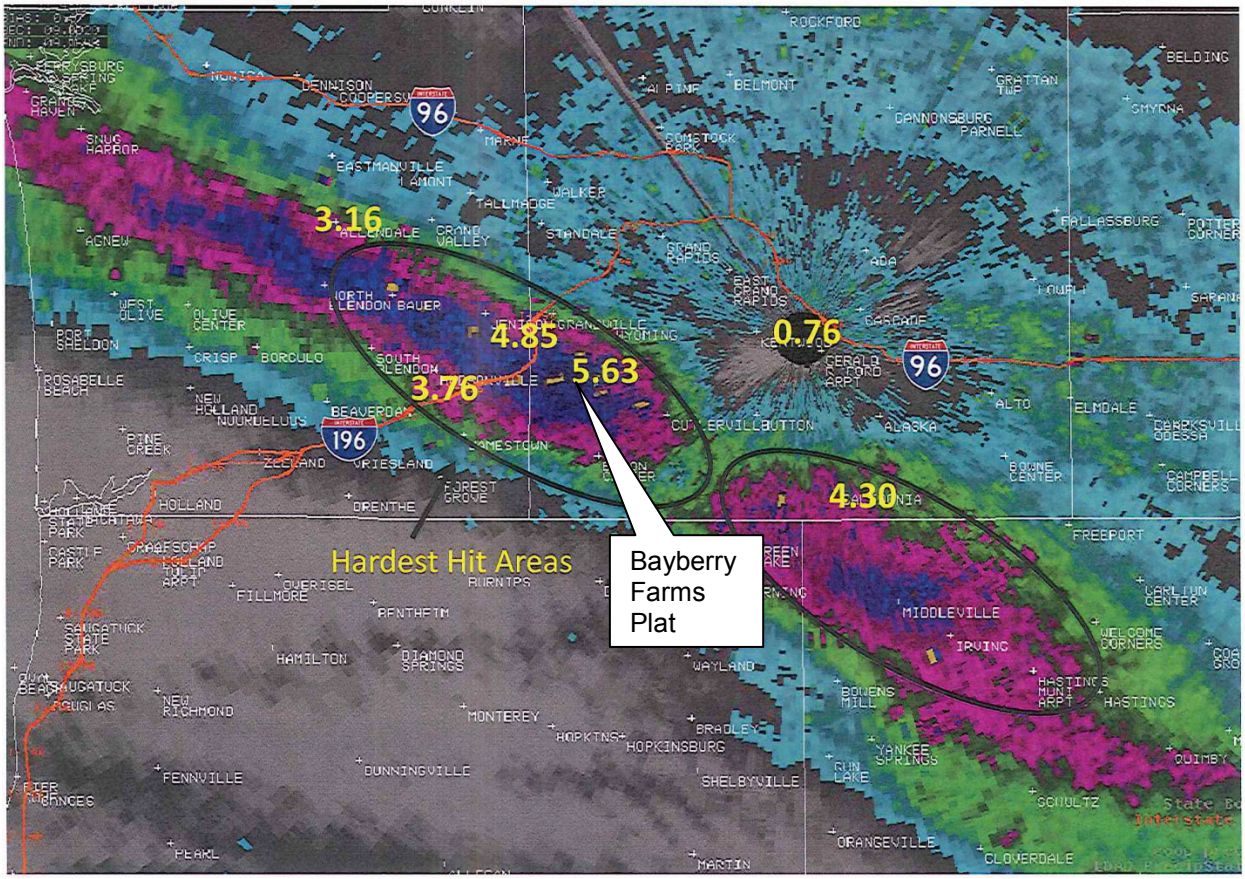
ANALYSIS

Hydrologic and hydraulic analysis is necessary to evaluate the performance of the existing stormwater system in the study area against City design standards and the rainfall event of September 9, 2013.

RAINFALL

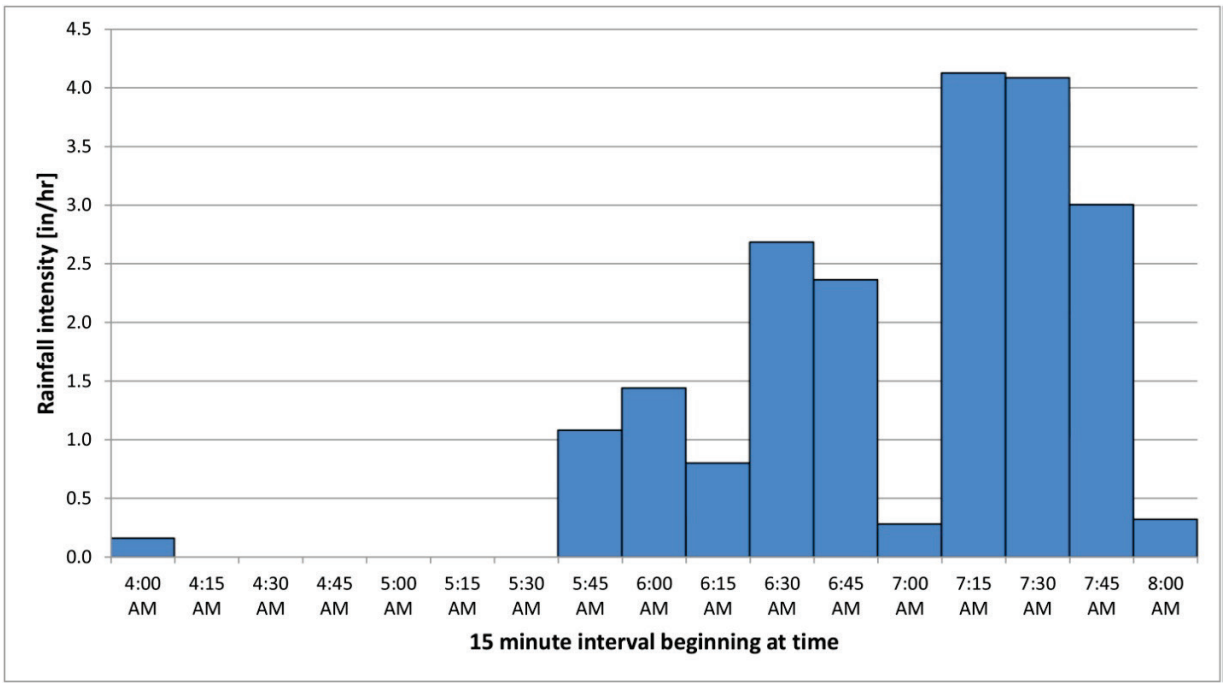
SEPTEMBER 9, 2013

The rainfall event of September 9, 2013, can be represented several ways. Graphic 1 shows a radar-based image of total rainfall depth from the Gerald R. Ford Airport. It shows the hardest hit areas follow a fairly narrow band running in a northwest to southeast direction with some of the most extreme values in the City's panhandle area.



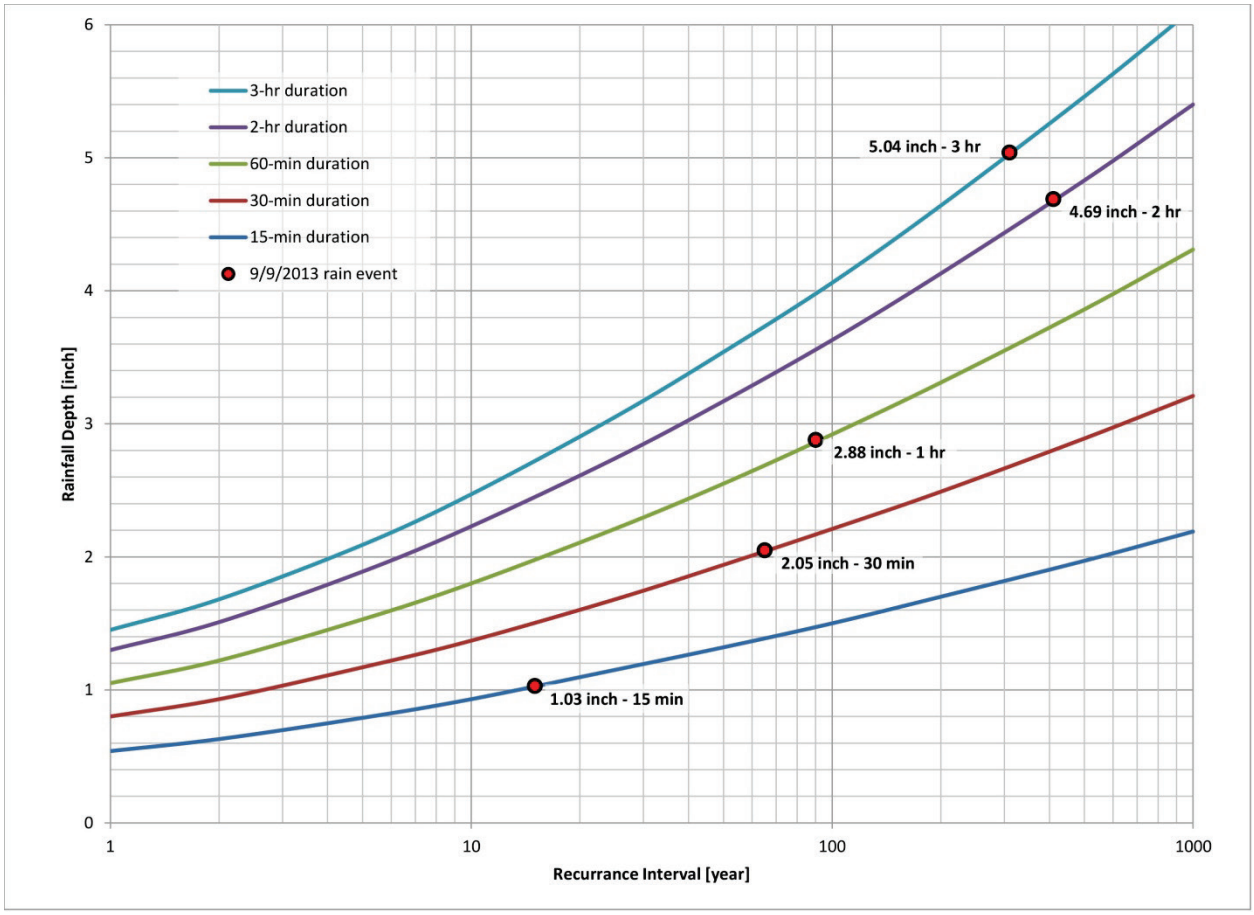
Graphic 1 - Radar Image of Rainfall Depth [in]

The Gezon pumping station located just east of Byron Center Avenue and Gezon Parkway has a weather station located at the base of the Gezon water tank. This is a much better source of precipitation data since it is only one-half mile from the Bayberry Development and it is based on physical measurement of rainfall (as opposed to radar data). Graphic 2 shows the rainfall hyetograph. This is a plot of rainfall intensity (measured in inches per hour) as a function of time. The total rainfall depth was measured at 5.08 inches, with 5.04 inches falling in the 3-hour period between 5:30 a.m. and 8:30 a.m. During the half-hour period between 7:00 and 7:30 a.m., the intensity was above 4 inches per hour.



Graphic 2 - Rainfall Hyetograph from Gezon Weather Station

As discussed previously, rainfall events are normally quantified either in terms of an exceedance probability (percent chance storm) or a recurrence interval. To classify a storm in either manner requires both the rainfall depth and storm duration. In April 2013, the National Oceanographic and Atmospheric Administration (NOAA) released updated precipitation frequency data for Midwestern States including Michigan (Atlas 14, Volume 8, 2013). Graphic 3 compares the September 9 storm to the new NOAA data. The solid lines show the NOAA frequency data for Wyoming, Michigan. The lowest curve is for storms of 15-minute durations, and the upper curve is for storms of 3-hour durations. The data for September 9, 2013, is shown with red markers. The most extreme part of the storm was a two-hour period where 4.69 inches of rain fell. This corresponds to a 400-year rainfall recurrence interval.



Graphic 3 - Precipitation Frequency Analysis

RAINFALL FREQUENCY RECORDS

The rainfall depths used for design in the Bayberry Farms Development are based on data from NOAA Bulletin 71, *Rainfall Frequency Atlas the Midwest* (Huff and Angel, 1992). This source of rainfall data includes records through 1987 and has been used for design in Michigan since publication in 1992. The rainfall amounts from Bulletin 71 are still included in the January 2013 edition of the KCDC *Development Drainage Rules*. With the publication of Volume 8 of Atlas 14, more recent extreme rainfall events have been incorporated into the data, and in many cases, rainfall depths have increased for a given recurrence interval as shown in Table 4.

DESIGN STORM

The approach used for design of stormwater systems is to use a standard rainfall depth and duration with the rainfall distributed throughout the selected duration (time). The distribution can be assumed to be uniform (simplest assumption), or reflect a more typical rainfall distribution for a particular region of the country. In Michigan, an SCS Type II rainfall distribution is most appropriate. Rainfall is distributed over a 24-hour period with about 64 percent of the rain falling in the most intense 2-hour period. This distribution accounts for both the high-intensity short burst rainfalls and the longer frontal systems.

The 10-, 25-, and 100-year recurrence intervals were used for evaluation based on City design criteria. Rainfall amounts from Bulletin 71 were used with design storms to evaluate the existing system and improvement alternatives. All design storms are 24-hour duration with an SCS Type II rainfall distribution. A comparison of design storms to the rainfall event of September 9, 2013, is provided in Table 4.

Table 4 - Design Storm Comparison

Precipitation	Event			
	10-year	**25-year**	**100-year**	**09/09/2013**
Depth	3.52 in (3.78 in)	4.45 in (4.70 in)	6.15 in (6.38 in)	5.04 in
Duration	24 hr	24 hr	24 hr	3 hr
Depth over peak 2 hours	2.25 in	2.84 in	3.93 in	4.69 in
Depths from Bulletin 71. Depths from Atlas 14 shown in parenthesis.				

EVALUATION OF EXISTING SYSTEM

METHODOLOGY

The Environmental Protection Agency (EPA), Stormwater Management Model (SWMM) was used to perform the hydrologic and hydraulic analysis for this study. SWMM is a public domain computer program widely accepted by the engineering profession and reviewing agencies. It is well suited to analyze complex storm sewer networks with pressure and reverse flow, can seamlessly integrate detention storage components, open channels, and parallel conveyance into the model environment.

The required SWMM input parameters include those that define the hydrology (rainfall-runoff process), the conveyance system (pipes and open channels), and storage (ponds and detention basins). Key parameters for the contributing drainage areas include area, slope, percent impervious, and Curve Number (a standard parameter measuring the infiltration capacity of the pervious surfaces using soil types). The conveyance system parameters include pipe diameter, slope, roughness, and length. In locations where storm sewers surcharged leaving no room for surface flows to enter the underground system, the roadway itself was modeled as an open channel conveyance element. Open channels require specification of their shape, slope, length, and roughness. The storage units required specification of the volume (area as a function of depth) and the outlet control.

Resource information was obtained from the Regional Geographic Information Services (REGIS) for roads, storm sewers, waterbodies, wetlands, floodplains, and aerial photography. Parcels and 2-foot contours were provided by Kent County Geographic Information System (GIS). Soils information was obtained from the Natural Resource Conservation Service (NRCS) Web Soil Survey.

The drainage area boundary was delineated using 2-foot topographical contours, which indicate surface flow patterns, and storm sewer maps, which indicate subsurface flow patterns. The drainage area was divided into 22 subcatchments for the purpose of calculating hydrologic input parameters. The amount of impervious area (roofs and pavement) in each subcatchment was determined using aerial photography. A subcatchment map including impervious cover is included in Figure 7. The subcatchments were then subdivided further, as necessary, for hydrologic modeling. A model schematic including tables of input parameters and runoff results is included in Appendix 2.

Pipe diameters, invert elevations, and structure rim elevations were taken from the GIS storm sewer data set. Pipe lengths were measured from the GIS storm sewer layer, and slopes calculated in SWMM. Standard values of pipe roughness were used. As-built elevations were used where obtained.

One-foot contours of the Bayberry Market detention basin and open area behind the Condominiums were generated from as-built survey elevations and used to calculate areas and volumes.

Computer modeling always involves focusing on the most relevant information and discerning the important from the unimportant details. Modeling assumptions include the following:

- Only the larger sewers were included in the model. Nearly all of the pipes included in the model are 15-inch diameter or larger.

- All storm sewers were assumed to be clean and in good condition.
- At model junctions (i.e. manholes) where the storm sewer system surcharges (i.e. water fills the manhole to the rim), the model includes surface flow paths (open channels) along the streets and through the parking lots.
- Stormwater from the flooded area in Byron Center Avenue was assumed to flow west into a commercial driveway and enter storm sewer contributing to the Bayberry Market detention basin. This was modeled as a surface flow path.
- Stormwater from a portion of Health Drive was assumed to cross Byron Center Avenue and enter the storm sewer contributing to the Bayberry Market detention basin. This was modeled as a surface flow path.
- Because of the difficulty in modeling the fraction of flow that would bypass the curb inlets, the model does not generally account for restrictions due to inlet capacity. Water is routed to surface flow paths based solely on surcharging of the storm sewer above the ground surface. The exception is at the curb inlets along Health Drive east of Byron Center Avenue. An entry loss coefficient was applied to the sewer pipe forcing these inlets to surcharge around the same time as those at the bottom of the hill. This location is important because of the large amount of surface water that bypasses this inlet and contributes to the Bayberry Farms storm sewer system, when otherwise the modeling would show no surcharging and therefore no contribution of flow from this area.
- Several subcatchments (Out-01, Out-2, and Out-3) were included in the model based on topography, even though they contain storm sewers that flow to other outlets outside of the study area (Figure 7). None of the storm sewers in these subcatchments were found to have surcharging above the ground surface, so the model did not include a surface flow path to the subcatchments in the study area. However, runoff from further east along Health Drive (Out-02) may have bypassed catch basin inlets during the rainfall event of September 9, 2013, due to the sheer amount of runoff and relatively steep roadway grades (momentum of the flow) and added to the stormwater volume reaching Byron Center Road. Conservative assumptions were included in the model in terms of the amount of future developed area contributing to Health Drive for existing conditions. For build-out conditions, the portion of Health Drive in Out-02 was included in the model to compensate for the future developed areas routed away from Health Drive toward the Metro Ponds as proposed in the site plan.
- Along 56th Street near the Senior Apartments, there is a low area along the curb where water ponding in the road can flow down the slope toward the Senior Apartments parking lot. This was also modeled as a surface flow path.

- During the Bayberry Market detention basin as-built survey, the outlet structure at the bottom of the pond could not be located. For existing conditions, the lower outlet was not included in the model. This leads to conservative results for the capacity of the basin.
- The berm along the west side of the Bayberry Market detention basin is essentially at the same elevation as the concrete spillway. Water spilling over the berm flows both north and south. The pond was therefore modeled with three outlets. One outlet is for water spilling over the berm in the direction of the Senior Apartments. The second outlet spills over the berm toward the swale behind the Condominiums. The third outlet is the spillway which discharges by a swale to a catch basin. When this catch basin surcharges, it spills over to the swale behind the Condominiums.
- The pipes connecting the swale at the Condominiums to the storm sewer are modeled with backflow preventers.

MODEL VALIDATION

Model validation involves running a known rainfall event and checking whether the model adequately reproduces observed system behavior. Model validation was performed using the rainfall data from the rainfall event of September 9, 2013. Model results reproduced observed water levels and points of overflow with a reasonable level of accuracy. A summary of the validation results is provided in Appendix 2.

BUILD-OUT

Several areas in Subcatchments 56-04, BBMarket, BFF-01, Metro-01 through Metro-05, Out-2, and Out-3 have existing pervious surfaces (grass, open areas) yet to be built-out. These are shown as future impervious surfaces in Figure 7.

RESULTS

The SWMM model was used to evaluate system performance for the 10-, 25-, and 100-year design rainfall events with full build-out. Numerical results are summarized in Table 5. Critical locations identified in the model are shown in conjunction with the identified flooding areas in Figure 3.

Table 5 - Results Comparison

No.	Description	Measure	Event			
			10-year	25-year	100-year	09/09/2013
1	Flooding on Byron Center Avenue, 200 ft south of 56th Street	Volume conveyed to Bayberry Market detention pond - No detention was modeled east of Byron Center Avenue	0.36 ac-ft	0.75 ac-ft	1.4 ac-ft	1.9 ac-ft
2	Flooding on Gezon Parkway just east of Byron Center Avenue	Volume conveyed on the street toward the intersection - No onsite detention was modeled for subcatchment	0.18 ac-ft	0.38 ac-ft	0.98 ac-ft	1.2 ac-ft
3	Flooding in sag at Fieldstone Drive and Cape Coral Drive	Depth of street flooding	1.1 ft	1.3 ft	1.8 ft	2.0 ft
4	Performance of Bayberry Market Detention Basin	Peak water elevation above the low point in the berm and spillway	0.1 ft	0.2 ft	0.3 ft	0.3 ft
		Volume discharged to Bayberry Condominiums swale	0.20 ac-ft	0.61 ac-ft	1.7 ac-ft	1.7 ac-ft
		Volume of the water discharged over the berm toward Senior Apartments	< 0.1 ac-ft	0.23 ac-ft	0.62 ac-ft	0.66 ac-ft
5	Flooding in sag on 56th Street, 600 ft west of Byron Center Avenue	Depth of the water relative to the curb inlet elevation (723.2)	1.4 ft below	0.3 ft above	0.9 above	0.8 ft above
		Volume conveyed over the curb toward the apartments	0 ac-ft	0 ac-ft	0.36 ac-ft	0.29 ac-ft
6	Flooding at Byron Center Avenue and Health Drive	Volume of the water conveyed to the Bayberry Market parking lot and routed to the detention basin	0 ac-ft	0 ac-ft	0.39 ac-ft	0.53 ac-ft
7	Flooding in Senior Apartments	Depth of the water relative to low catch basin in the parking lot (716.4)	3.5 ft below	3.3 ft below	1.8 ft above	1.9 ft above
8	Flooding in the swale behind the Condominiums	Depth of the water relative to lowest basement opening	2.8 ft below	1.1 ft below	1.0 ft above	1.6 ft above
9	Flooding at 5678 and 5660 Bayberry Farms Drive	Volume released from the nearby catch basin	0 ac-ft	0 ac-ft	0.15 ac-ft	0.28 ac-ft
10	Flooding at 2614 Thackery Drive	Volume discharged from the yard inlet in the back of the house	0 ac-ft	0 ac-ft	0.5 ac-ft	0.45 ac-ft
11	Metro Health Ponds	Volume discharged through overflow structure	0 ac-ft	0 ac-ft	2.83 ac-ft	0.02 ac-ft

Elevations taken from design drawings and confirmed through as-built survey.
Design storm results assume build-out conditions; 09/09/2013 storm results assume existing conditions.
Blue shading indicates no surcharging above the top of casting or overflow.

10-year Design Storm

In general, model results indicate that the storm sewer system has capacity for the 10-year design storm (3.52 inches of rain in 24 hours) as would be expected. Critical locations that begin to show up in the model include:

1. The sag in Byron Center Road, 200 feet south of 56th Street - The pipe at this location is only a 12-inch diameter. However, no onsite detention was modeled from the contributing subcatchment (BC-01), so results are conservative.
2. Gezon Parkway just east of Byron Center Avenue - The pipe at this location is a 15-inch diameter. However, no onsite detention was modeled from the contributing subcatchment (56-03), so results may be conservative.
3. The sag in Fieldstone Drive at Cape Coral - A low area where surcharging in the model exceeds the ground surface.
4. The Bayberry Market detention basin - Due to the low elevation of the berm, the model shows the basin just begins to discharge over the berm. However, the model assumed no low flow outlet due to plugging, so results are conservative.

25-year Design Storm

Results for the 25-year design storm (4.45 inches of rain in 24 hours) indicate surcharging (flooding) above the ground surface at all of the above locations. The Bayberry Market detention basin shows a discharge into the catch basin in the overflow spillway and over the top of the berm to the west. This detention basin should have no overflow occurring during the 25-year storm. Overflows occur due to the additional stormwater contribution from overland flow areas not considered in the design and the slight undersizing of the basin. No flooding occurs at the Condominiums for the 25-year storm, where results indicate over 1 foot of freeboard between the high water level and the lowest opening in accordance with design standards.

100-year Design Storm

Results for the 100-year design storm (6.15 inches of rain in 24 hours) show additional critical locations in the storm sewer system:

5. The sag in 56th Street, 600 feet west of Byron Center Avenue - Ponding depth of 1 foot in the street and water discharges over the slope to the south in front of the Senior Apartments.

6. Surface flows cross Byron Center Avenue at Health Drive adding stormwater to the Bayberry Market storm sewer.
7. Surcharging in Senior Apartments storm sewer to 1.8 feet above low catch basin rim elevation.
8. Flooding approximately 1 foot above the lowest basement opening at the Condominiums.
9. Flooding in the catch basin behind 5678 Bayberry Farms Drive.
10. Flooding in the catch basin behind 2614 Thackery Drive.
11. Metro Health Ponds - Water discharges to Bayberry Farms storm sewer through a 48-inch diameter overflow structure and 24-inch pipe under Byron Center Avenue, but water surface elevation stays below roadway.

Rainfall Event of September 9, 2013

Table 5 also provides a comparison to the rainfall event of September 9, 2013. Several findings warrant further discussion:

Modeling shows an additional 2.43 ac-ft (105,900 cft) of water directed to the Bayberry Market detention basin from the flooding on Byron Center Avenue and surface flows from Health Drive during the rainfall event of September 9, 2013 (Location 1, Table 5). In comparison, the directly contributing subcatchment (BBMarket-N) for which the basin was designed delivered 1.37 ac-ft (acre feet) (59,800 cft (cubic feet)) of runoff (Appendix 2).

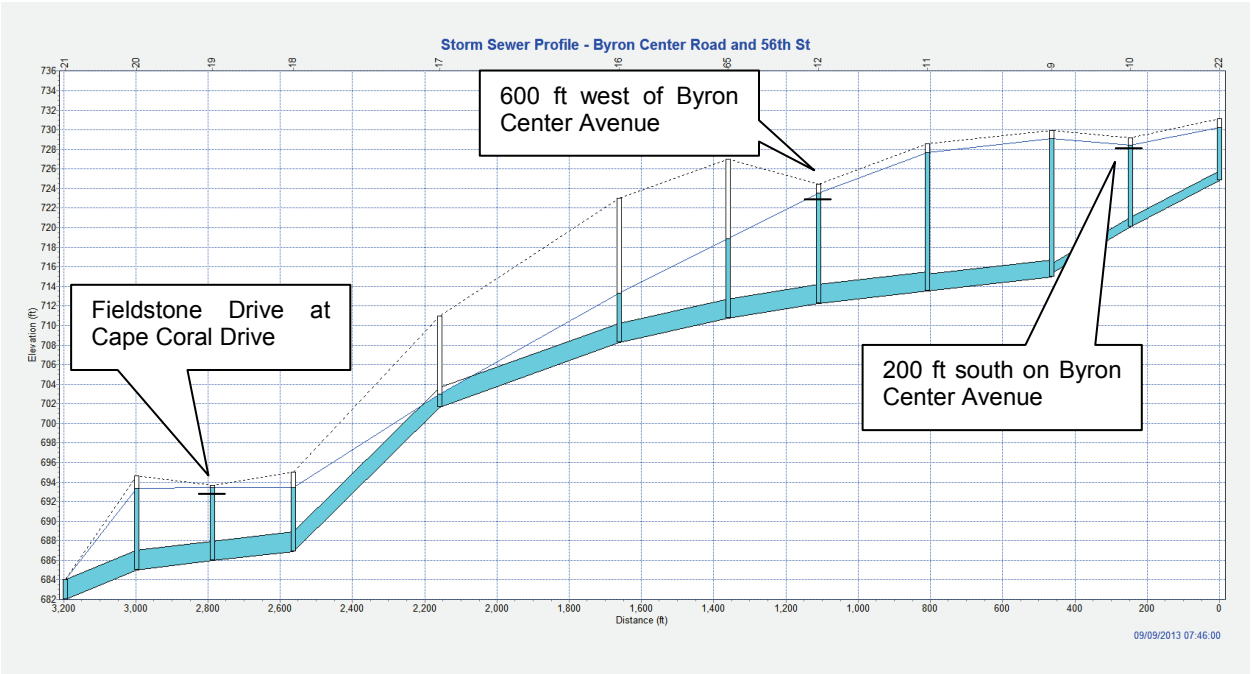
Modeling shows the Bayberry Market detention basin (Location 4, Table 5) discharged 1.7 ac-ft to the Condominiums and 0.66 ac-ft to the Senior Apartments, so the remaining 1.44 ac-ft, or about 40 percent of the volume was discharged through the overflow spillway and storm sewer.

The water that flooded in 56th Street in front of the Senior Apartments (Location 5, Table 5) came from a total contributing area of 25.4 acres (subcatchments 56-02, 56-03 and BC-01) with an average of 70 percent impervious cover (Figure 7). The directly contributing subcatchment (56-02) is only 8.8 acres. Modeling shows the total volume of water directed to this location during the rainfall event of September 9, 2013, was 10 ac-ft, with 0.29 ac-ft being discharged into the Senior Apartments parking lot.

Modeling shows the Senior Apartments (Location 7, Table 5) received a total of 1.91 ac-ft of stormwater runoff with 0.29 ac-ft coming from 56th Street, 0.66 ac-ft from the Bayberry Market detention basin and 0.96 ac-ft from onsite runoff.

Results of the hydraulic modeling are also presented in a series of storm sewer profiles that provide perspective on individual flooding locations. On these plots, the peak water surface during the rainfall event of September 9, 2013, is shown by the blue line, and the dashed line represents the ground surface.

A profile of the storm sewer in 56th Street from the outlet at Fieldstone Drive to Byron Center Avenue is shown in Graphic 4.

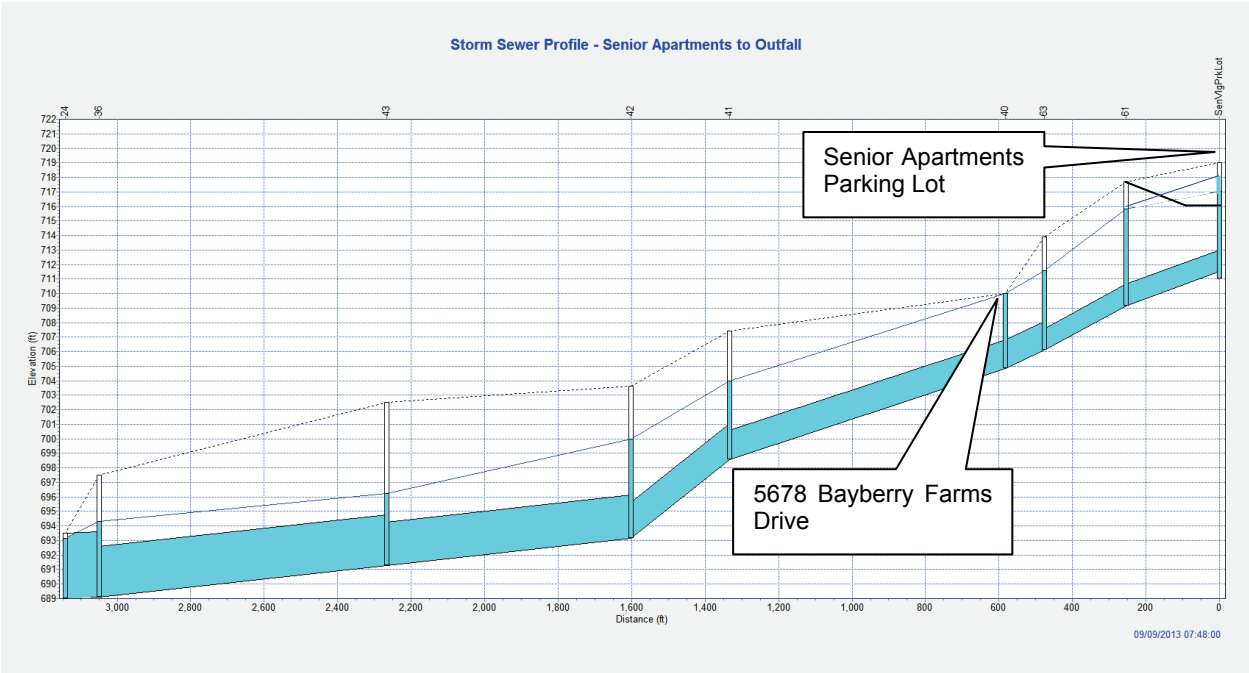


Graphic 4 - Profile of 56th Street and North Byron Center Avenue Storm Sewer (09/09/2013)

The upper two runs of 12-inch pipe are located in Byron Center Avenue. In this profile, the dashed ground surface line is shown 1 foot above the actual top-of-road due to the modeling of overland flow. Top-of-road elevations are shown by the black line at critical locations.

The profile shows the storm sewer system is taxed during an extreme rain event except through the reach of steep pipe west of Bayberry Farms Drive. The sag curves in the roadway tend to pond the water that surcharges from the catch basins or reaches these locations by overland flow.

A profile of the storm sewer up Barcroft Drive to the Senior Apartments is shown in Graphic 5.

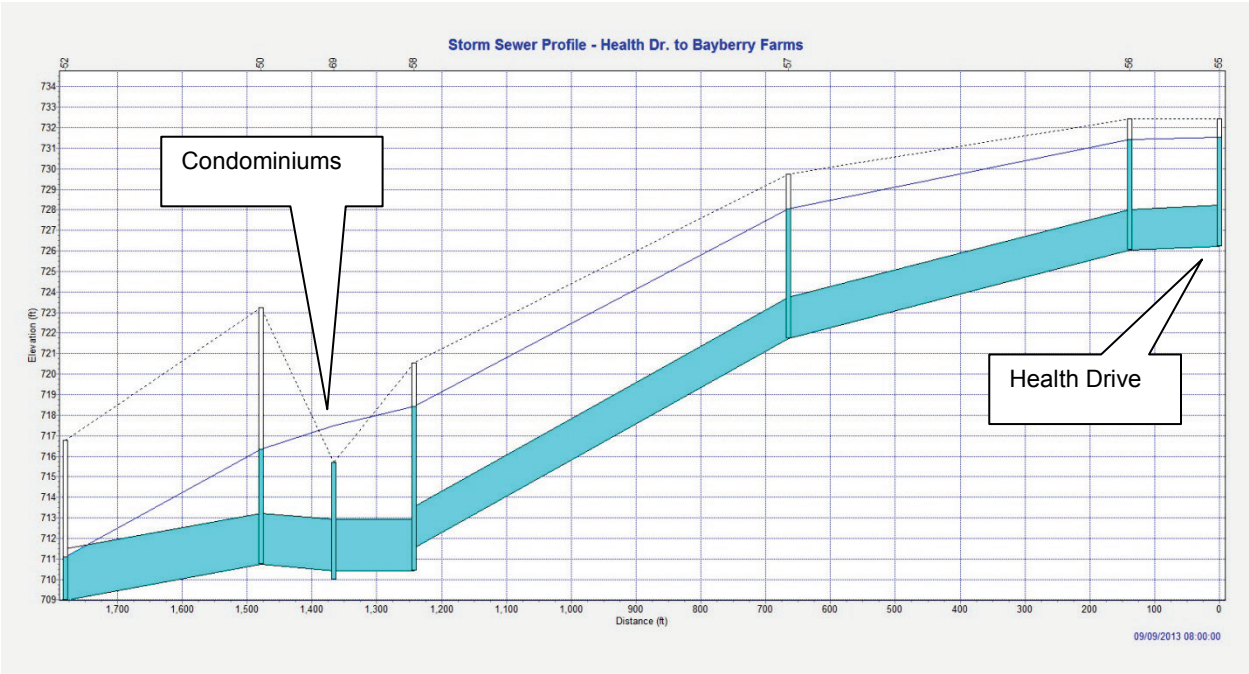


Graphic 5 - Profile of Barcroft Drive Storm Sewer (09/09/2013)

Model results shows the storm sewer functions well even for extreme rainfall events. However, the profile plot clearly shows the critical location in the system is the low area east of Bayberry Farms Drive where two homes experienced basement flooding. As-built survey shots show the house at 5678 Bayberry Farms Drive has a first floor elevation of 715.5 feet, which is 2 feet lower than the neighboring houses. The nearest catch basin is 5 feet lower than the finished floor elevation, which means the basement floor is approximately 3.5 feet below the catch basin rim. Minimum building openings for these lots are shown as 706.0 feet in restrictive covenants. However, this elevation does not correspond with existing grades and would set minimum openings 4 to 5 feet below the adjacent ground surface surrounding these lots.

Flooding of the Senior Apartments parking lot is also shown in the profile plot. Since this area was modeled as a storage unit, the dashed line represents the peak storage elevation and not the ground surface. The black line indicates top-of-casting for the lowest catch basin in the Senior Apartments parking lot.

A profile of the storm sewer through the Condominiums and around the south side of Bayberry Market from Bayberry Farms Drive to Health Drive is shown in Graphic 6.

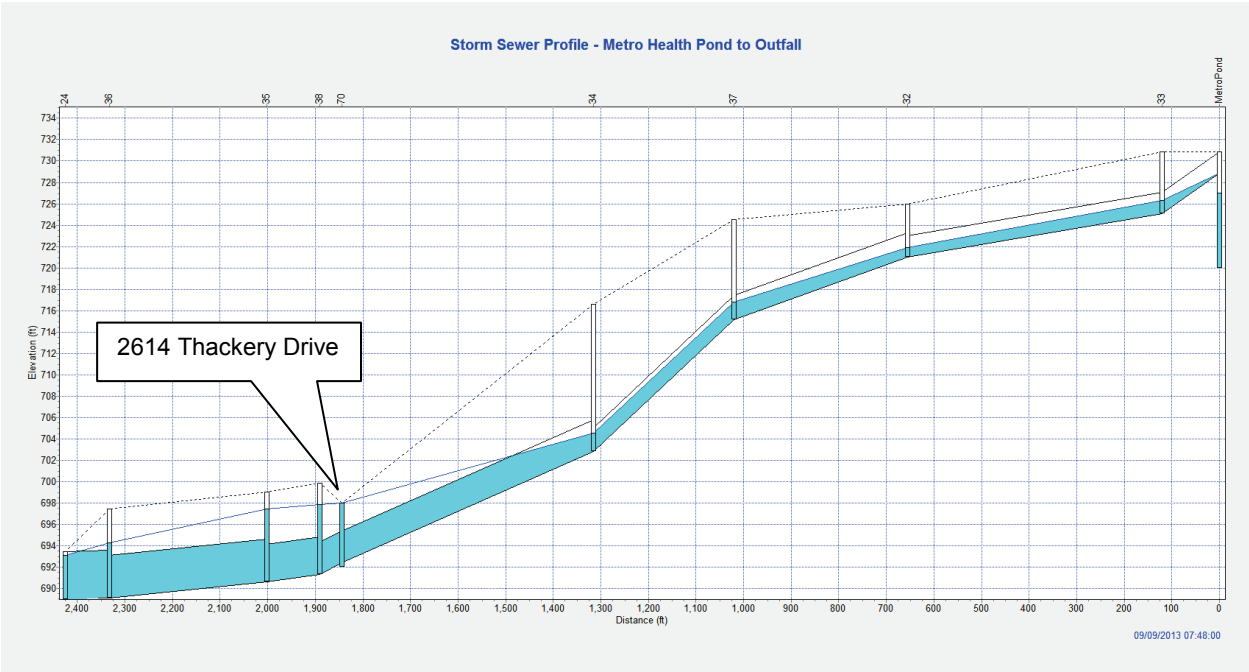


Graphic 6 - Profile of Bayberry Farms Condominiums Storm Sewer (09/09/2013)

The profile shows the susceptibility of the Condominium units to flooding from surcharging of the storm sewer system. The backflow preventers included in the model prevent the storm sewer from discharging water back into the swale behind the Condominium units. The water surface flooding at this location is caused primarily from surface runoff from the immediate drainage area and overland flow from the Bayberry Market detention basin. However, the ability of this water to drain away is dependent on the water elevation in the downstream pipe, so the swale will only drain when the water level in the pipe is below the water level in the swale.

As seen by the water surface below the top of pipe at the left-hand side of this profile, the Bayberry storm sewer has no effect on backwater in the Condominium storm sewer.

A profile of the storm sewer in Bayberry Farms Drive between Barcroft Drive and the Metro Health Hospital detention ponds is shown in Graphic 7.



Graphic 7 - Profile of Bayberry Farms Drive Storm Sewer (09/09/2013)

Model results show the storm sewer functions well even for extreme rainfall events. However, the profile plot clearly shows the critical location in the system is the low area south of Thackery Drive. Two trunk sewers also come together at this location in Scarsdale Drive (Figure 2). The effect of this combined flow can be seen by the flattening of the water surface, indicating a backup of water, which floods due to the low topography (Figure 3). As-built survey shots show a low opening sill elevation of 701 feet and a basement floor elevation of 697.3 feet for the residence at 2614 Thackery Drive. GIS shows a storm sewer invert of around 692 feet with a catch basin rim elevation around 698 feet. The minimum building opening elevation required for this lot by restrictive covenant is 701.0 feet, so the structure is in compliance.

The contribution of flow from the two additional traffic lanes on Byron Center Avenue south of Health Drive has no impact on the flooding at Thackery Drive. The storm sewer system has adequate capacity for the 25-year storm with no surcharging above the catch basin at Thackery Drive.

Future build-out of the Metro Health Complex has the greatest impact on the volume of stormwater discharged to this section of Bayberry Farms storm sewer for storms greater than the 25-year event (Table 5). The available capacity in the upper end of the storm sewer seen in the profile will be then be used.

EVALUATION OF IMPROVEMENT ALTERNATIVES

The SWMM model was used to evaluate several improvement alternatives based on standard design criteria and rainfall data from Bulletin 71. The following alternatives were evaluated for flood reduction benefit and cost. All costs are rounded up to the nearest ten thousand dollars.

- Expand the Bayberry Market detention basin.
- Reduce overflows from Health Drive to Bayberry Market.
- Reduce overflows from 56th Street to the Senior Apartments.
- Reduce overflows from Byron Center Avenue to Bayberry Market.

EXPAND BAYBERRY MARKET DETENTION BASIN

The design standard used for this detention basin is a 25-year storm, if an acceptable overland flow path is available. The overland flow route is particularly important at this location since a high flood risk exists downstream of the basin due to the proximity and elevation of the Condominiums.

Improvements to the basin include raising the berm to a minimum elevation of 728 feet to provide for 1 foot of freeboard above the design overflow high water elevation (assumes water flowing 1-foot deep over the spillway) and expanding the volume to contain the 25-year storage volume at the spillway crest elevation of 726 feet.

Results indicate the detention basin volume would need to be 60,000 cubic feet, or 1.5 times larger than the existing basin, accounting for additional water from Byron Center Avenue. The overflow swale (upper swale) would also need to be bermed to provide a minimum of 1 foot of freeboard for the design discharge, and eliminate flows between the upper and lower swale. Overflows beyond this would still be directed into the lower swale behind the Condominiums.

Benefits in terms of flood reduction are summarized in Table 6.

Table 6 - Benefits of Bayberry Market Detention Basin Expansion

Location	Measure	Event			
		10-year	25-year	100-year	09/09/2013
Senior Apartments	Depth of the water relative to low catch basin in the parking lot (716.4)	3.5 ft below	3.3 ft below	1.4 ft above (-0.4 ft)	1.3 ft above (-0.6 ft)
5678 Bayberry Farms Drive	Volume released from the nearby catch basin	0	0	0.13 ac-ft (-0.02 ac-ft)	0.23 ac-ft (-0.05 ac-ft)
Condominiums	Depth of the water relative to the lowest basement opening	2.8 ft below	1.3 ft below (-0.2 ft)	0.2 ft below (-1.2 ft)	0.1 ft above (-1.5 ft)
Design storm results assume build-out conditions; 09/09/2013 storm results assume existing conditions. Reduction (from Table 5) is shown in parenthesis.					

The estimated project cost is $60,000 for 900 cubic yards of excavation (60,000 cft – 36,000 cft/27) using a budgetary unit cost of $60 per cubic yard to cover excavation, disposal, storm sewer appurtenances, restoration, engineering, and contingencies.

If a 100-year design is necessary because an adequate overflow pathway cannot be assured, the detention basin volume would need to be 123,500 cubic feet, or 3.35 times larger than the existing basin. The estimated project cost is $200,000 (123,500 cft – 36,000 cft /27 = 3,240 cy) using a budgetary unit cost of $60 per cubic yard. Further investigation would be needed to determine if adequate space is available for expansion of the basin to this extent.

REDUCE OVERFLOWS FROM HEALTH DRIVE

The design standard used is the excess runoff from a 100-year storm, since no volumes are conveyed across Byron Center Avenue for the 10-year and 25-year storms.

Improvements at Health Drive include regrading the roadway to create a sag curve and adding additional inlets east of the existing catch basins that outlet to the Metro Health Hospital detention ponds. Alternative inlet grates placed within the roadway to intercept high-velocity stormwater runoff volumes could also be explored. An overland flow path should be preserved above the pipe.

The estimated project cost is $60,000 for 200 lineal feet of roadway rework using a budgetary unit cost of $300 per lineal foot to cover removals, fill, regrading, pavements, curb and gutter, sidewalk, catch basin inlets, leads, restoration, engineering, and contingencies.

REDUCE OVERFLOWS FROM 56TH STREET

This alternative consists of berming along the south side of 56th Street in front of the Senior Apartments to reduce the frequency of overtopping from water ponded in the sag in 56th Street. The present elevation of 724 can reasonably be raised 2 feet to elevation 726. In raising this elevation, consideration must also be given to the effects of eliminating an overflow route. Water will be able to pond up to 2 feet higher in 56th Street and on the north side of the roadway. Therefore, a detention basin should be constructed on the north side of 56th Street to minimize negative impacts of berming on the south side.

The design standard used for the detention basin is the 100-year storm, since raising the berm on the south side of the road has no effect on the 25-year storm.

Model results indicate a detention area with a volume of 44,000 cft would be required. This volume takes into account the contribution from the storm sewer in Byron Center Avenue, which was assumed to flow to the Bayberry Market detention basin. A bottom elevation of 720 would require about 3 to 4 feet of excavation. An area of 20,000 square feet (0.45 acre) would result in a water depth of 2.2 feet. Further investigation is needed to determine availability of land and site limitations.

Benefits in terms of flood reduction to the Senior Apartments are summarized in Table 7, which includes the reductions achieved by eliminating overtopping of the berm from the Bayberry Market detention basin.

Table 7 - Benefits of Reducing 56th Street Overflow

Location	Measure	Event			
		10-year	25-year	100-year	09/09/2013
Senior Apartments	Depth of water relative to the low catch basin in the parking lot (716.4)	3.5 ft below	3.3 ft below	0.9 ft above (-0.9 ft)	0.9 ft above (-1.0 ft)
5678 Bayberry Farms Drive	Volume released from the nearby catch basin	0	0	0.13 ac-ft (-0.02 ac-ft)	0.23 ac-ft (-0.05 ac-ft)
Design storm results assume build-out conditions; 09/09/2013 storm results assume existing conditions. Reduction (from Table 5) is shown in parenthesis.					

The estimated project cost is $100,000 for 1,650 cubic yards (44,000 cft/27) using a budgetary unit cost of $60 per cubic yard to cover excavation, berming, disposal, storm sewer appurtenances, restoration, engineering, and contingencies. This cost does not include land acquisition.

REDUCE OVERFLOWS FROM BYRON CENTER AVENUE

The design standard used for storm sewer is the 10-year storm. However, since it is the objective to eliminate overland flows discharging to the Bayberry Market detention basin, the peak flow required to keep ponding in Byron Center Avenue from entering the Bayberry Market driveway was determined from the model for the 100-year storm.

Improvements at Byron Center Avenue and 56th Street include upsizing 600 lineal feet of storm sewer between the sag in 56th Street and the sag in Byron Center Avenue, and placing additional catch basin inlets in the sag on Byron Center Avenue. Pipe diameters would range from 24- to 36-inch to convey a peak flow of 50 cfs. The new storm sewer would tie into the existing 24-inch in 56th Street 600 feet west of Byron Center Avenue and rely on a new detention basin as described above to mitigate any additional flooding in the sag on 56th Street.

The estimated project cost is $240,000 for 600 lineal feet of storm sewer and roadway restoration using a budgetary unit cost of $400 per lineal foot to cover removals, storm sewer, drainage structures, pavements, curb and gutter, utilities, restoration, engineering, and contingencies.

CONCLUSIONS

The rainfall of September 9, 2013, was an extreme event and can be categorized as a 400-year storm for the most intense 2-hour period using current rainfall frequency references. This event greatly exceeded the rainfall depths and intensities used for design of stormwater systems. City and private stormwater systems in the study area were taxed, but generally performed well when tested with an extreme rainfall event. Where flood damage occurred, it was in low areas without an adequate overland flow route.

Analysis shows the Bayberry Farms and City storm sewer systems function satisfactorily for the 10-year design storm. One exception is Byron Center Avenue, 200 feet south of 56th Street, which begins to discharge water through the Bayberry Market North commercial development.

Although the low area in 56th Street, 600 feet west of Byron Center Avenue, discharged stormwater to the Senior Apartments parking lot during the rainfall event of September 9, 2013, the storm sewer meets City standards for trunk sewers (10-year) and overland flow paths (25-year).

The Bayberry Market detention basin was found to have several deficiencies. The outlet pipe has become buried, which increases the chance of overflow. The basin is undersized for the 25-year design storm. Most importantly, the berm on the west side of the basin is too low and overflows are directed to the Condominiums and Senior Apartments storm sewers, which were not designed for this additional water. Finally, the upper swale downstream of the overflow spillway has only 0.5 foot of depth before cresting and flowing into the lower swale of the Condominiums.

The walk-out basements of the Condominiums are in a topographically low area without an available overland flow route. If the capacity of storm sewer inlets is exceeded and water ponds more than 3.5 feet, the walk-out basements will flood. A minimum of 1 foot of freeboard is provided between the 25-year design high water level in the swale and the lowest opening by City design standards. However, it appears the swale may have filled somewhat over time (noted during the as-built survey), which reduces storage capacity and can increase the risk of flooding. Analysis indicates overtopping of the Bayberry Market detention basin was the primary factor in flooding of the Condominiums. Additional information received by the Bayberry Condominium Board indicates the backflow preventers were not in place during the September 9, 2013 rain event, which may have exacerbated the extent of flooding.

The Senior Apartments are located on a flat plateau with higher ground to the north and east. Storm sewer inlets encircle the apartment building and are all very close in elevation with drainage divides in between. The drainage divides are 1 foot lower than the finished floor of the Senior Apartments and act as overflows for ponded water around catch basin inlets. The elevation of these drainage divides is an important factor that prevented the flooding of the apartment units. Analysis indicates the majority of runoff during the rainfall event of September 9, 2013, came from the directly contributing area and overflows from the Bayberry Market detention basin.

Analysis shows the runoff contribution from Health Drive that crossed Byron Center Avenue and flowed into the Bayberry Market parking lot would not impact the design of the Bayberry Market detention basin since it occurs for events greater than the design storm event. However, this additional stormwater does take up capacity in the Bayberry Market and Condominium storm sewer during extreme events when the Condominiums have been shown to be flood prone. Drainage of the lower swale in front of the walk-out basements cannot occur when water is backed up in the 30-inch storm sewer downstream.

RECOMMENDATIONS

Recommendations are provided to address identified stormwater system deficiencies and present feasible options to the City and private landowners to further minimize flood hazard risk. Recommendations are categorized by maintenance, capital improvements, and design standards.

MAINTENANCE

The following maintenance activities should be completed by the owners of the private stormwater facilities:

1. *Clean and restore the low flow outlet of the Bayberry Market detention basin.*

   This outlet was found to be buried during the as-built survey. Consideration should also be given to design improvements to prevent the inlet from becoming buried. At a minimum, the developer/property owner should establish an annual maintenance plan that includes a dedicated budget, regular inspections, and a timeframe for required actions and provide a copy to the City. If such a plan already exists, the developer should review the plan for needed updates and proceed to implement regular maintenance.

2. *Reinstall the backflow preventers in the storm sewer downstream of the lower swale in back of the Condominiums.*

   The Bayberry Condominium Board should contract for the reinstallation of the backflow preventers removed during the spring of 2013. Tideflex check valves, or a similar product, to be approved by the City is recommended. The City should include this area as a critical location in their operation and maintenance plan.

3. *Regrade the lower swale in back of the Condominiums to restore design depth.*

   Although modeling showed sufficient freeboard greater than 1 foot is present for the 25-year design storm, any additional storage volume regained in the drainage swale will increase the factor-of-safety against flooding of walk-out basements. At a minimum, the developer/property owner should ensure the swale is regraded to design depth and slopes.

CAPITAL IMPROVEMENTS

The following capital improvements are recommended:

1. *Berm the Bayberry Market detention basin and overflow route to comply with the City design standards.*

   The developer/land owner should bring the Bayberry Market detention basin into compliance with the City design standards for a 25-year storm. Safe passage for overflows from the emergency spillway for the design discharge with a minimum of 1 foot of freeboard should also be provided along the overflow route in the upper swale. This is important since any overflow from the upper swale will spill over to the lower swale in back of the Condominiums.

2. *Consider expanding the Bayberry Market detention basin to accommodate the additional contribution of stormwater runoff from Byron Center Avenue.*

   With the detention basin brought up to design standards, it will still be undersized for the additional contribution of stormwater runoff from Byron Center Avenue, causing the overflow spillway to be used more frequently and taking up more capacity in the Condominium storm sewer. The City should consider taking ownership of the detention basin and expanding it to accommodate the additional offsite stormwater and reduce a major source of the flooding at the Condominiums and Senior Apartments. While City ownership will most reliably ensure the long-term operation and maintenance of this critically located detention basin, the City could also contribute financially to expansion of the basin and execute a maintenance agreement including reporting requirements with the private owner of the basin. The estimated project cost for this alternative is $60,000. This is 5 times less than the cost of the alternative to upsize the storm sewer in Byron Center Avenue and 56th Street, and could be completed in lieu of the storm sewer improvement project

3. *Floodproof high-risk Condominium units to achieve a greater level of flood protection.*

   The Condominiums would have a 25-year level of flood protection with the Bayberry Market detention basin brought up to design standards, although the overflow spillway would be expected to engage more frequently as described above. The Condominiums would have a 100-year level of flood protection with the Bayberry Market detention basin brought up to design standards, expanded to account for additional offsite stormwater, and with the upper swale redesigned to store the water discharged from the spillway during the 100-year storm in excess of the

downstream storm sewer capacity. In either case, floodproofing could be pursued by individual property owners if a greater level of flood protection is desired.

4. *Further evaluate the need for a City stormwater detention area on the north side of 56th Street.*

   Water from 56th Street overtopped the south side or the roadway and flowed into the parking lot of the Senior Apartments during the rainfall event of September 9, 2013. The stormwater conveyance system meets the City standards for this reach of storm sewer and roadway. The City has also added another catch basin inlet on the south side of the road (Figure 6). While berming will reduce the occurrence of water overtopping the south side of the road, it will increase the depth and extent of roadway flooding and/or flooding to the north. Before the City agrees to berming, further evaluation of the impacts to the north side of 56th Street is needed. Establishment of a stormwater detention area with associated easements or land acquisition is the most reliable way to provide for a higher level of flood protection if the City determines it is warranted. The estimated project cost, not including land or easement acquisition, is $100,000 or less depending upon the final size. At a minimum, an emergency action plan should be put in place for anticipated road closures in this location during large storm events.

5. *Regrade Health Drive and add additional inlets to route excess flood flows to the existing Metro Health detention ponds.*

   The City does not require developers to detain stormwater runoff onsite for the 100-year or larger storms, particularly when the runoff historically flowed to a given outlet. However, it appears excess stormwater flows from Health Drive can be intercepted and directed to existing onsite detention ponds to reduce the impacts to Byron Center Avenue and the Bayberry Market storm sewer system. Storm drainage improvements in Health Drive are estimated at a project cost of $60,000.

6. *Floodproof individual basements and lowest openings.*

   Analysis shows the Bayberry storm sewer system is adequately sized for the 25-year design storm as specified in City standards when no available overland flow path exists. The isolated basement flooding that occurred on September 9, 2013, was due to the extreme nature of the rainfall event. Private property owners who experienced basement flooding may choose to floodproof through the use of footing drains and sump pumps, waterproofing, and/or elevation of low openings.

DESIGN STANDARDS

The following recommendations are provided to the City for future development activities:

1. *During design review, re-emphasize the requirement to provide safe passage of overland flow routes for extreme flood events and require the same for storm sewers, open channels, and detention/retention basins.*

   City (and County) stormwater design standards require checking that safe passage is available by overland flow routes for extreme events up to the 100-year flood. If overland flow routes do not exist, the design standard is raised from a 10-year to a 25-year for open channels. More recent Kent County standards require a 100-year design for both storm sewers and open channels. Checking for safe passage and setting critical overflow elevations is an important design consideration. The locations where flood damage occurred (or did not occur) in the study area during the rainfall event of September 9, 2013, was due in great part to whether or not an overland flow route was available at an acceptable elevation and to an adequate outlet. Flooding will always occur and flood prone areas will always exist, but identification of these areas is important to minimize flood damage. The storm used for the overland flow path design standard should be clearly specified for storm sewers, open channels, and detention/retention basins, including freeboard requirements. The City should decide whether or not to raise the standard from the 25-year to the 100-year storm.

2. *Incorporate Atlas 14 rainfall data into the City design standards.*

   Atlas 14 includes the larger magnitude rainfalls experienced with increasing frequency during the last 20 years or so. As a result, rainfall amounts have increased for the standard design storms (10-, 25-, and 100-year). It is important to make use of the latest data for new and redevelopments as weather patterns change and the City is continually challenged to manage flood risks.

4. *Require as-built certifications from developers.*

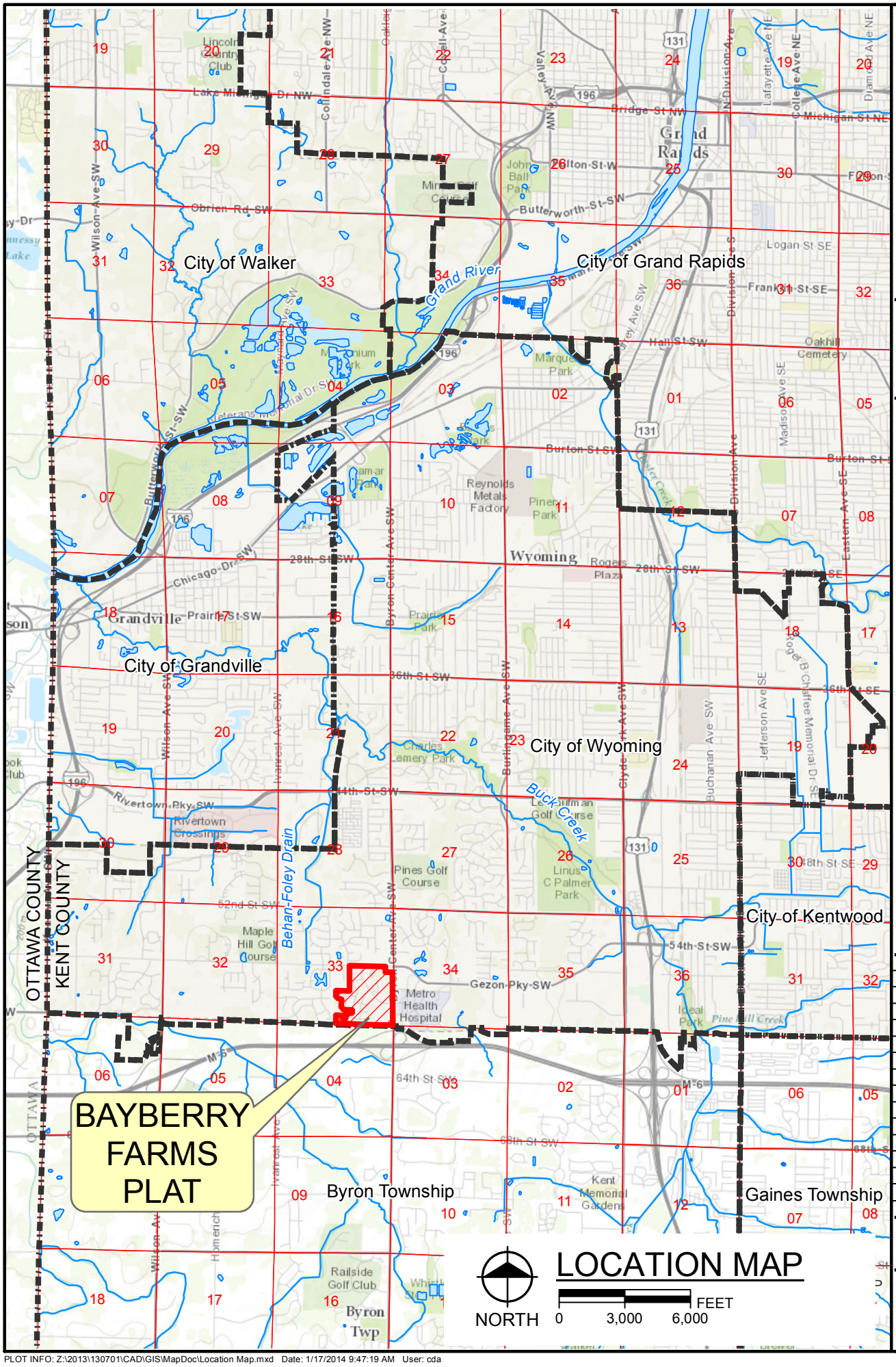
   City ordinance language should be modified if it does not currently require engineer-certified construction record drawings (as-builts) be submitted for the stormwater management systems for all private developments. The KCDC currently requires as-builts for final plats and developments established as county drainage districts under Section 433 of the Michigan Drain Code. As-builts should be required prior to issuance of a Certificate of Occupancy and return of surety. The ordinance language should include a list of the minimum as-built information required and any

GIS digital submission requirements. A procedure should also be determined for the receipt, approval, and filing of construction record drawings with all costs incurred clearly identified to the responsibility of the developer, including a final site inspection as the City deems necessary.

5. *During design review, pay special attention to minimum building openings.*

   Block grading plans including minimum allowable building opening elevations are required by the KCDC for developments under their review and included in the standards used by the City. Reviewing engineers should closely evaluate proposed minimum building openings to ensure sufficient freeboard is provided above design high water levels and along overland flow routes. When individual lots are developed, the City building inspector should require an elevation certificate and certification of lot grading from the builder prior to issuing an occupancy permit.

Figures



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City of Wyoming
Kent County, Michigan

Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
1

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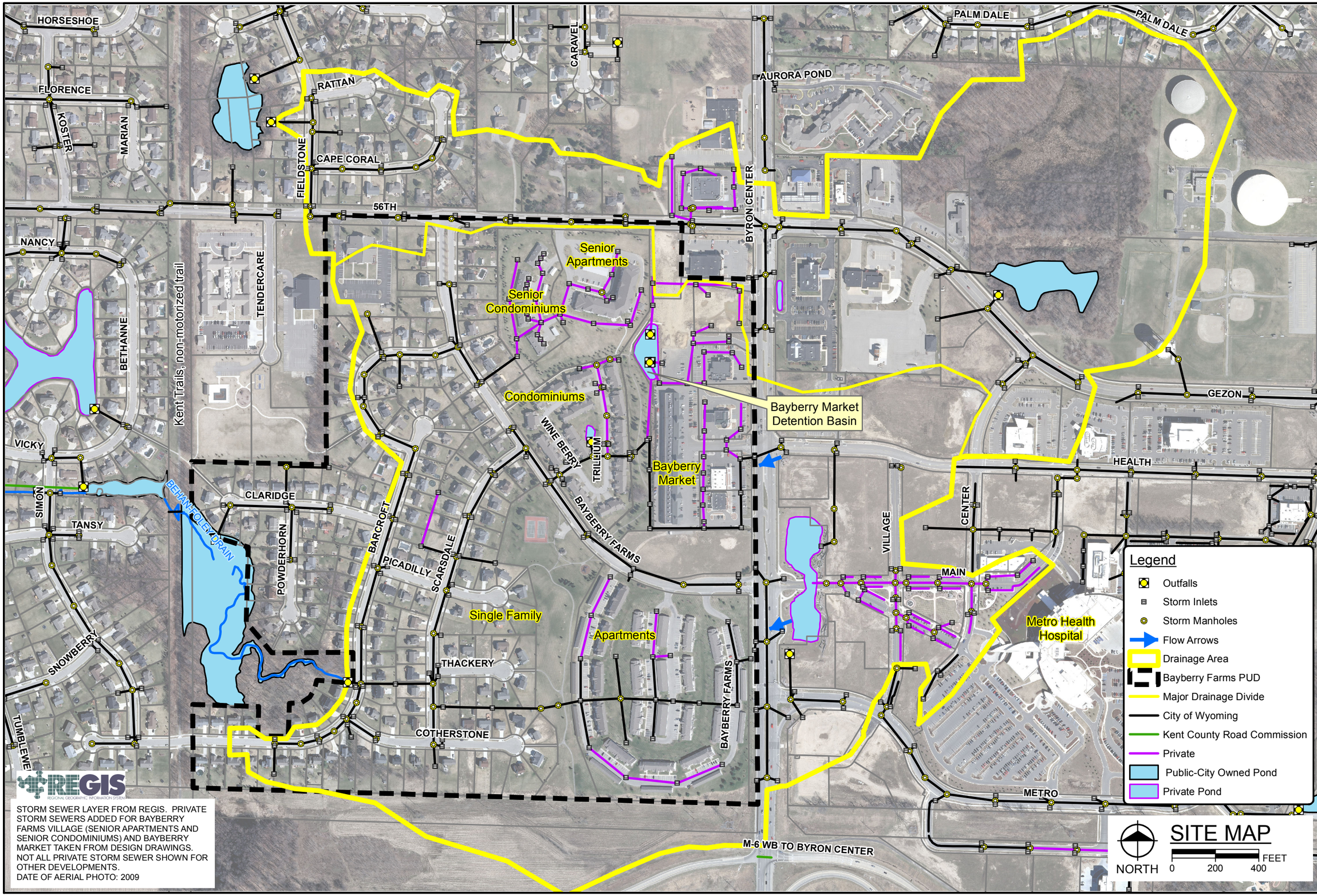

STORM SEWER LAYER FROM REGIS. PRIVATE STORM SEWERS ADDED FOR BAYBERRY FARMS VILLAGE (SENIOR APARTMENTS AND SENIOR CONDOMINIUMS) AND BAYBERRY MARKET TAKEN FROM DESIGN DRAWINGS. NOT ALL PRIVATE STORM SEWER SHOWN FOR OTHER DEVELOPMENTS.
DATE OF AERIAL PHOTO: 2009

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City of Wyoming
Kent County, Michigan

Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
2

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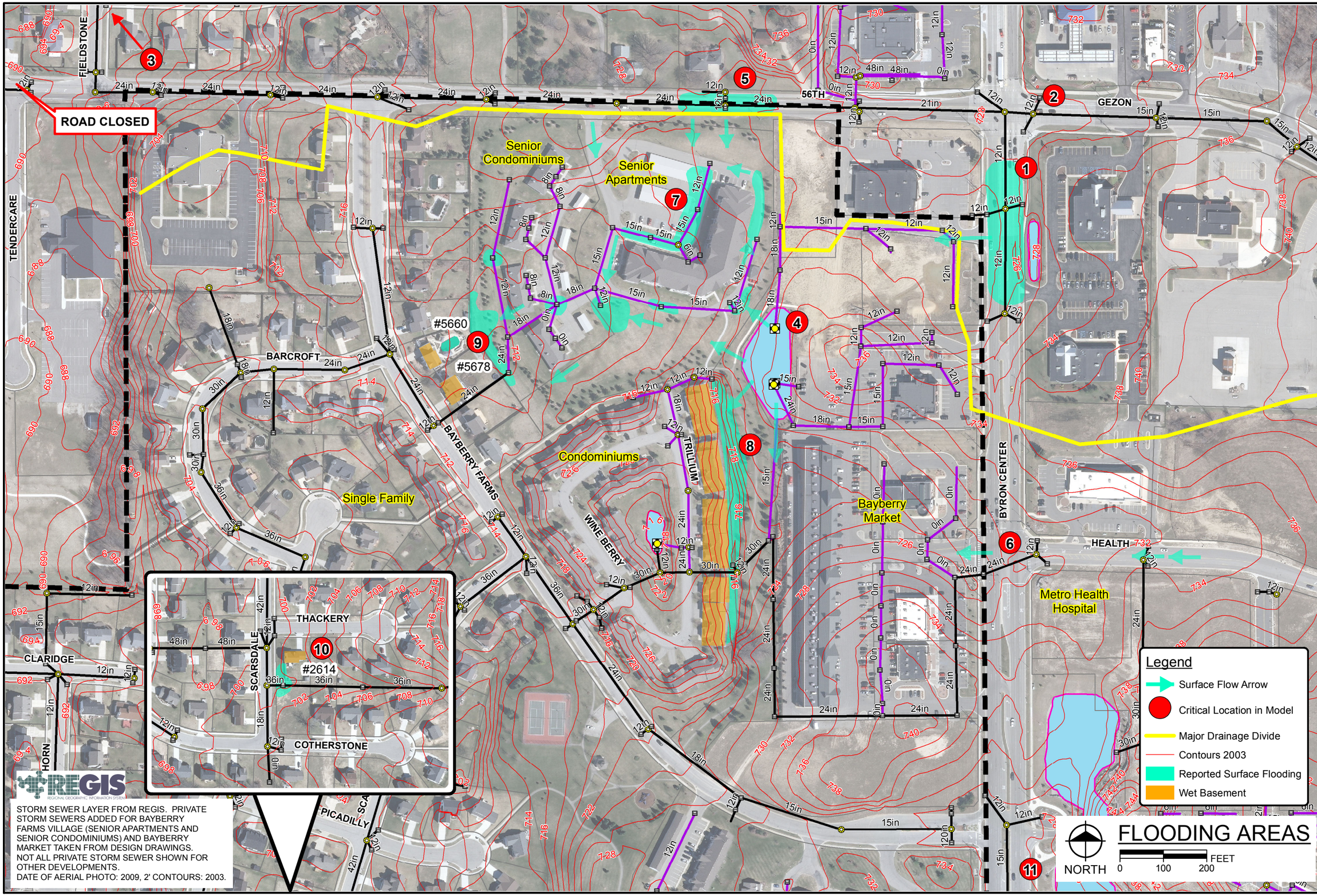

STORM SEWER LAYER FROM REGIS. PRIVATE STORM SEWERS ADDED FOR BAYBERRY FARMS VILLAGE (SENIOR APARTMENTS AND SENIOR CONDOMINIUMS) AND BAYBERRY MARKET TAKEN FROM DESIGN DRAWINGS. NOT ALL PRIVATE STORM SEWER SHOWN FOR OTHER DEVELOPMENTS.
DATE OF AERIAL PHOTO: 2009, 2' CONTOURS: 2003.

FLOODING AREAS

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City of Wyoming
Kent County, Michigan
Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
3

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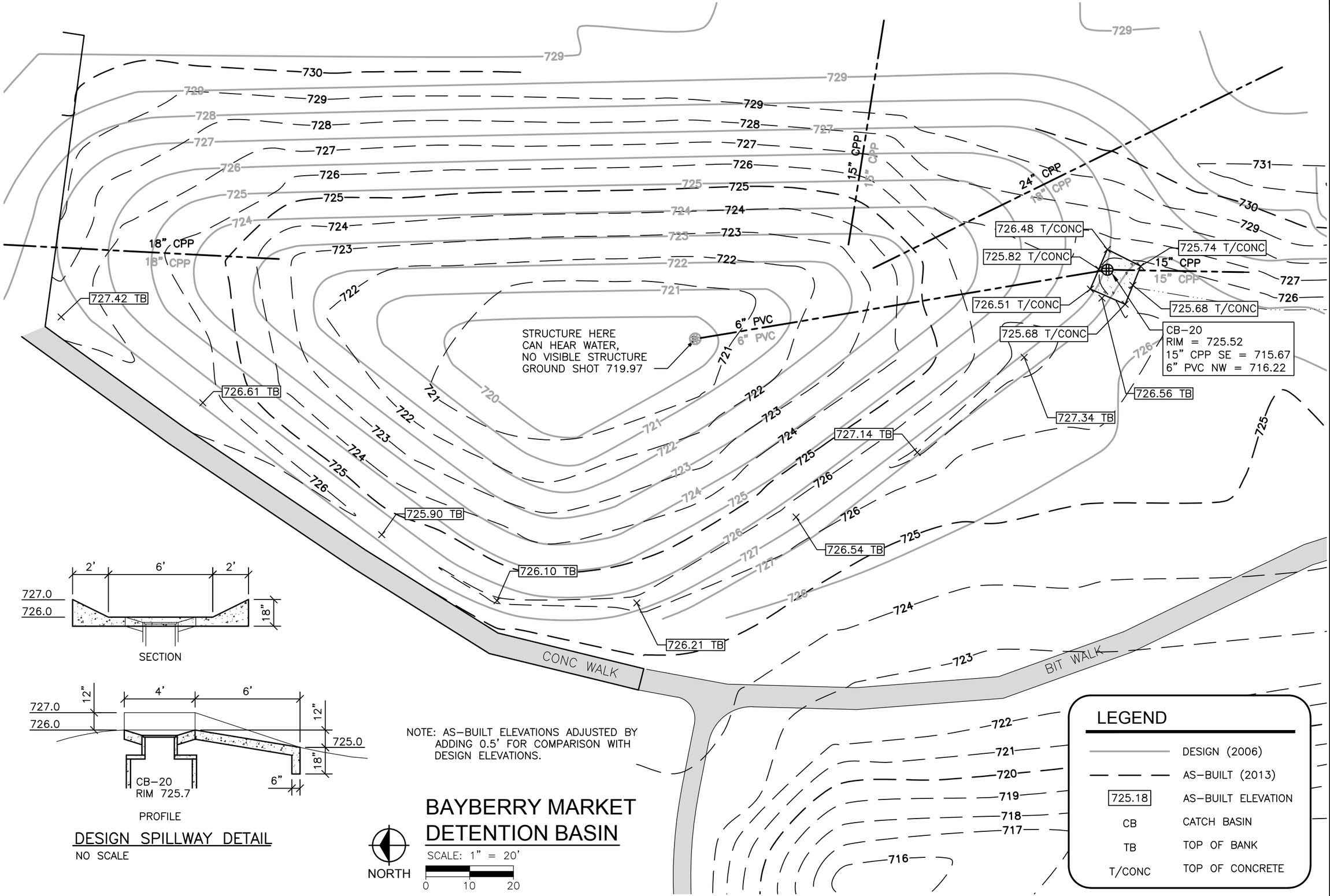

SECTION

PROFILE

DESIGN SPILLWAY DETAIL

NO SCALE

NOTE: AS–BUILT ELEVATIONS ADJUSTED BY ADDING 0.5' FOR COMPARISON WITH DESIGN ELEVATIONS.

NORTH

BAYBERRY MARKET DETENTION BASIN

SCALE: 1" = 20'

0 10 20

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Kent County, Michigan

Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
4

PLOT INFO: Z:\2013\130701\CAD\PRECD\DETENTION BASIN.DWG LAYOUT: LAYOUT1 DATE: 1/16/2014 TIME: 9:01:08 AM USER: MB2

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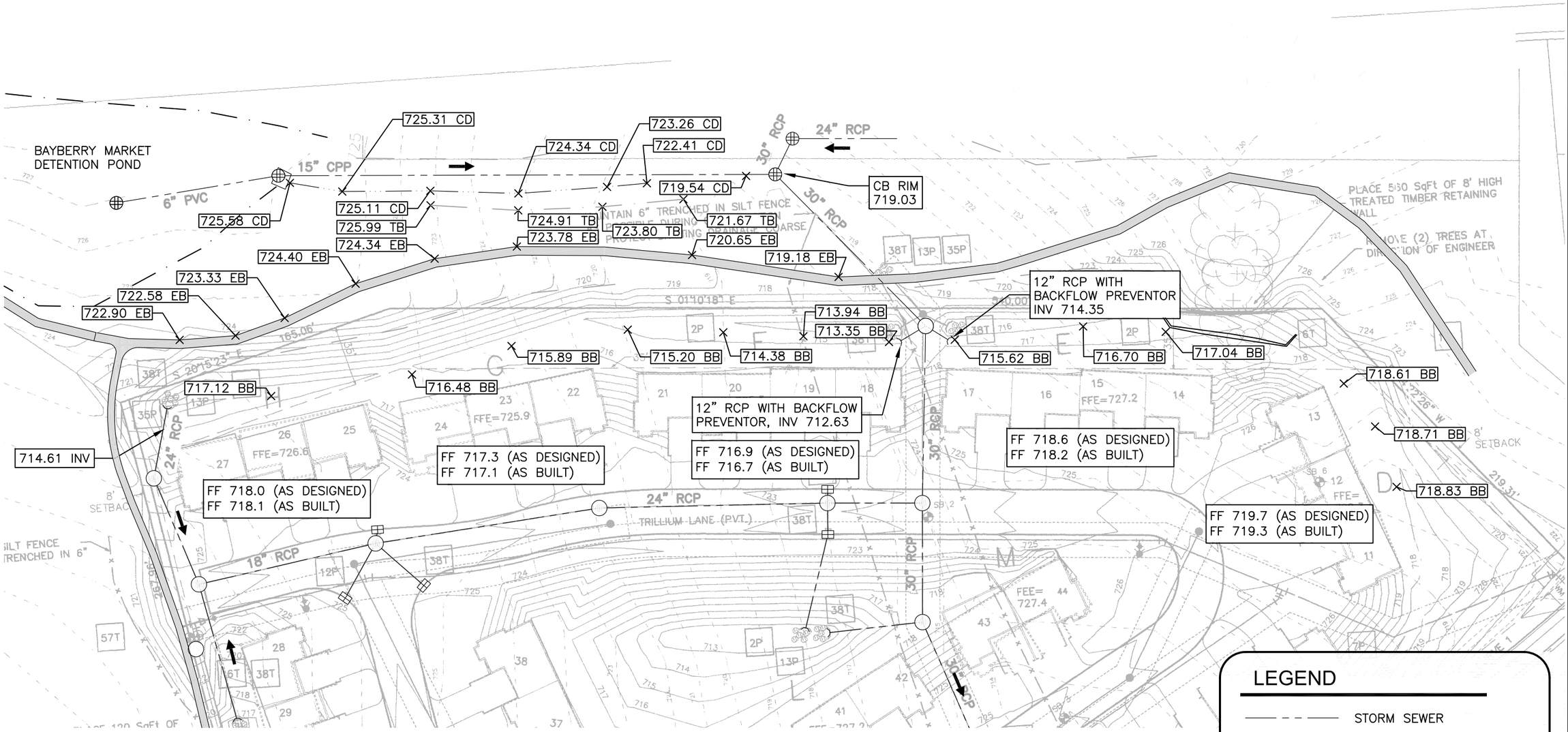

BASE DRAWING: GRADING AND EROSION CONTROL PLAN, CONDOMINIUM HOMES OF BAYBERRY FARMS PHASE 1 (1995).

NOTE: AS–BUILT ELEVATIONS ADJUSTED BY ADDING 0.5' FOR COMPARISON WITH DESIGN ELEVATIONS.

NORTH

BAYBERRY FARMS CONDOMINIUMS

SCALE: 1" = 60'

0 30 60

LEGEND

— — —	STORM SEWER
723.00	AS–BUILT ELEVATION
→	FLOW ARROW
BB	BOTTOM OF BANK
CB	CATCH BASIN
CD	CENTER OF DITCH
EB	EDGE OF BITUMINOUS
FF	FINISHED FLOOR ELEVATION
INV	INVERT
TB	TOP OF BANK

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City of Wyoming
Kent County, Michigan

Bayberry Flooding Elevations

PROJECT NO.
G130701

FIGURE NO.
5

PLOT INFO: Z:\2013\130701\CAD\PRECD\BAYBERRY FARMS CONDOS.DWG LAYOUT: LAYOUT1 DATE: 1/16/2014 TIME: 9:10:24 AM USER: MB2

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BASE DRAWING: SITE GRADING AND SOIL EROSION PLAN, BAYBERRY FARMS VILLAGE (2003).

NOTE: AS-BUILT ELEVATIONS ADJUSTED TO DESIGN DRAWING DATUM BY ADDING 0.5' BASED ON FOUND BENCHMARK.

LEGEND

— — —	STORM SEWER
723.00	AS-BUILT ELEVATION
FF	FINISHED FLOOR ELEVATION
TB	TOP OF BANK
TC	TOP OF CURB

NORTH

BAYBERRY FARMS VILLAGE SENIOR APARTMENTS

SCALE: 1" = 80'

0 40 80

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City of Wyoming
Kent County, Michigan

Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
6

PLOT INFO: Z:\2013\130701\CAD\PRECD\BAYBERRY FARMS SENIOR APT.DWG LAYOUT: LAYOUT1 DATE: 1/16/2014 TIME: 2:40:54 PM USER: MB2

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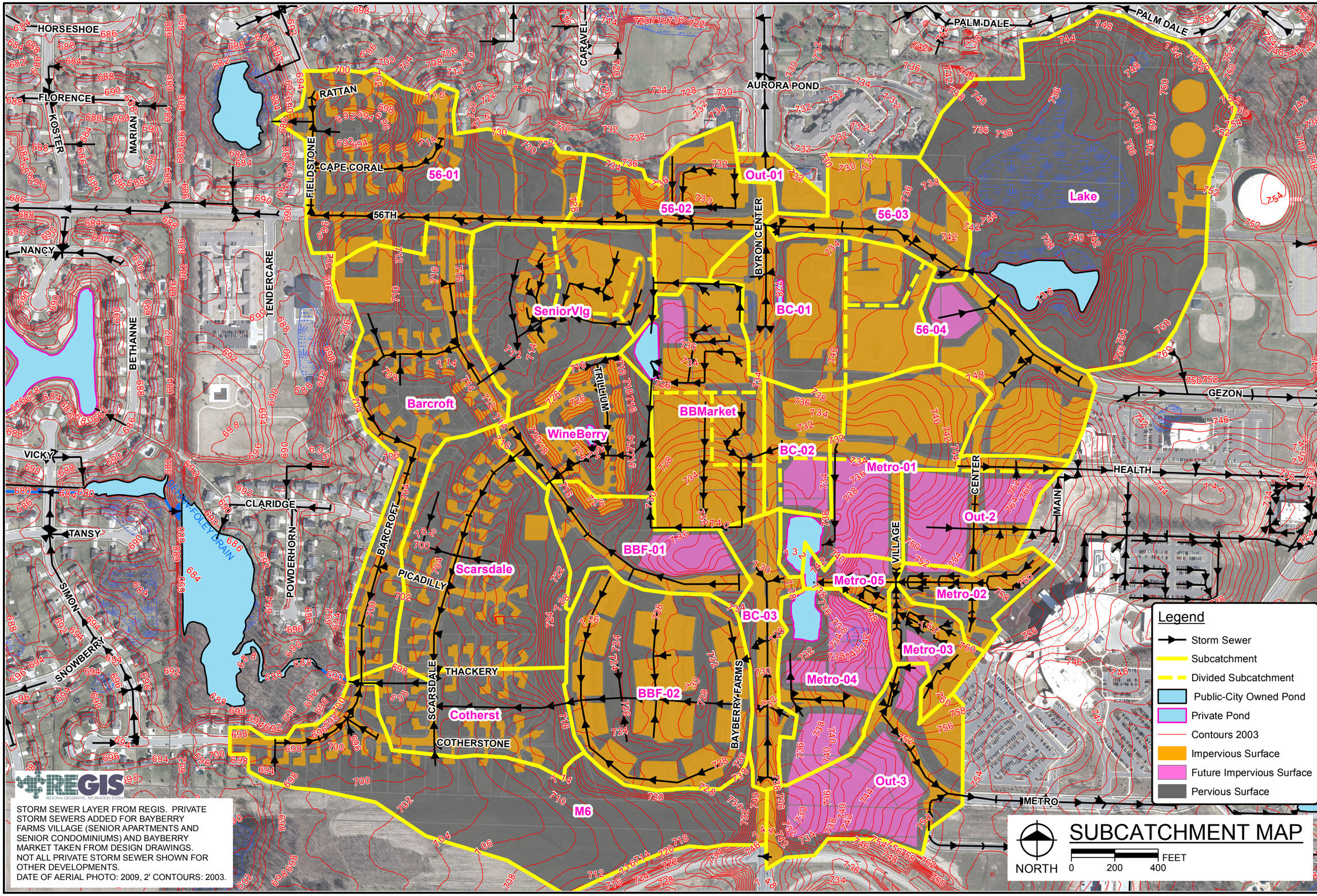

STORM SEWER LAYER FROM REGIS. PRIVATE STORM SEWERS ADDED FOR BAYBERRY FARMS VILLAGE (SENIOR APARTMENTS AND SENIOR CONDOMINIUMS) AND BAYBERRY MARKET TAKEN FROM DESIGN DRAWINGS. NOT ALL PRIVATE STORM SEWER SHOWN FOR OTHER DEVELOPMENTS.
DATE OF AERIAL PHOTO: 2009, 2' CONTOURS: 2003.

PLOT INFO: Z:\2013\130701\CAD\GIS\MapDoc\Subcatchment Map.mxd Date: 2/28/2014 9:50:29 AM User: CDA

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Kent County, Michigan

Bayberry Flooding Evaluation

PROJECT NO.
G130701

FIGURE NO.
7

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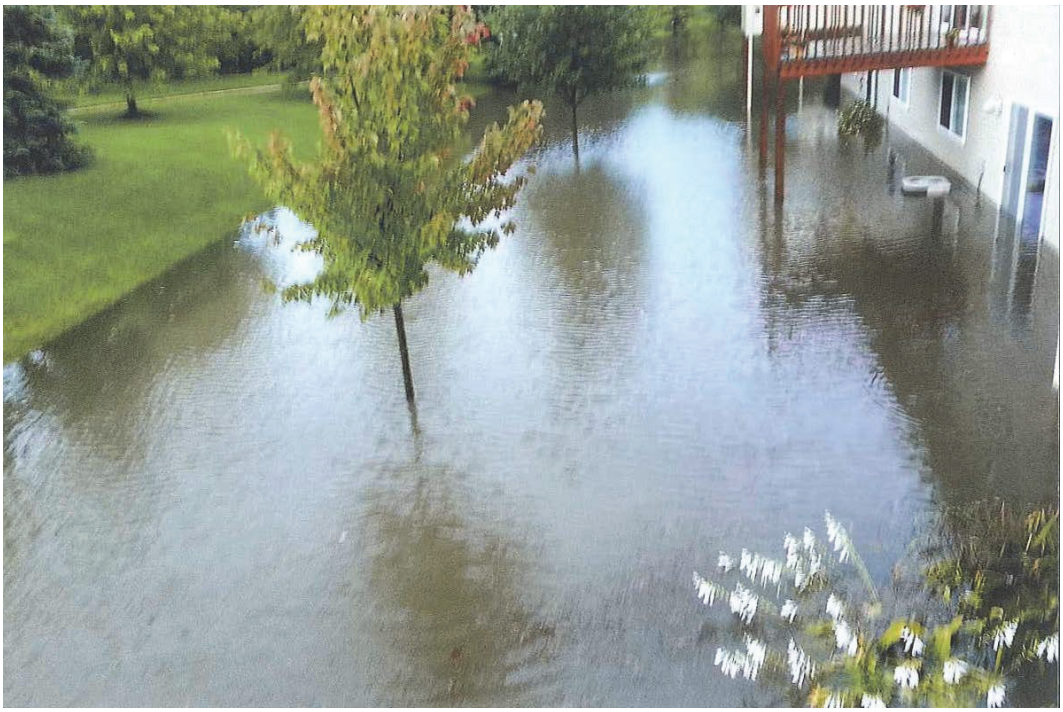
Appendix 1

1. Looking northeast at Bayberry Market detention basin.

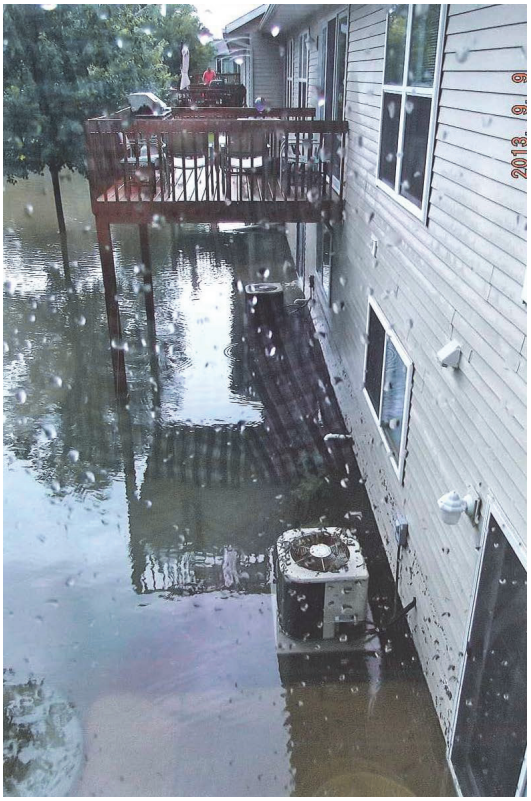
2. Looking southeast at Bayberry Market detention basin.

3. Looking south toward condominiums.

4. Looking south along the walking path at water spilling into the low area in back of condominiums.



5. Flooding in back of condominiums.



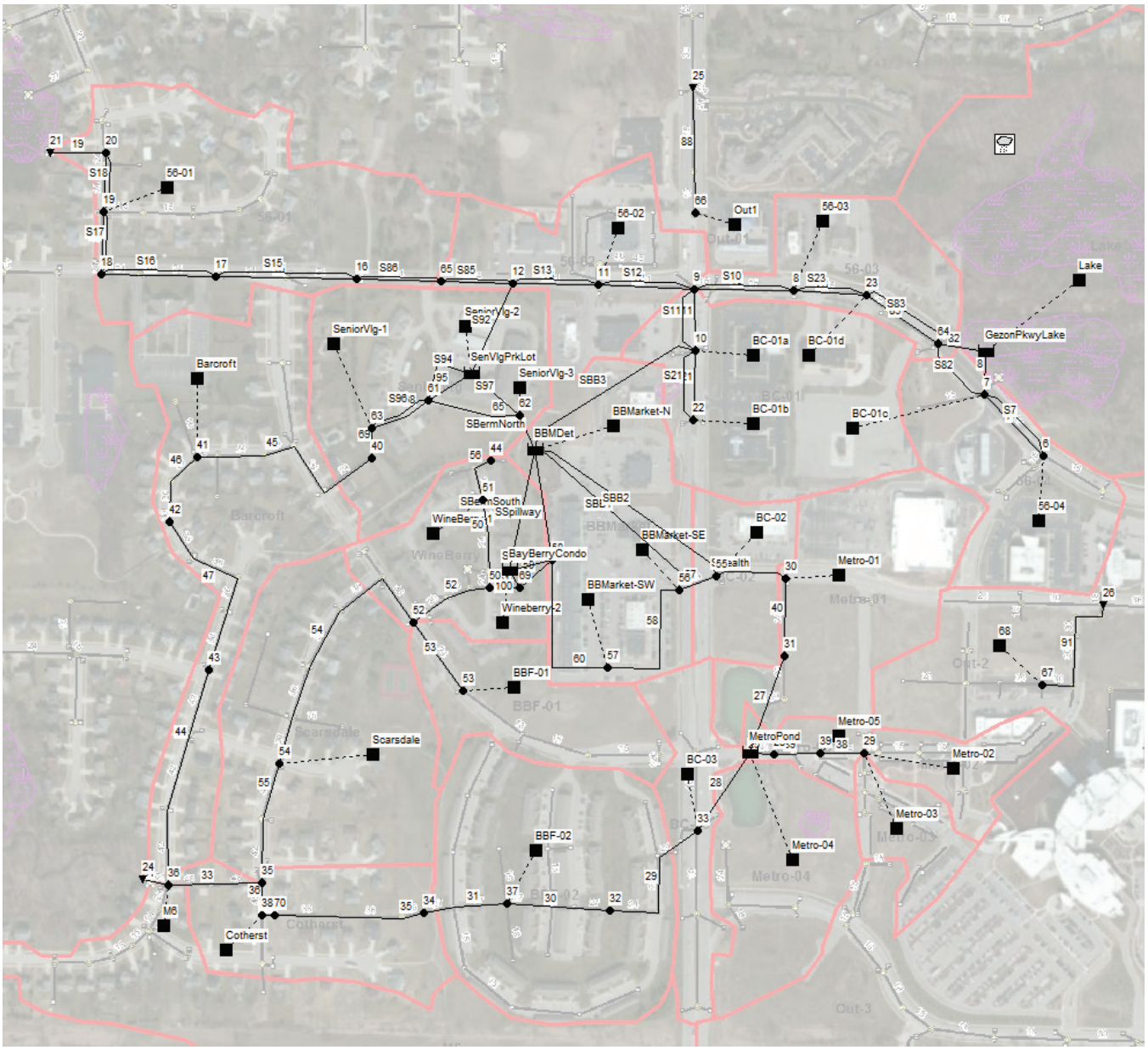
6. Flooding in back of condominiums.

7. Flooding of condominium unit.

8. Flooding of condominium unit.

Appendix 2

SWMM Model Schematic
Existing Conditions



SWMM Model Schematic
Build-out Conditions

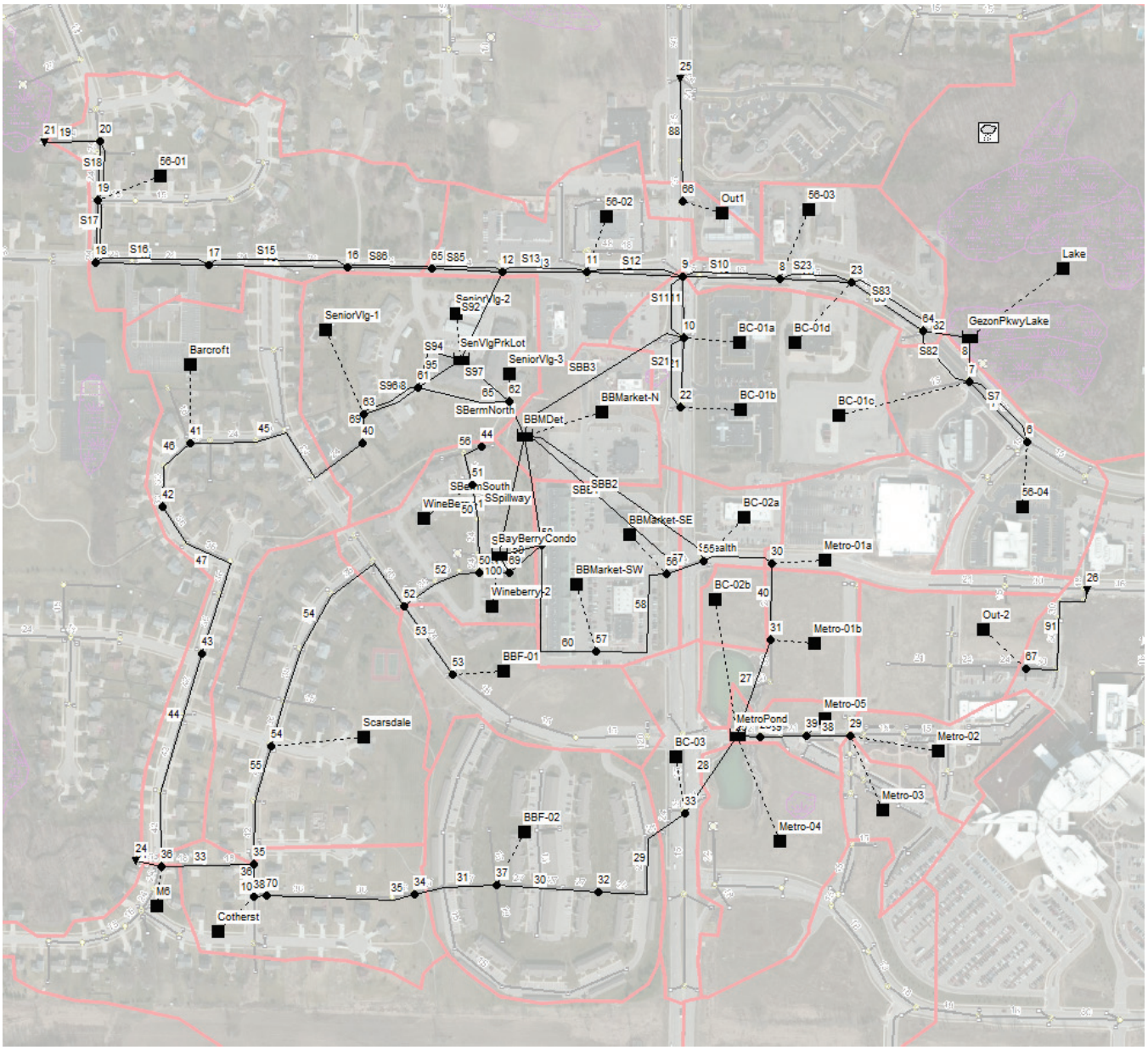


Table A2-1 - Subcatchment Areas and Percent Impervious for Existing Conditions

Subshed	Area [acre]						% Imperv	Perv CN
	Total	Impervious	Perv with HSG					
			A	B	C	D		
56-01	17.7	5.7	7.5	4.5	0.0	0.0	32%	47.2
56-02	8.8	6.0	2.2	0.5	0.0	0.0	69%	43.6
56-03	6.7	4.2	0.4	2.1	0.0	0.0	62%	57.6
56-04	8.9	5.5	1.7	1.7	0.0	0.1	61%	51.2
Barcroft	17.1	6.6	0.0	4.0	6.5	0.0	39%	69.0
BBF-01	7.0	1.6	0.0	4.7	0.7	0.0	23%	62.6
BBF-02	16.5	9.2	0.0	5.5	1.8	0.0	56%	64.3
BBMarket	12.8	9.8	0.0	2.5	0.4	0.0	77%	62.8
BBMarket- N	5.1							
BBMarket-SE	4.1							
BBMarket-SW	3.6							
BC-01	13.2	9.3	1.5	2.1	0.3	0.0	70%	53.6
BC-01a	3.3							
BC-01b	3.3							
BC-01c	3.3							
BC-01d	3.3							
BC-02	4.4	2.1	0.0	2.3	0.0	0.0	47%	61.0
BC-03	5.1	3.0	0.0	0.7	1.5	0.0	58%	69.8
Cotherst	8.4	2.1	0.0	1.1	5.2	0.0	25%	71.8
Lake	36.6	1.8	11.5	6.6	5.3	11.4	5%	61.9
M6	24.9	2.1	4.5	8.7	9.5	0.0	9%	78.7
Metro-01	11.4	4.9	0.0	5.1	1.5	0.0	43%	63.9
Metro-02	3.5	1.8	0.0	1.7	0.0	0.0	51%	61.0
Metro-03	3.1	1.8	0.0	1.2	0.0	0.0	60%	61.0
Metro-04	8.1	0.7	0.0	6.0	1.4	0.0	9%	63.5
Metro-05	1.8	0.8	0.0	0.9	0.2	0.0	41%	63.4
Scarsdale	16.4	4.1	0.0	3.9	8.5	0.0	25%	69.9
SeniorVlg	13.0	4.4	0.0	5.3	3.3	0.0	34%	66.0
SeniorVlg-1	7.2							
SeniorVlg-2	2.9							
SeniorVlg-3	2.9							
WineBerry	7.5	3.2	0.0	2.6	1.7	0.0	43%	66.2
Total In	**252.9**	**90.6**	**29.3**	**73.7**	**47.7**	**11.6**	**36%**	**62.2**
Out-01	1.5	1.2	0.3	0.0	0.0	0.0	77%	39.0
Out-2	5.9	1.7	0.0	4.2	0.0	0.0	29%	61.0
Out-3	10.8	2.7	0.0	8.1	0.0	0.0	25%	61.0
Total Out	**18.2**	**5.5**	**0.3**	**12.3**	**0.0**	**0.0**	**30%**	**60.4**

Table A2-2 - Subcatchment Areas and Percent Impervious for Build-out Conditions

Subshed	Area [acre]						% Imperv	Perv CN
	Total	Impervious	Perv with HSG					
			A	B	C	D		
56-01	17.7	5.7	7.5	4.5	0.0	0.0	32%	47.2
56-02	8.8	6.0	2.2	0.5	0.0	0.0	69%	43.6
56-03	6.7	4.2	0.4	2.1	0.0	0.0	62%	57.6
56-04	8.9	6.4	1.2	1.2	0.0	0.1	72%	51.2
Barcroft	17.1	6.6	0.0	4.0	6.5	0.0	39%	69.0
BBF-01	7.0	3.2	0.0	3.3	0.5	0.0	45%	62.6
BBF-02	16.5	9.2	0.0	5.5	1.8	0.0	56%	64.3
BBMarket	12.8	10.3	0.0	2.5	0.4	0.0	80%	62.8
BBMarket- N	5.1	3.4	0.0	1.5	0.2	0.0	66%	62.8
BBMarket-SE	4.1	3.7	0.0	0.3	0.1	0.0	90%	62.8
BBMarket-SW	3.6	3.2	0.0	0.3	0.1	0.0	90%	62.8
BC-01	13.2	9.3	1.5	2.1	0.3	0.0	70%	53.6
BC-01a	3.3							
BC-01b	3.3							
BC-01c	3.3							
BC-01d	3.3							
BC-02	4.4	3.2	0.0	1.2	0.0	0.0	73%	61.0
BC-02a	3.0	2.1	0.0	0.9	0.0	0.0	70%	61.0
BC-02b	1.4	1.1	0.0	0.3	0.0	0.0	75%	61.0
BC-03	5.1	3.0	0.0	0.7	1.5	0.0	58%	69.8
Cotherst	8.4	2.1	0.0	1.1	5.2	0.0	25%	71.8
Lake	36.6	1.8	11.5	6.6	5.3	11.4	5%	61.9
M6	24.9	2.1	4.5	8.7	9.5	0.0	9%	78.7
Metro-01	11.3	8.1	0.0	2.5	0.7	0.0	72%	63.9
Metro-01a	6.5	5.1	0.0	1.1	0.3	0.0	78%	63.9
Metro-01b	4.8	3.0	0.0	1.4	0.4	0.0	62%	63.9
Metro-02	3.5	2.0	0.0	1.5	0.0	0.0	56%	61.0
Metro-03	3.1	2.3	0.0	0.8	0.0	0.0	75%	61.0
Metro-04	8.1	4.9	0.0	2.6	0.6	0.0	61%	63.5
Metro-05	1.8	1.3	0.0	0.4	0.1	0.0	70%	63.4
Scarsdale	16.4	4.1	0.0	3.9	8.5	0.0	25%	69.9
SeniorVlg	13.0	4.4	0.0	5.3	3.3	0.0	34%	66.0
SeniorVlg-1	7.2							
SeniorVlg-2	2.9							
SeniorVlg-3	2.9							
WineBerry	7.5	3.2	0.0	2.6	1.7	0.0	43%	66.2
Total In	**252.8**	**103.4**	**28.8**	**63.6**	**45.9**	**11.5**	**41%**	**63.1**
Out-01	1.5	1.2	0.3	0.0	0.0	0.0	77%	39.0
Out-2	6.0	4.9	0.0	1.1	0.0	0.0	83%	61.0
Out-3	10.8	7.8	0.0	3.0	0.0	0.0	73%	61.0
Total Out	**18.3**	**13.9**	**0.3**	**4.1**	**0.0**	**0.0**	**76%**	**59.2**

Table A2-3 - Subcatchment Runoff Results 09/09/2013 Rainfall Event

```
****************************
Subcatchment Runoff Summary
****************************
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Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
Lake	5.08	0.00	0.00	3.47	1.55	1.54	54.01	0.306
56-03	5.08	0.00	0.00	1.40	3.53	0.64	20.64	0.695
56-04	5.08	0.00	0.00	1.58	3.36	0.81	26.65	0.661
BC-01a	5.08	0.00	0.00	1.15	3.78	0.34	11.46	0.743
56-02	5.08	0.00	0.00	1.42	3.51	0.84	25.57	0.690
56-01	5.08	0.00	0.00	2.92	2.07	1.00	28.97	0.408
BC-01b	5.08	0.00	0.00	1.15	3.78	0.34	11.46	0.743
BC-01d	5.08	0.00	0.00	1.15	3.78	0.34	11.46	0.743
BC-01c	5.08	0.00	0.00	1.15	3.78	0.34	11.46	0.743
Metro-03	5.08	0.00	0.00	1.44	3.49	0.29	9.12	0.688
Metro-02	5.08	0.00	0.00	1.81	3.13	0.30	8.56	0.617
Metro-01	5.08	0.00	0.00	1.99	2.97	0.92	28.93	0.585
Metro-04	5.08	0.00	0.00	3.23	1.79	0.39	13.53	0.353
Metro-05	5.08	0.00	0.00	2.03	2.94	0.14	4.84	0.579
M6	5.08	0.00	0.00	2.10	2.48	1.68	30.15	0.489
Cotherst	5.08	0.00	0.00	2.26	2.74	0.62	18.45	0.539
BBF-02	5.08	0.00	0.00	1.54	3.39	1.52	44.42	0.667
BC-03	5.08	0.00	0.00	1.34	3.58	0.50	13.98	0.705
Barcroft	5.08	0.00	0.00	2.09	2.86	1.33	31.75	0.563
SeniorVlg-1	5.08	0.00	0.00	2.59	2.40	0.47	14.12	0.473
BBMarket-SW	5.08	0.00	0.00	0.00	4.85	0.47	14.80	0.955
BC-02	5.08	0.00	0.00	1.88	3.08	0.37	11.99	0.605
WineBerry-1	5.08	0.00	0.00	1.90	3.06	0.42	12.85	0.602
BBF-01	5.08	0.00	0.00	2.83	2.16	0.41	10.39	0.426
Scarsdale	5.08	0.00	0.00	2.47	2.53	1.12	26.60	0.497
BBMarket-N	5.08	0.00	0.00	1.71	3.23	0.45	13.07	0.637
BBMarket-SE	5.08	0.00	0.00	0.34	4.53	0.50	15.80	0.891
Wineberry-2	5.08	0.00	0.00	1.97	2.99	0.19	5.30	0.589
SeniorVlg-2	5.08	0.00	0.00	0.97	3.95	0.31	10.51	0.778
SeniorVlg-3	5.08	0.00	0.00	2.52	2.48	0.19	6.82	0.487
Out1	5.08	0.00	0.00	1.04	3.87	0.16	4.87	0.762
68	5.08	0.00	0.00	2.55	2.44	0.39	12.62	0.481

Table A2-4 - SWMM Model Validation

Observation	Model Results
Surface runoff from areas east of Byron Center Avenue and north of Health Drive crossed Byron Center and flowed through the Bayberry Market parking lot.	2.4 ac-ft of runoff crossed Byron Center Avenue.
Bayberry Market detention basin filled, sending water over the spillway and the berm.	The model showed a peak water surface elevation above the top-of-berm, discharging 0.7 ac-ft of water over the pond berm in the direction of the Senior Apartments, and 1.7 ac-ft of water into the swale behind the Condominiums.
The swale behind the Condominiums flooded to a depth estimated from photographs to be 1.7 feet above the lowest floor openings.	The model showed a peak water surface elevation in the swale at 1.6 ft above the lowest floor openings.
Water flowed over the curb in 56th Street into the Senior Apartments parking lot.	Water levels on 56th Avenue exceeded the berm along the south curb by 0.1 ft and discharged 0.4 ac-ft into the Senior Apartments parking lot.
Flooding occurred in the Senior Apartments parking lot up to the level of automobile trunks, but did not enter the first floor of the apartments.	Maximum ponding depth was modeled at 1.9 feet above lowest catchbasin, which is over the top of curb, but approximately 1-foot below the finished floor of the apartments.
The swimming pool at 5660 Bayberry Farms Drive was flooded, and the home at 5678 Bayberry Farms Drive experienced a wet basement.	The manhole directly behind 5678 Bayberry Farms Drive showed a discharge of 0.28 ac-ft of water. However, the model did not show overland flow from the upstream storm sewer.
Flooding of the basement at 2614 Thackery Drive was reported.	The inlet behind the home discharged 0.45 ac-ft of water.
No flooding was reported at the two Metro Health Hospital ponds along Byron Center Avenue.	Water levels peaked at 0.76 feet below the pond outlet.