CHAPTER 12

STORM WATER MANAGEMENT EVALUATION

The final component of the Sister Bay Comprehensive Utilities Plan was the evaluation of storm water runoff and drainage within the planning area, and the evaluation of the existing storm water system and performing a deficiency analysis. This chapter summarizes the findings from this evaluation.

12.1 GENERAL

Throughout this chapter several key terms and phrases are used to identify or describe important storm water management activities, facilities or natural features. The following terms/phrases are defined for use in this section:

- **Best Management Practices (BMP):** Structural storm water management practices such as detention or retention basins, swales, bio-retention, infiltration, etc. that mitigate peak flows and/or attenuate pollutants.
- **Natural Closed Depression (NCD or basin):** Naturally occurring hollow that is defined by concentric 2 foot closed contours.
- **Storm Water Storage Zone:** A proposed zoning unit for the horizontal area extent of the flooded area in storm water storage areas – most often natural closed depressions - during the 100-year event. It is defined by the Flood Protection Elevation.
- **Flood Protection Elevation:** The elevation of flooding plus a defined freeboard height in a Storm water Storage Zone during the 100-year event.
- **Watershed:** The total contributing area of the landscape directing storm water runoff to a point of interest or outfall. All Study Area watersheds have been given individual identification numbers (e.g., #xx00).
- **Subwatershed:** A subset of a watershed contributing runoff to a feature of interest such as a natural closed depression, a storm water inlet, culvert, etc. Subwatershed basins are labeled using a sub-series of numbers of the associated watershed (e.g., #xx10, #xx11).
- **Dry Detention Basin:** A manmade basin that has the characteristics of holding a water volume with an outlet control such as a pipe or weir. The outlet control is typically at or near the bottom elevation of the basin allowing it to drain dry between rainfall events.
- **Wet Retention Pond:** Similar to a dry detention basin except the outlet control is higher and the basin holds water to promote deposition of sediment and associated pollutants on the pond bottom in the still waters held back by the outlet. Detention and retention are often used interchangeably - wet vs. dry is the critical difference in how the two differ.

12.2 STORM WATER STUDY METHODOLOGY

A computer model of the planning area was created to assist with the hydrologic and hydraulic analysis of the storm sewer and storm water drainage/runoff systems. The model was developed based on the planning area data provided by the Village and from readily available information sources. In addition, existing data was supplemented by field investigations performed over a five day period in

November 2005. The existing storm sewer infrastructure is limited to a very small portion of the overall planning area. The vast majority of the planning area has no distinct or identifiable drainage system.

The topography for the Sister Bay study planning area is unusually complex with numerous naturally closed depressions capturing runoff. The planning area geology is conducive to the formation of sinkholes and karst. A more typical ground surface landscape would contain obvious concentrated flow areas and 7.5 minute USGS quadrangle maps would show first order intermittent (dashed blue) streams.

The natural drainage system of the study planning area is poorly developed. There is a lack of well-defined channels; the storm water runoff is captured upslope in natural closed depressions or basins.

Many of the significant NCDs represent storm water outfalls. For every basin there exists a rainstorm (unlikely as it may seem) that can cause flooding or overtopping. But for the normal range of rainfall events up to and including the 100-year or 1 percent chance occurrence in any one year, it is anticipated that many of the NCDs in the study area will contain the runoff that reaches them. Therefore, for the purpose of this study, these NCDs are outfalls. They replace the lake or stream surface water that is usually associated with the final destination of surface water runoff.

The significance of NCDs as outfalls is in the perspective of how they are viewed. Instead of viewing them simply as low points or temporary holding areas in the topography that are normally dry, as outfalls they are the ultimate receiving point for surface runoff. This is how they normally function; the natural final destination of the runoff is to the Natural Closed Depressions. It is imperative that this function be allowed to continue. The alternative is to pump and convey a large portion of the study area runoff to Green Bay. As noted above, the topography of this area does not drain to Green Bay. Instead it naturally rises and falls. Existing development often lies along the best drainage route. To install a gravity drainage system would require deep trenches well into the bedrock at significant cost. Minimizing depth would require piping constructed across parcels which would create the need for easements and easement purchase costs. While this may be the best practical alternative if conveyance is necessary (as in the case of sanitary sewer collection). it is not the least cost alternative when compared to utilizing the storm water collection and storage system that naturally exists.

In the hydrologic cycle, the NCDs are collectors of surface runoff. Under predevelopment conditions, the collected water either infiltrated into the ground water or evapo-transpired. After development occurred, area roads are often found adjacent to these basins. The possibility for culverts or ditches to drain the basins is introduced incidentally to roadway construction. There are several storm water routing possibilities at road crossings adjacent to significant closed depressions. These include:

- Pure surface storage - storm water collected in a basin will pond on the surface. Infiltration rate is low and the water is eliminated mainly through evapo-transpiration.
- Drain off through culvert - storm water collected in basin discharges across roadway through existing culvert.
- Drain off down road ditch – storm water collected in basin reaches ponding depth allowing some water to drain away by gravity along the ditch (provided road ditch profile is not in a deep sag curve).
- Seepage into underground aquifer - storm water infiltrates into the ground through soil voids and rock fractures and discharges into dolomite aquifer.

To implement specific storm water infrastructure it will be necessary to conduct a detailed site survey to determine which of these situations may be occurring. A complete culvert survey will accurately

determine the runoff routing for each watershed. It will determine if runoff is diverted by roadside swales or ditches to a different drainage system. A detailed survey will also accurately establish the available storage volume, elevation of overtopping or escape route of excess runoff water, and the elevation of existing development.

For the purpose of this study, the probable drainage system routes were established using GIS maps. The GIS maps included topographic features, contour lines, and point elevations. Engineering judgment was used to establish the connectivity of adjacent subwatersheds across roadways and the demarcation of significant storage basins.

12.3 INFRASTRUCTURE DATA AND FIELD OBSERVATIONS

Detailed infrastructure information on the existing storm sewer system was obtained from record drawings of the recent East Mill Road and South Bay Shore Drive project (2005); Bluff View to Green Bay drainage system project (1981); and the lift station project (1973) that lies within Watershed #2700, and the storm system draining NCD found in Watershed #6300 (1973).

Input data for the storm water computer models was based primarily on information available from Door County and Village of Sister Bay. Construction/as-built drawings were available only for some areas, which limited the accuracy of the models in the remaining study areas. However, using knowledge of specific areas prone to flooding, the modeling results do provide insight into targeting solutions to the storm water concerns.

Existing GIS-based data was available for planning area wetlands, soils, parcels, topographic elevations (2 foot contours), land use/zoning, and roads, along with digital ortho photos from Door County. The Village of Sister Bay provided storm sewer record drawing information where available.

12.3.1 Data Collection Methods

Field data was collected by using a hand-held Trimble GPS unit that included a data collector for hand entry of system characteristics. System characteristics collected included pipe or channel dimensions and depth, flow direction, structure type, condition, material type, etc. Following collection of this information, the data was downloaded to a computer and was integrated into the GIS attribute database for each feature.

Field information was collected on the three primary storm water drainage features existing in the planning area, including storm sewer piping, manholes, inlets/catch basins, culverts and roadside drainage ditches and channels.

12.4 STORM WATER INFORMATION DEVELOPMENT AND ANALYSIS

Hydrologic analysis is used to determine peak runoff and volumes from infrequent storm events. Key parameters used in the analysis are land cover, soil types, topography, and drainage systems. Watershed boundaries are defined by the topography that drains runoff to a point of interest. Figure 12-1 is a Study Area planning map showing all of the watersheds down to the delineated subwatershed level. Planning area GIS elevation contour maps were used to define drainage subwatersheds. It should be noted that 2 foot contour intervals are limited to an accuracy of plus or minus half the contour interval, or in this case, 1 foot. In turn, all calculations based upon the contours have a degree of uncertainty. Although adequate for a planning level study, a more accurate base map should be developed for analysis and

design of projects. Soil map information was combined with the sub-basin boundaries and land cover information to determine runoff characteristics.

XP-SWMM, version 9.14 was used to model the water hydrologic and hydraulic characteristics for rainfall events of the 2, 10, and 100-year return intervals. The model evaluated storm sewer and channel capacity, storage, and discharge values.

ESRI ArcMap GIS computer software was used to process information found in the public domain from NRCS, Village of Sister Bay, and Door County. This software creates GIS features and uses the attributes to generate the data used in the analysis of both the water quantity and quality modeling.

The second step was to convert the zoning codes to a corresponding land use code. Land use is keyed to both water quantity and quality runoff. The SLAMM Standard Land Use (SLU) Codes are more detailed than the zoning codes. The SLU codes were selected and entered into the GIS tables and used to generate the parameter values used in both types of analyses. . To complete the conversion from zoning code to SLU code, the ortho photos were viewed and used to assign specific SLU codes to each zoning/land use area.

The third step was to create a GIS map of SLU areas that differentiated areas that were currently undeveloped vs. potential development. This information was used in the H&H analysis for the development of the curve number (CN) used in the SCS (NRCS) hydrologic method. These features were also used to develop output files for the SLAMM computer model.

The modeling software employed to determine runoff allows the choice of entering either a composite CN that includes the impervious area, or to enter the percentage of imperviousness and a CN for the remaining areas. In this effort, the latter method was chosen. Lacking information on specific land cover, it was decided to choose a pervious open space CN from the range of available CN's. This range, where categorized by soil Hydrologic Soil Group (HSG), was relatively narrow for the typical range.

The percentage of impervious surface was determined starting with the typical values given by NRCS and using engineering judgment to adjust these values according to evidence found in the ortho-photos for the Sister Bay study area. The NRCS land use description is keyed to the SLU code and determines the percent imperviousness. The hydrologic soil group determined the CN.

The time of concentration was developed from watershed sub-basin specific route calculations or engineering judgment.

In some cases, CN was adjusted to account for available storage areas. The topography of the study area is marked by a high number of closed depressions that function as hydrologic storage or detention areas. Watershed sub-basins with significant closed depression areas were modeled as storage. Most computer models do not account for soil infiltration within these depressions. This is useful because it provides discharge values that would occur without infiltration. As discussed later, it would be beneficial to prevent infiltration to avoid aquifer contamination. If this is the case, then model result discharge values can be used as the initial basis for sizing storm sewer system improvements.

It should be noted that hydrologic analysis is an inexact science. There are several different methodologies recognized in the industry as valid for use in this type of study. The SCS or NRCS method (TR-55) used for this project is used most often. When comparing results from different methods or in selecting equally valid parameters using engineering judgment, the results obtained can vary. This

should be kept in mind when comparing study results with work done by others that used more detailed information. The value of a hydrologic study of this level is in the conceptual planning level information it provides. The results of this study identify issues or areas requiring more detailed review, and analysis. The study findings and recommendations provide a basis for planning and implementing future projects.

12.5 FUTURE DEVELOPED CONDITION MODELS

The developed condition model can effectively define the increase or change in runoff rates and volumes from a given area for a given storm recurrence interval. However, it is not practical to design storm water management systems for hypothetical developments. The future condition models provide information demonstrating the change in runoff that would occur at the same point of interest without mitigating practices.

The existing condition land use includes relatively large areas of sparsely developed or semi-rural areas. Parcel maps indicate that outside of the already intensely developed areas, residential lots are relatively large. For the purpose of this storm water study, the direction given by Sister Bay for future development patterns in these areas is the same as is used for the water and sanitary sewer studies to project the density of future residential development.

12.6 HYDRAULIC AND HYDROLOGIC (H&H) ANALYSIS

12.6.1 Objectives

The purpose of the analysis is to provide planning level guidance for specific storm water conveyance improvements to relieve flooding, to provide a process for guiding future development to prevent increased flooding to downstream areas, and to develop strategies for improving water quality in Green Bay to prevent beach closures and promote tourism.

Some of these objectives can often be in conflict. If an upland landowner wants to reduce ponding on their property, they are inclined to look for a way to drain water off faster. This often promotes the delivery of pollutants and water volume rates downstream to other landowners. As is well known, new development typically converts soft absorptive land covers into hard impervious surfaces. The result is more storm water runoff and increased chances of flooding.

Another challenge for the Sister Bay region is the shallow dolomite bedrock and associated karst. Its presence increases the cost of storm sewer construction, and can either physically prevent infiltration in some areas, or accelerate it through fractures in other areas and potentially contaminate the aquifer.

12.6.2 Planning Level Recommendations

In the discussion below each watershed is described, the results of the analysis reported, and recommendations specific to addressing watershed issues are presented. The planning level recommendations provide background for a better understanding of the specific recommendations for each watershed.

In general, existing storage areas within the planning boundary are recommended to be preserved for flood storage. No further development should be allowed within the Storm Water Storage Zones. Preservation of the storage areas is recommended for two primary reasons: flood control and protection of surface waters from storm water pollutants. First, modifying a drainage system can lead to conflict

between the landowner properties draining and those receiving storm water. Often those receiving are likely to be in a poor position to accommodate the change in runoff. Wisconsin water law in this regard is based on precedents set in case law. It uses the concept of reasonable use. As such, each case becomes unique. To rely on the courts to settle disputes arising from changes in the natural drainage system would result in chaos, discourage development, and lower land values.

The second reason to preserve natural closed depressions is to trap pollutants and prevent their transport to Green Bay. The water along the area beaches has already experienced degradation which would be exacerbated by increasing developed area delivery of pollutants. Likewise, the preservation of storage detains runoff and reduces downstream flooding.

To achieve this, Sister Bay must create the authority through zoning ordinance adoption to require the preservation of natural closed depressions to be dedicated to flood storage. The ordinance should allow for the alternative to replace their function through other means. The language of the zoning ordinance should also allow for floodproofing existing structures. For the purposes of this study, the natural storage areas are referred to as **storm water storage zones**. The storm water storage zones will be bounded by the **flood protection elevation**.

The flood protection elevation as used in Wisconsin's Floodplain Management Program and NR 116 is the elevation 2 feet above the regional (100-year event) flood elevation. Floodplain zoning restricts development at the floodplain boundary. Development within the floodplain boundary if allowed at all, is required to be above the flood protection elevation or 2 feet above the floodplain elevation. The difference between the water surface and the flood protection elevation is referred to as freeboard. Sister Bay has the option of setting the criteria for the flood protection elevation at a different height. The freeboard used for the difference between the modeled 100-year ponding elevation and a buildable ground surface elevation should be set with consideration for the level of risks for potential harm to health, safety, and property.

The flood elevations provided by this study and found in Appendix C are based on approximate data. Given the level of uncertainty, the 2 foot freeboard height is recommended for the Flood Protection Elevation to set the Storm Water Storage Zones. However, it is recognized that 2 feet of freeboard in a relatively flat area can prevent development in large areas which will affect property values and tax revenue. Reduced uncertainty could lead to less freeboard. To reduce uncertainty the system should be inventoried and analyzed at a more detailed level.

This would require an on-the-ground survey of the proposed Storm Water Storage Zone to accurately define the available storage and executing the computer H&H models with the new data to accurately define the ponded elevation for the 100-year event.

An additional step to reduce uncertainty is to create an escape path for flood water to a relatively safe route such as a roadway leading to Green Bay or to designated drainage routes. Realize that the circumstances for this occurring are less than 1 percent in any given year, but increase over a longer period. If circumstances do not permit this, then the freeboard should remain at 2 feet. Another common practice is to compute the Storage Zone volume necessary to contain back-to-back 100-year runoff events.

The ponded elevations found for each of the NCDs does not consider infiltration. It is broadly understood that karst is common in this area and the working assumption should be that all NCDs overlie karst and bedrock fractures. So in the existing condition with the probability that large volumes of runoff can enter

the aquifer at each of these NCDs, the modeled flood elevations will appear unreasonably high and the resulting size of the Storm Water Storage Zones unreasonably large. But as will be discussed in Chapter 13, if the drinking water aquifer is to be protected, the karst short circuit for runoff must be cut off. Prevention of ground infiltration will result in dramatic changes in ponded elevations approaching the results provided in this study. Unless site specific conditions show adequate treatment for infiltrating runoff, the choice is between flood damage protection of dwellings at the surface, or drinking water contamination in the ground. If adequate soils provide aquifer protection, then the ponded elevations are more likely to be similar to the current condition due to slow infiltration.

Another consideration is the potential for wet basements due to lateral movement of groundwater. It may not be enough to have the low adjacent grade for a dwelling be above the ponding elevation if the floor level below that is prone to water damage. A restriction on the lowest floor level with respect to the ponding level should be considered. Some flexibility for site specific knowledge of groundwater conditions and engineered solutions should be built into the ordinance.

However, property subject to development and ownership of the property encompassing the storage area do not necessarily coincide. The ordinance should contain language preventing landowners from increasing runoff volume or rates to other properties including rights of way without a formal agreement with the receivers. This protects not only those downstream of existing storage depressions, but also the owner of the storage basin from increased runoff from changes in land use and cover from contributing area land owners.

A final consideration in the designation of a Storm Water Storage Zone is that existing development can become a nonconforming structure. There will likely be opposition to creating a zone that results in some structures becoming nonconforming. Designation of the Storm Water Storage Zone will reduce the value of the property and the value of existing development. There are cases where development is so low in the NCD that there is no practical means of diverting or removing runoff without the occurrence of flooding. In such a case, it is imprudent to let further development to take place.

Model ordinances, found in Appendix D, will provide language for water quality similar to the model ordinance found in NR 152. In addition, and of interest to the discussion of this chapter, is the language requiring flood control via peak flow mitigation in all new development for the large storm events. This is discussed in greater detail in Chapter 13 of this report.

12.6.3 System Hydraulic Performance

A primary objective of this study was the performance analysis of the storm system conveyance at the 10-year event discharge and for ponds at the 100-year event discharge level. The computer models determine the runoff discharges for each contributing area and routes these through the storm water conveyance system. Flow bypass at inlets, capacity of the street curb and gutter system, localized depressions not recorded by the 2 foot contours, and perhaps most importantly, the infiltration of rainfall into the fractured bedrock are considerations not captured by the H&H models. Each watershed system should be reviewed in light of these characteristics to determine the actual impact indicated by the computer model results.

The discharge for each watershed for both the existing and future build-out condition at the 2, 10 and 100-year recurrence intervals is summarized in Appendix C of this report. The discharge values listed are for the peak discharge from the landscape and not as modified by storage areas or conveyance capacities. Also listed are the important elevations for the watersheds NCDs including; Existing Low Adjacent Grade

or the elevation of the contour closest to visible structures, the maximum modeled ponded elevation of flooding in the NCD during the runoff event for the existing and future developed conditions, and the elevation of a surface feature over which ponded water can escape should it reach that elevation. Of particular note is the difference between the Low Adjacent Grade and the Escape route Elevation. The preferred condition is that the escape elevation is lower than the low adjacent grade. Should runoff event exceed the modeled volume, the ponded elevation will exceed the value given and reach a structure if there is no escape route below the dwelling's low adjacent grade elevation. A second table is included in this appendix that shows the area and elevation of the Storm Water Storage Zones as shown in the figures of each of the Watersheds discussed below.

Each watershed number refers to a corresponding number as discussed under Section 12.1 for the watersheds and sub-basins. Each watershed discussion includes a probable cost of construction and engineering of recommended improvements. Shallow rock excavation costs for the storm sewer is included at $40/lf. The costs for modifying NCDs to function as water quality BMPs are presented separately in Chapter 13. The potential costs for easements or property purchase is not included. The following summarizes the system performance analysis findings.

12.6.3.1 Watershed #900 – Meadow Wood Lane

Watershed Description. There is relatively dense development within the study area that lies within the NCD of this almost 200 acre watershed. Most of the watershed lies outside of the study area boundary and is agricultural. Figure 12-2 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no identified storm water system in the area other than roadside ditches.

10-Year Event Storm System Analysis. Since there is no storm water system within the watershed, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. Under current development conditions, Basin #900 overtops and flows west beyond the study area boundary. The escape elevation is between 720 and 722 feet NGVD 29. The flooded elevation for the developed condition is approximately 722 feet NGVD 29.

Watershed Recommendations. The ortho photos indicate development has already occurred in the low area of the NCD, precluding the designation of a **storm water storage zone.** To construct a storm sewer would require traversing topography that drops below elevation 712 feet NGVD 29 and rises to elevation 730 feet NGVD 29 before steadily dropping to Green Bay. The developer's drainage plan should be reviewed to see how the watershed runoff was planned to be handled. If homeowners are placing fill as each home is constructed, it will raise the ponded elevation eventually the increasing the number of homes that will be flooded. Watershed 900 drains to an NCD to the west. The NCD is approximately 6 feet deep and has a high potential for karst conditions. Added runoff from Watershed 900 to the adjacent landowners has the potential to create conflict from increased flooding. The Town of Liberty Grove or Door County Zoning Administrator should be contacted to apprise them of the situation before added development exacerbates the problem.

12.6.3.2 Watershed #1000 – Beach Road South of Seaquist Road

Watershed Description. This 230 acre watershed is composed of low-density residential, agricultural and wooded land. The topography is steep with a relatively continuous positive drainage system. Development exists within the NCD along Beach Road and to the west fronting Green Bay. Figure 12-3 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no identified storm water system in the area other than roadside ditches.

10-Year Event Storm System Analysis. Since there is no storm water system within the watershed, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. Under current development conditions, NCD #1002 overtops and flows west across Beach Road, inundating existing development and spilling across developed property. The escape elevation is between 646 and 648 feet NGVD 29. The flooded elevation for the developed condition is approximately 646.3 feet NGVD 29. Existing development is shown at or below the 644 foot elevation contour.

The above analysis does not include any infiltration. Use of detention basins in the upland areas in accordance with the proposed ordinance will maintain the present rate of runoff but will increase volume unless infiltration can be used. The existing condition runoff discharge to the NCD is 140 cfs. The existing development is too low in the basin to effectively utilize it for storage.

Watershed Recommendations. The NCD is outside of the wellhead protection zones. The extension of a municipal water supply to residents in this area will allow them to use the municipal water system instead of private wells with the potential for contamination from any karst activity within the NCD. Since the NCD is close to Green Bay, the likely direction of ground water flow is to the Bay. For this situation the best course of action is to monitor flooding during high runoff events to determine the true level of risk of flooding.

It is still recommended to designate this NCD as a **Storm Water Storage Zone** to prevent additional development in a flood prone area.

12.6.3.3 Watershed #1400-#1900-#2000 – Beach Road and STH 42 North of Wildwood Road

Watershed Description. This 150 acre watershed is composed of low density residential, agricultural and wooded land. Watersheds #1400, #1900, and #2000 were analyzed together as the H&H analysis results revealed that they were connected. A natural closed depression straddles Wildwood Road at the western (lower) end of the watershed. Parcel mapping shows that the watershed is extensively subdivided in Watersheds #1400 and #1900. Figure 12-4 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm water system in the area other than roadside ditches.

10-Year Event Storm System Analysis. Since there is no storm water system within the watershed, the 10-year event storm water system analysis was not performed. However, the natural closed depressions on either side of Wildwood Road were modeled separately to determine if Basin #1900 overtopped.

Under current conditions Basin #1900 (natural closed depression) appears to reach the approximate road centerline estimated at approximate elevation 637 feet NGVD 29. Storm water runoff overtopping Wildwood Road is a possibility. The peak 10-year water level within Basin #2000 reaches elevation 629.2 feet NGVD 29 and surface runoff is contained within the basin.

100-Year Event Pond System Analysis. Under current development conditions, Basin #1900 overtops and flows into Basin #2000 to the south. Basin #1900 floods to 637.3 feet NGVD 29 or 0.2 feet above the approximate road centerline elevation. During the 100-year rainfall event, water in Basin #2000 reaches elevation 632 feet NGVD 29, which is approximately 8 feet below the crest. The topographic elevation contour near the only structure shown (Mary Smith) on the ortho-photo is 642 feet NGVD 29, or 10 feet above the modeled flood elevation.

Watershed Recommendations. Designate both of the natural closed depressions as **storm water storage zones** with the boundaries set at the future conditions flood protection elevation. The future condition flooded elevation is approximately 637.5 feet NGVD 29 for Basin #1900, and 634 feet NGVD 29 for Basin #2000. More detailed analysis should be developed prior to setting zoning boundaries.

12.6.3.4 Watershed #1500 Muffin Road Cul de Sac

Watershed Description. This 43 acre watershed is currently includes light residential development with some orchards. It is projected to be developed up to a medium density residential. Current development at the west end of the Muffin Road cul-de-sac shows a home constructed in one of the lowest parts of the watershed in an NCD. The parcel is owned by Laura Rush. **Based upon the available data, this home is at a high risk for flooding**. Even the existing condition 10 year event floods the NCD to elevation 684 feet NGVD 29. Figure 12-5 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm sewer system.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The NCD ponded depth is elevation 685 feet NGVD 29. The 684 foot contour surrounds the Rush property structure. Based upon the 2 foot contours the surrounding surface drainage elevation is at or above 688 feet NGVD 29. The likely surface water runoff route is north along Beechwood east to Green Road. The 690 foot elevation contour crosses Muffin Road to the east.

Watershed Recommendations. Unless the affected structure noted above can be flood-proofed, there is minimal benefit in creating a Storm Water Storage Zone. Development on surrounding lots will doubtless further encroach upon the NCD. The area should be investigated to determine the true risks of flood damage. This NCD is not suitable as a **storm water storage zone**. An area developer's drainage plan should be reviewed to see how the watershed runoff will be handled. If ponding does not occur, there is a greater than usual likelihood of karst short-circuiting the drainage directly to the groundwater. A parcel owned by Douglas and Merisue Haas is a possibility for a storage basin, but given the bedrock conditions the outlook is not favorable.

Without some means of detention, a storm water system capable of handling the future condition 100-year event discharge of 52 cfs is needed to prevent runoff from entering the aquifer or flooding homes. If homeowners are placing fill as each home is constructed, eventually the ponded elevation will rise flooding more homes. This area is a concern for future potential legal action regarding flooding. The Town of Liberty Grove or Door County Zoning Administrator should be contacted to apprise them of the situation before added development worsens the problem.

12.6.3.5 Watershed #1600

Watershed Description. This 70 acre watershed contains primarily agricultural land uses with some light residential development. A large NCD lies in the middle of the watershed. Future development is projected to be medium density residential. Figure 12-6 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm sewer system.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The watershed's NCD has no development within its boundaries. The future development ponded elevation is 694.3 feet NGVD 29. The upper boundary of the NCD is at elevation 696 feet and would be an appropriate Flood Protection Elevation. It encompasses 12 acres while the 694 foot elevation contour is 6 acres.

Watershed Recommendations. To maximize developable area, some grading can modify grades to the extent necessary to make a practical **storm water storage zone**. Zoning action should be accomplished as soon as possible to prevent a situation similar to Watershed #1500.

12.6.3.6 Watershed #2300 – Beach Road and STH 42 North of Waters End Road

Watershed Description. This 20 acre watershed is largely wooded and subdivided into parcels that typically range in area from ¾ to 2 acres in size. About 40 percent of the area is developed, primarily with single family dwellings. A significant natural closed depression lies within the watershed that prohibits runoff from entering surface waters. No wetland areas have been previously mapped. The majority of the depression is labeled on the area soil maps as containing sandy soil. It is highly likely that runoff infiltrates to the groundwater at this location.

It was reported that there are no significant culverts crossing STH 42. Therefore, it was determined that area surface runoff from Watershed #2600 runs downhill along STH 42, and crosses Waters End Road

Figure 12-7 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The lowest existing adjacent dwelling appears to belong to George and Eileen True and has a parcel with a residence at or above elevation 632 feet NGVD 29. The natural detention area ponds up to 623 feet NGVD 29 which provides almost 9 feet of freeboard during the existing condition 100-Year rainfall event.

Watershed Recommendations. Designate the natural closed depression as a **storm water storage zone** with the boundary set at the future conditions flood protection elevation. The future condition flooded elevation is approximately 625 feet NGVD 29.

12.6.3.7 Watershed #2500 – Beach Road and STH 42 North of Waters End Road

Watershed Description. This 11 acre watershed is largely wooded and subdivided into 5 parcels that vary widely in size. It is mostly developed with commercial and residential land uses. A significant natural closed depression lies within the watershed that prohibits runoff from entering surface waters. No wetland areas have been previously mapped. Figure 12-8 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The lowest existing adjacent dwellings appear to belong to Bruce and Carol Bell and Peter Jr. and Janet Peterson on parcels with a residence below elevation 590 feet NGVD 29. The NCD ponds up to 589 feet NGVD 29 during both the existing and future conditions 100-year rainfall event. There is little or no freeboard and the difference is within the tolerances of the contour mapping.

Watershed Recommendations. Designate the natural closed depression as a **storm water storage zone** with the boundary set at the future conditions flood protection elevation. Encourage residents to flood proof structures to the flood protection elevation. Given the proximity of Green Bay to the NCD, the possibility of adding an outlet and pipe to Green Bay to control flooding should be explored. A detailed study and investigation should explore this and/or if it is feasible to enlarge and deepen the storage volume of the NCD.

12.6.3.8 Watershed #2600 – Waters End

Watershed Description. The watershed land use is a combination of commercial and low density residential. No natural closed depressions exist. Figure 12-9 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. The storm water system consists of a roadside ditch, culverts along the lowest part of STH 42 with pipe and manhole leading down to Green Bay from STH 42. These channels are in fair-to-poor condition showing signs of erosion.

10-Year Event Storm System Analysis. The storm system capacity is exceeded by the 10-year discharge.

100-Year Event Pond System Analysis. There are no ponds within the watershed to analyze.

Watershed Recommendations. The contributing area north of Waters End should be diverted into a new conveyance down Waters End Road to Green Bay. This will relieve the existing system south of Waters End Road. The inlet on the east corner of the Waters End-STH 42 intersection should be situated in a sump condition to effectively capture storm water runoff as it travels from the northeast along STH 42.

An analysis of the remaining runoff peak flow velocities is recommended to determine the type of lining for the channel, followed by channel reconstruction. If at all feasible, a grassed swale should be constructed to act as a pollutant removal BMP.

Public Capital Improvement Cost Estimate

Diversion Storm Sewer $125,000

12.6.3.9 Watershed #2700 – Storm Water Wetland Lift Station

Storm System Description. This watershed is without a storm system in the upland areas of the watershed. Storm water drains to a wetland lying between North Bay Shore Drive, North Spring Road, Scandia Road, and Hill Road. The water outlet used for this wetland area is a Village-owned lift station. No information was available on the existing pump performance capabilities. The existing lift station pump is beyond its useful life and is recommended to be replaced. The pump discharge capacity has been reported to be acceptable.

Figure 12-10 illustrates the location of the watershed boundaries and surface water flow direction.

10-Year Event Storm System Analysis. The existing storm system is limited to the outlet side of the lift station pump. There is no storm water system within the upland area of the watershed. The pump discharges to a system of storm sewer piping with the outfall on the Green Bay shoreline. The first storm sewer pipe segment has the flattest slope, and limits the total flow that can be delivered to the outfall. This segment is a 30 inch CMP at 0.1 percent slope, which has a gravity flow capacity of 14.4 cfs, well in excess of the capacity of most typical storm water lift station pumps.

100-Year Event Pond System Analysis. Without the storm water lift station operating, water in the wetland area would reach an elevation of approximately 587 feet NGVD 29 during the 100-year rainfall event, which would cause flooding problems for adjacent homes. The ortho photo shows trees obscuring many dwellings, but it appears that several homes including Jeanette Tveten, John and Janet Sharp, and James and Lois Pellegrini have low adjacent grades below the 584 foot elevation. Flooding in the area has not been reported to be a current concern. The operation of the lift station and/or downstream storm sewer system are apparently adequate for the existing condition and for the rainfall events experienced since the lift station was installed. It has been noted that areas along North Spring Road have experienced flooding in the past due to high runoff rates from the bluffs to the east. A single culvert reportedly exists that limits the effectiveness of storm water runoff to drain from the east side of North Spring Road.

However, the modeling for the 100 year existing condition shows that in order to maintain an existing conditions ponded elevation at or below 583 (no freeboard) a discharge of 100 cfs (45,000 gpm) is necessary. This is far in excess of any lift station pump. Since the lift station has been effective at preventing flooding to-date, there is very likely an alternative discharge route such as diversion into a karst feature. To maintain a <u>future</u> conditions ponded elevation at or below 583 feet NGVD 29 (no freeboard) a discharge of 120 cfs is necessary during the 100 year event.

Even when disregarding Subwatersheds #2701 and #2702, Subwatershed #2703 alone will discharge 246 cfs at peak flow and raise the ponded elevation to above 586 feet NGVD 29 with no outlet. This demonstrates that even with upslope detention or diversion, the NCD capacity and outlet conditions pose a serious threat of flooding.

Watershed Recommendations. Remove and replace the existing lift station pump with a new pump. Improve conveyance of storm water across North Spring Road. This will require a detailed analysis of alternatives for capturing runoff and directing it to the existing culvert, or the installation of addition culverts under North Spring Road. As noted in the discussion below for Watersheds #2900 and #3000, runoff from #2900 and #3000 may be contributing to the problem. If as suggested below, a storm sewer draining the #2900 NCD is connected to the #2700 storm sewer piping, the capacity of the total drainage system (both pipe and surface channels) should be confirmed. Analysis to determine if the new pump is sufficient to handle the added water brought in by improving drainage across North Spring Road is recommended.

The necessary discharge capacity (100 cfs) of the lift station is impractically high for a pump if it is the only outlet for the 2703 NCD. It would be need to be even higher if Scandia Road is diverting the other watersheds to it. The 2703 NCD lies within the primary Wellhead Protection Zone. If substantial or significant discharge is occurring through infiltration and karst drainage it may be contaminating the aquifer. Well 1 is within a few hundred feet of the lowest area of the NCD. Monitoring of this well is vital given the apparent direct connection between the runoff entering the NCD and the unexplained outlet for much of the water entering it. The best course of action may be to continue to allow runoff to outlet from the wetland in this manner until it is determined to be a source of contamination. If contamination becomes an issue, the alternatives are to find and seal the karst voids and fractures or abandon the well. If the karst outlet is successfully sealed, the development properties are at risk of flooding during large events. As noted earlier, a lift station pump is not a practical solution since the pump's capacity would need to be at least 100 cfs.

Since pumping is not a practical alternative, a surface outlet alternative has been modeled. Such an alternative will require the shortest possible route to Green Bay. If the flood protection elevation must be held at 583 feet NGVD 29 (little or no freeboard) to protect existing development, there is really no practical way to drain water to the Bay when the Lake Michigan water level is at historically high levels (582.3 feet IGLD). Even when normal water levels exist, a surface drainage outlet with a crest at 582.5 feet (0.5 feet above the lowest contour and 0.5 feet below the assumed low adjacent grade) would need to be at least 150 feet wide. There is no undeveloped corridor to Green Bay for such a channel. The difference in datums (IGLD and NGVD 29) is discussed in the summary.

There is little opportunity to detain or divert the runoff from Subwatershed #2703 due to the existing topography. Even if a system of storm sewers were to be installed, the overland flow during a large event would bypass the piped system and follow the ground surface to the NCD. It still is best to divert runoff from Subwatersheds #2701 and #2702 to the extent possible.

Subwatershed #2702 is approximately 100 acres of what is projected to become low and medium density land use. Generally 5 percent of the contributing area is needed for a detention basin of sufficient size (5 acres) to control flooding. The logical location for such a basin is on the property of Edgar and Nancy Hillner just north of Hillcrest Lane.

Subwatershed #2701 is largely outside of the study area. But it has similar opportunities that can be implemented when developed.

Public Capital Improvement Cost Estimates

Culverts for North Spring Road	$16,000

New Lift Station Pump	$30,000
Subwatershed #2702 Retention Basin	$950,000
Replace Lift Station Storm Sewer Outlet	$200,000
Total	**$1,196,000**

12.6.3.10 Watershed #2800 – Harbor Shores

Watershed Description. The land use within the watershed is primarily commercial with approximately 25 percent low density residential. No natural closed depressions exist within the watershed. There is approximately 1,000 feet of storm sewer pipe along North Bay Shore Drive terminating in an outfall discharging into Green Bay. Figure 12-11 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. The existing storm sewer system along North Bay Shore Drive (STH 42) is predominantly 18 inch diameter concrete pipe with manholes that connects to a 24 inch diameter outfall pipe.

10-Year Event Storm System Analysis. Based on the hydraulic modeling completed, and the area of contribution defined by the 2 foot elevation contour plans, the existing pipe system does not have sufficient capacity for the anticipated 10-year rainfall event discharge. The proposed or fully developed condition storm discharge increases from 52 to 58 cfs.

100-Year Event Pond System Analysis. There are no ponds within the watershed to analyze.

Watershed Recommendations. With regard to the storm sewer pipe system, if there is a swale in addition to the pipe system to carry runoff, it should be sufficient to carry the runoff in excess of the pipe capacity parallel to the road. If there is no swale, it is recommended that a more detailed study be undertaken to determine the changes to the pipe size necessary to adequately convey storm water. A review of current problems (erosion, flooding) should be made before implementing any infrastructure modifications. Should it become necessary to increase the size of the pipe, the 30 inch pipe leading down to the outfall should be increased to a 36 inch diameter, while the pipes leading up to it should be 30 inch with the upstream pipe at 24 inch diameter.

Public Capital Improvement Cost Estimate

Increase Pipe Sizes	$100,000

12.6.3.11 Watershed #2900 – Scandia Road and Sunset Road

Watershed Description. The land use within this 85 acre watershed is a mixture of light to medium residential and agricultural, with some limited multifamily residential. It is largely wooded with steep topography. A 4+ acre NCD straddles Scandia and Sunset Roads. The NCD intersects as many as a dozen parcels most of them already developed. It is likely that roadside drainage along the east-west roads drains the NCD before it causes any flood issues, although a very large storm may cause some flooding. Figure 12-12 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. None.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The existing NCD has minimal volume and depth and is not significant enough to consider as storage. No pond analysis was performed.

Watershed Recommendations. Since flooding has not been noted as an issue in the area, the current conditions are anticipated to be adequate. However, based on modeling results, the future conditions discharge is expected to increase by 50 percent. It is recommended that this area be given further detailed study to determine a feasible means of routing of runoff and to observe conditions in the area of the NCD during a large rainfall event. It may become necessary to install piping in this area connecting to the storm sewer system draining from the lift station. Flooding along North Spring Road may be partially related to the discharge from the #2900 NCD.

The future conditions 10 year peak discharge for this watershed is 27 cfs, requiring a 30 inch RCP pipe for a 0.5 percent slope. This will exceed the capacity of the downstream system which is about half this and must also carry the lift station discharge. Sunset Drive provides a lower escape route elevation than Scandia Road, but the route would require water running through more developed area to reach it. If Scandia Road can be modified so that the roadside ditches maintain a maximum elevation of 616.0 feet NGVD 29 it would help to divert large runoff events.

There is a location in the upland area for a detention basin on the property of Rodger Swenson that would mitigate development from 30-40 percent of the 85 acre watershed. A 2 acre basin should be an adequate area for minimizing increased runoff. But the lower part of the watershed with the steeper topography remains unmanageable with the level of existing development cutting off options for detention and storage.

This NCD is not suitable for designating as a **storm water storage zone**.

Public Capital Improvement Cost Estimates

30 inch Storm Sewer	$170,000
Retention Pond	$360,000
Total	**$530,000**

12.6.3.12 Watershed #3000 – East Scandia Road

Watershed Description. The land use within this 83 acre watershed is a mixture of light to medium residential, agricultural, and institutional. The non-agricultural area is largely wooded with steep topography. A 6 acre NCD contains the runoff without surface discharge. Figure 12-13 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. None.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The future conditions NCD ponded depth is 631 feet NGVD 29. The existing conditions ponded depth is 630 feet NGVD 29. A dwelling within the parcel owned by

James and Kristine Johnson lies on the 630 foot elevation contour, below the future flooded elevation. Several other parcels without visible structures are within the flood elevation contour and are apparently owned by the Johnsons as well.

Watershed Recommendations. Since flooding has not been noted as an issue, the current condition is anticipated to be adequate. There are approximately 22 acres of agricultural land that could be open to development. Implementation of flood ordinance protection can prevent increases in peak runoff but does little to control the increased volume if infiltration is not a feasible BMP.

Once again as in Watershed #2900, Scandia Road may actually divert much of the runoff from the contributing area to the west. If this is the case, the NCD is ineffective in terms of storing runoff.

Although there are challenges due to the presence of a dwelling and directing the runoff to the NCD, it is recommended that this NCD be utilized for a **storm water storage zone** if the Johnson's are agreeable. It is also recommended that this location be investigated for use as a wet retention pond with a surface drainage system (including storm sewer pipe). An underdrain can be included to dry the area after sufficient detention period is allowed so that the pond functions as a wet detention pond.

Public Capital Improvement Cost Estimates

15 inch Storm Sewer with underdrain $100,000

12.6.3.13 Summary: Watersheds #2700, #2900, and #3000

It is apparent from the preliminary analysis performed that the area encompassed by Watersheds #2700, #2900, and #3000 needs additional detailed investigation to accurately determine the route and destination of storm water runoff. It appears possible that Watershed #2900 and #3000 runoff is diverted by Scandia Road before reaching the NCDs, to either the system draining the lift station or even on to North Spring Road. In either case the downstream storm system is incapable of handling the 10 year event, the benchmark capacity for storm sewers. The pipe size required to handle the 10 year event from those two watersheds alone would be at least 48 inches and would be slightly undersized for the 51 cfs necessary. If these systems are contributing to the Watershed #2700 NCD at the lift station, their runoff needs to be captured and diverted to the assumed NCD outfall in the case of Watershed #3000 and to the proposed detention basin for the future development of Watershed #2900.

Subwatershed #2703 NCD served by the lift station poses a serious challenge for flood relief. Without details on the current flood concern noted on the map at the September 2005 CUPAC meeting, it is difficult to conclude if there is really a flooding problem as indicated by the results of the modeling. But if the reason no problem exists is due to karst drainage, the threat to the aquifer is real and has to be balanced by any action that increases the likelihood of flooding existing development when options for protection from flooding have limited effectiveness.

The most costly course if reducing karst drainage becomes necessary is to purchase properties at greatest risk and create a surface outlet to Green Bay that would require a gate to prevent inundation from Green Bay during extreme high water levels. Changes in water levels due climate change are unpredictable but the possibility of water levels above the 1986 elevations are certainly possible.

12.6.3.14 Watershed #3100 - Pheasant Park, Village Park to South of Maple Drive

Watershed Description. This 580 acre watershed is made up of five separate Subwatersheds of which three have significant storage in natural closed depressions. The contributing area extends almost 1 mile east of Woodcrest Road and as far as a ½ mile south of Maple Drive (CTH ZZ). Much of the watershed area is agricultural but also includes multifamily, single family, and commercial land uses in approximately one-quarter of the area. Located within the watershed area is the new Village/Town fire station and Pheasant Park development; each property has its own storm water management system but each property area only contributes a very small portion of the overall watershed storm water runoff.

Watershed runoff ultimately discharges to a very large natural depression which overlaps with an existing wetland. It is reported that there is a high groundwater infiltration rate in the north end of the wetland where runoff reappears in Subwatershed #6301 in a closed depression. The rate of soil infiltration at this depression is evident to casual observation.

It has been reported that the Village park area immediately east of Woodcrest Road and south of Autumn Court has experienced flooding in the past. This area is relatively flat and lacks proper drainage.

Figure 12-14 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. The fire station property includes an existing detention pond that discharges to the Subwatershed #3101 natural closed depression. Pheasant Park development uses an open channel infiltration trench drainage system. Runoff drainage west across Woodcrest Road from the east is controlled by an existing culvert.

East Mill Road has a discharge pipe available for discharge to the Subwatershed #3101 basin.

10-Year Event Storm System Analysis. The Pheasant Park channel system is the only storm water conveyance system besides the existing culverts. The Pheasant Park channel system has excess capacity for the 10-year rainfall event.

100-Year Event Pond System Analysis

Subwatershed Basin #3101. The existing development east of the north end of Subwatershed #3101 basin is situated at approximately elevation 600 feet NGVD 29. The final NCD is a wetland. A high rate of discharge through what is probably a karst feature leading to the Subwatershed #6300 NCD has been reported. The basin was modeled with a high level of infiltration and without infiltration to test the variability of the flood elevation. With significant infiltration, the pond tops out at 596.4 feet NGVD 29. With some pond overtopping (modeled as a 75 foot weir at a crest at elevation 599.5 feet), the basin tops out at 599.6 feet. With no outlet, the basin is just under capacity at elevation 600 feet NGVD 29. Observation by Village personnel during flood conditions indicates that the NCD has reached very near capacity.

Subwatershed Basin #3102. The flood elevation for the natural closed depression found immediately east of Woodcrest Road is at or slightly above storage capacity (elevation 616 feet NGVD 29) including the discharge through a 24 inch culvert under Woodcrest Road. The 100-year modeling results agree with reports of flooding onto the pavement without overtopping the road.

Subwatershed Basin #3105. Existing agricultural buildings are the lowest elevation structures exposed to potential flooding at approximately elevation 630 feet NGVD 29. This elevation would allow close to 2 feet of freeboard. The ortho photos indicate that the existing residential dwellings are an additional 2 feet higher in elevation.

Watershed Recommendations. Due to the large undeveloped/agricultural areas of Subwatersheds #3104 and #3105, there will be dramatic increases in peak runoff after full development. Both of these areas feed into Subwatershed #3102 and to the Woodcrest Road area already experiencing flooding. Flood control of developing areas - much of which is outside of the current municipal boundary - is vital to avoid a steadily increased problem with flooding.

The Village is currently considering the construction of a new soccer field in the park that could act as a storm water detention basin. There are some limitations to this concept. Creating an outlet for the pond is difficult since the area is flat. One option is an underground pipe but it may have to run a long distance to achieve daylight. The most obvious route is west along Autumn Road to the wetland in Subwatershed #3100. Considerations should be given to treating storm water prior to discharge. A soccer field would function as a dry detention basin to restore its normal function as a recreation facility. However, no water quality benefits result from dry detention basins.

An alternative possibility is to utilize the existing NCD at the east side of Woodcrest. The landscape already drains to this location. The parcel mapping indicates that the Village already owns this property. The poor drainage near the park facilities could be remedied with an open channel leading to the basin. The basin bottom could be lined as discussed in Chapter 13 and the outlet modified to create a wet detention pond with flood storage. The dual purpose of soccer field as detention basin savings would be lost and is a drawback, but this alternative has fewer challenges from the landscape and the outlet is readily available. It would not re-route water from the existing drainage patterns. Its feasibility depends on whether the volume of the available storage can be increased with grading and/or excavation to enlarge it into the hillside to the east or deepen it. The parcel to the south owned by the Curtis B and Roxann J. Wiltse Trust might need to be purchased. The possibility of raising Woodcrest Road in the low section could also be considered.

The general rule for a flood control structure is 5 percent of the contributing area. The combined contributing area for Subwatersheds #3102 and #3104 is 160 acres. At 5 percent, the required area of the detention basin is 8 acres. The approximate total of the two parcels is approximately 8 acres. To be effective, the soccer field as detention basin would need to be 5 percent of the Subwatershed #3104 contributing area of 120 acres, or 6 acres.

The runoff from #3105 and #3106 is mitigated by the NCD south of Maple Drive (CTH ZZ). This NCD should be designated as a **storm water storage zone**.

The Pheasant Park channels are below capacity and therefore capable of receiving additional storm water discharge. It is recommended that the existing Pheasant Park storm water channel, detention system and outlet be evaluated using existing construction record drawings (if available) or accurate site survey information to determine if routing additional storm water flow through the existing detention system outlet is feasible without flooding adjacent structures.

The Village is considering installation of a new storm sewer pipe for Subwatershed Basin #3101 crossing Sunset Road that would discharge to an existing open ditch on the north side of the road. Storm water runoff would flow toward the existing storm sewer system that currently receives flows from the NCD lift

station. A review of the existing topography indicates that there is sufficient elevation for this new storm sewer to gravity feed the existing system. A 24 inch reinforced concrete pipe carrying 25 cfs would maintain the level of the NCD below 600 feet NGVD 29. However, given the potential for the connection of Watersheds #2900 and #3000 to this same system it is recommended that the combined impacts of the entire system should be evaluated prior to pursuing this project.

Public Capital Improvement Cost Estimates

Channel	$12,000
#3102 retention pond	$2,041,000
#3105 outlet storm sewer	$41,000
Total	**$2,094,000**

12.6.3.15 Watershed #3200

Watershed Description. This watershed of less than 30 acres is primarily golf course which is not expected to change land use. An NCD is indicated by the 2 foot elevation contour plan. Immediately below the NCD is a multi-family or condominium development. One of the structures lies within the footprint of the NCD near the edge below the 626 foot elevation contour. Figure 12-15 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm sewer system.

10 Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100 Year Event Pond System Analysis. The NCD floods to elevation 628.4 feet NGVD 29. This is above the elevation of the structure noted above.

Watershed Recommendations. Flood proofing around the structure encroaching upon the NCD would allow this area to become a **storm water storage zone** which is compatible with its use as a golf course. A safe outlet should be installed to drain off water past the downhill development should infiltration be the current primary outlet. Modifying this NCD for aquifer protection is unnecessary unless private wells are in the vicinity. The wellhead protection zone is up-gradient and the NCD is reasonably close to Green Bay. Encouraging a nutrient and pest management program for the golf course (if not already in place) would help to minimize pollutant runoff impacts to Green Bay.

12.6.3.16 Watershed #3600 - Country Lane, Fieldcrest, & Golf Course

Watershed Description. This 860 acre watershed is one of the largest in the study area. Existing land uses run the spectrum from commercial, park (golf course), and all residential density types. Storm water flow is directed through a series of culverts crossing STH 42 and adjacent frontage roads down through a wet golf course hazard pond, then through another series of culverts and channels to a natural closed depression adjacent to the shore of Green Bay.

There are only two other significant natural closed depressions in this system. One is very shallow and the other has development at a relatively low ground elevation. Figure 12-16 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. The storm water conveyance system consists of series of channel segments and culverts. The channel segments on the east side of the watershed along Bay Shore Drive were determined to carry insignificant discharge in the upland areas with little contributing area.

The culverts across STH 42 appear to be undersized. During large rainfall events flooding is a likely occurrence on the southeast side of the road. Although the culverts across STH 42 limit the flow rates to the golf course pond area, these flow rates exceed the capacity of the system of channels and culverts downstream of from the golf course pond. This system appears to be grossly undersized, given that the areas around the golf course pond generate significant runoff in addition to the runoff from discharge, the culverts from the contributing area north of the highway alone is much more than it can carry.

100-Year Event Pond System Analysis.

Subwatershed Basin #3601. The home of George and Arlene Schiestel sits along the 648 foot elevation contour providing less than 1 foot of freeboard to the flood protection elevation. Parcels immediately to the south and east are all situated on land with substantial areas at or below elevation 648 feet NGVD 29.

Subwatershed Basin #3603. Development on the parcel owned by Lester Hammersmith is shown on topographic mapping to be below elevation 642 feet NGVD 29 and is at least 3 feet below the flood elevation. Open Hearth Lodge is not much higher in elevation.

Golf Course Condominium Area. This area has experienced flooding issues in the past. Subsequent to the most recent major flooding event (Spring 2004), Village staff had discovered that one of the existing drainage culverts was plugged with debris. Despite correction of the culvert plugging issue, computer modeling results of the 100-year rainfall event indicate that current detention by existing upstream basins and the capacity of downstream culverts is inadequate to contain the runoff within the system and roadway overtopping is likely. The overflow elevation of the golf course is 622 feet. It appears that nearby adjacent structures are within 2 feet or less of this level. Therefore, there will be little to no freeboard during a large rainfall event.

Subwatershed Basin #3605. The capacity of the "ridge depression" at the outfall to Green Bay was exceeded in computer simulations for the 100-year event. However no infiltration was modeled. This NCD should be designated a **storm water storage zone**.

Watershed Recommendations. Options for reducing flooding are very limited due the placement of existing development low in the landscape in subwatershed #3603 and adjacent to the golf course hazard pond. The two primary options are to move water downstream more quickly from the area of potential flood damage or to detain it upslope. The recommended method of alleviating flooding is to increase storage and detention in the existing NCDs of subwatersheds #3601 and #3603 and prevent increased flooding through added detention BMPs in the upland areas contributing runoff as development occurs in accordance with the proposed ordinance. Additional flood storage should be constructed in the two NCDs of Subwatershed Basins #3601 and #3603 if excavation is permitted by existing bedrock and/or groundwater conditions. The feasibility of flood protection of existing development should be explored using berms or other measures to protect structures. These NCDs and the Watershed #3605 NCD should be designated as **storm water storage zones**.

Part of the flooding may be alleviated by increasing the size of pipe culverts leading to and across Little Sister Road. The downstream NCD would receive little additional runoff volume except for what

presently infiltrates. The peak discharge rate should be reduced somewhat by the detention added to the system. The property owner of the subwatershed #3605 NCD, West Capitol Incorporated, has been receiving water from the system for at least as long as the culvert crossing under Little Sister Road has existed. However, during high water events, some of the water was probably diverted by the road when the culvert capacity was exceeded.

The STH 42 culvert system consists of a pair of existing 30 inch diameter corrugated metal pipe culverts crossing STH 42. They are preceded by a single 30 inch diameter culvert under Country Lane. Little Sister Road has a similar culvert condition. These culverts should be replaced by a continuous culvert from south of Country Lane to the north of Little Sister Road, preferably even beyond the private drive. Runoff from between the road could be captured by inlets connected to the culvert. Whether or not they are adequately sized is a matter of perspective. The development above STH 42 could be better served by larger culverts. The development below STH 42 would be better served if there were no culverts.

The existing condition 100-year event peak discharge through the STH 42 culvert system is over 80 cfs. The peak discharge from the landscape downstream of STH 42 is over 120 cfs. Added detention capacity in the Subwatershed #3601 and #3603 NCDs will reduce the 80 cfs discharge. Protection of the area downstream of STH 42 can be improved by increasing detention capacity in the golf hazard pond, floodproofing the adjacent development, and eliminating culverts where possible and lowering and enlarging them where they must remain.

It is recommended that the golf course pond be modified to function as a true detention pond. The drainage from the nearby buildings should be diverted downstream of the pond so that the high flood elevation of the modified pond isolates the proposed pond from the building and creates freeboard. As this area is privately held, the responsible party should undertake the necessary engineering evaluation and design.

The culverts both in the privately held area and under Little Sister Road are undersized. But there are practical limitations to what can be modified. To prevent flooding the drainage needs to be lowered dramatically. In the extreme case where upland storage cannot be modified for Subwatersheds #3601 and #3603, the following would be required to safely pass the discharge from the existing condition development runoff. The description below summarizes modeling results. Each element was modeled as it currently exists. Each element could be modified to a limited degree without changing the flood elevations, but the description below is essentially what would be required.

The culverts under STH 42 would need to be replaced by a continuous set of culvert pipes as described earlier. In order to maintain a headwater below 642 feet NGVD 29 to protect the existing development, a 6 foot by 3 foot high concrete box culvert is required. The inverts would be close to the existing elevations.

The receiving channel should be shaped using a 4 percent slope, would be trapezoidal, and have a 10 foot bottom, be 2 feet deep and have 4-to-1 sideslopes and lead to the golf course pond.

The golf course hazard pond should be modified to the extent possible. Modeling used a theoretical proposed detention basin pond in place of the existing golf course hazard pond for a maximum area approximating an ellipse of 400 feet long, 160 feet wide at the axes (about 1.2 acres of maximum surface area) with a top elevation of 624 feet NGVD 29.

The outlet of the pond would be a channel with a 20 foot bottom at a pond outlet invert elevation of 620 feet NGVD 29, or 2 feet lower than presently indicated on the contours.

The next culvert downstream, an existing 40 foot by 28 foot elliptical corrugated metal pipe should be replaced by a 6 foot by 3 foot high box culvert lowered to elevation 618 feet from the presently estimated invert of 619 feet.

The channel leading west to Little Sister Road would need to be reconstructed at an invert elevation of 614 feet, 6 feet below the existing contour elevation.

The culvert presently crossing Little Sister Road should be replaced south of the present crossing, aligned with the east-west channel using a 6 foot by 4 foot box culvert with an upstream invert elevation of 613 feet. The culvert would be 140 feet long, discharging to the proposed Storm Water Storage Zone of the Subwatershed #3605 NCD. A safe outlet should be constructed for discharge from the NCD. The NCD is close to the Bay, outside of the Wellhead Protection Zones and does not require a liner.

Alleviating flooding by means of increasing conveyance from STH 42 through Little Sister Road is not a recommended alternative, although some elements will improve the situation. The culvert locations discussed above crossing Country Lane, STH 42 and Little Sister Road should be followed when it becomes convenient to replace them. The new location of the Little Sister Road crossing eliminates unnecessary additional flow restrictions and the extension of the STH 42 culverts eliminates the obstructions created by the culverts crossing the frontage roads.

Country Lane and Fieldcrest Road Areas. Storm water flows from the Country Lane and Fieldcrest Road areas will increase with imminent development. The current low gradient channel south of STH 42 that drains the area is inadequately sized for these flows. It is recommended that the Village develop a plan for a 10 foot wide, 1.5 foot deep channel with a greenway flood buffer (these areas are typically used for recreation paths as well) where shown on Figure 12-16. Future development in the area should be required to conform to the plan as a condition of plat approval.

Private Capital Improvement Cost Estimates

Floodproofing	$27,000
Golf Hazard retention pond	$360,000
Channel& Culvert Replacement/Reconstruction	$100,000
Total	**$487,000**

Public Capital Improvement Cost Estimates

Culvert Replacement/	$120,000
Capacity Expansion of NCDs in Subwatersheds #3601 and #3603	$3,800,000
Total	**$3,920,000**

12.6.3.17 Watershed #3900 – STH 42 and STH 57 Convergence

Watershed Description. The existing watershed land use is a mixture of commercial and residential uses and is approaching full development. There are no known natural closed depressions or retention/ detention ponds. Figure 12-17 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. The upper parts of the watershed are made up of isolated networks of culverts, channels, and storm sewer. A 42 inch pipe is connected to a downstream 36 inch pipe on Bluffside Lane between Gateway Drive and North Bay Shore Drive. A channel connects this to a downstream system of smaller pipes.

10-Year Event Storm System Analysis. The existing 36 and 42 inch diameter pipe sizes feed into a smaller diameter system downstream. There is no apparent available storage to mitigate the runoff peak except for the connecting channel. The computer model results start at the pair of 18 inch CMP parallel to Bluffside Lane. The succeeding pipes are single 24 inch diameter leading across Maple Drive to a 20 foot wide, 3 foot deep open channel, followed by a series of 24 inch CMPs and finally to a 30 foot wide, 3 foot deep open channel discharging to the bay.

While the outfall channel appears to have excess capacity, the storm sewer upstream as far as North Bay Shore Drive does not have capacity for the total runoff. The large diameter pipes are capable of feeding water to the smaller downstream system beyond the system's capacity. While the large diameter pipes most likely have the necessary capacity, based on the modeling completed and the area of contribution defined by the 2 foot elevation contour plans, the smaller downstream pipes do not have sufficient capacity for the anticipated 10-year rainfall event discharge.

100-Year Event Pond System Analysis. There are no ponds within the watershed to analyze.

Watershed Recommendations. No flood issues have been reported although the modeling results suggest otherwise. There is an opportunity for a detention/retention system for Subwatershed #3901 on what is already publicly-owned property. The parcel is apparently owned by the Village described as *"that part of Government Lot 4 Section 5-31-28 that forms a triangle where Hwy 57 meets Hwy 42 DESC 14P121 DCR"*. STH 57 appears to effectively channel water from the south and east toward a 42 inch pipe leading to the parcel with the potential pond. The inlet conditions may need to be modified to allow more efficient entry to avoid road overtopping. This pond could be constructed as a lined wet pond to treat polluted runoff and protect groundwater, although it is just outside the wellhead protection management zone. This pond would capture the Subwatershed #3901 runoff from 30 acres. The site is steep which severely limits the possible area of the pond. The pond should be as large as physically possible to achieve water quality benefits. Due to the limited area, large events should simply bypass the BMP to avoid flooding out the pond and resuspending solids.

Downstream the topography flattens in the area south of E. Larson where a channel leads to a pipe system. The transition from open channel to pipe is likely to back up water during large events - assuming that the contributing area is not diverted during overland flow along streets such as Maple Drive. The ortho photos do not indicate development on some of these properties including that of William and Louise Robbins where much of the channel is located. If flooding has occurred, it may not have been observed. The property owned by Dwight and Mary Jo Anderson is landlocked and adjacent properties have irregular boundaries. This suggests the possibility of purchase by the Village for a detention/retention facility for water quality treatment and if large enough, for peak discharge reduction. The contributing area is approximately 45 acres suggesting a pond of 2-2.5 acres to be effective at flood reduction. But it does not appear that there is sufficient undeveloped area for a facility of this size.

Gateway Drive. Current storm water flows are eroding the existing ditch along Gateway Drive. The current system of alternating pipes and ditches results in high energy, concentrated flows exiting the

existing pipes and eroding the ditches. The system should be converted into an all piped system and tied into the STH 57 drainage network recently updated as part of the WDOT work.

Public Capital Improvement Cost Estimates

Gateway Drive Retention Pond	$100,000
Larson Road Retention Pond	$100,000
Increase Storm Sewer Size	$32,000
Total	**$232,000**

12.6.3.18 Watershed #4000 - North Bay Shore Drive and East Mill Road

Watershed Description. The existing watershed land use is a mixture of commercial and residential uses and is approaching full development. Figure 12-18 illustrates the location of the watershed boundaries and surface water flow direction. Although a storm sewer system will intercept runoff for the design storms, bypass from larger storms may be reaching the area northeast of Mill Street. The elevation in this area bottoms out at a contour elevation of 586 feet NGVD 29. The mapping of problem areas in the fall 2005 CUPAC meeting indicated flood problems in this vicinity, but the nature of the flooding was not defined.

The upper half (south end) of Subwatershed #4002 is the development known as Scandia Village which is served by an engineered detention basin.

The downstream end of Subwatershed #4002 is north of East Mill Road and South Spring Road. A small NCD (4002B) is found there. The 1 foot contours provide added definition as shown in Figure 12-18a. Most of Subwatershed #4002 is intercepted by streets and would not reach the interior of the block north of East Mill Road. For the purpose of mapping the flooded area, only the area lying within the block that would not normally be graded to drain to the street was considered as part of the contributing area. The volume of water that might bypass the storm system and reach the interior of the area is indeterminant. The only outlet for the NCD is to the natural closed depressions to the north (Subwatershed #6301).

The larger portion of the watershed drains overland and through storm sewers to the bay.

Storm System Description. The storm water system consists of a privately-owned detention basin serving the upper 2/3 of Subwatershed #4002, which primarily incorporates the Scandia Village development area. The detention basin discharges to a storm sewer system running north along Claflin Street to East Mill Road. The storm sewer continues northwest to North Bay Shore Drive, where it connects to the existing system that drains Subwatershed #4001. This existing storm sewer originates uphill approximately 750 feet from the afore mentioned junction at Mill Road from southwest along Bay Shore Drive, draining the area south of Maple Drive. The existing downtown storm sewer system runs approximately 200 feet west of the Mill Road/Bay Shore Drive intersection along West Mill Road, before turning north to the outfall discharge to the Sister Bay portion of Green Bay.

The entire system described above (except for the segment leading from the Scandia Village detention pond to the intersection of Claflin Street and East Mill Road) is less than 2 years old.

The engineering details of the recently constructed storm sewer work in this area are documented on existing project record/as-built drawings. The information from these documents was used as the basis for input data the H&H computer model. Input data for the older, non-documented part of the system was

based on field GPS data, GIS topographic elevation data, selected field measurements, and field observations. Figure 12-18 illustrates the location of the watershed boundaries and surface water flow direction.

10-Year Event Storm System Analysis. The minor drainage system requires supplemental capacity to meet the discharge requirements of the drainage area Subwatersheds. Based on the modeling completed, and the area of contribution defined by the 2 foot elevation contour plans, the existing pipe system does not have sufficient capacity for the anticipated 10-year rainfall event discharge. The Scandia Village detention basin does reduce the discharge of the 10-year storm from 32 cfs to 17 cfs, but the basin is at the point of overtopping. The existing basin it is not capable of containing the 100-year storm event.

The Claflin Street-East Mill Road segment of the storm sewer system is close to design capacity and appears adequate for the 10-year event. The North Bay Shore Drive storm sewer pipe lies on a significant grade; it is anticipated that there is substantial bypassing of the inlets by storm water running northeast down the North Bay Shore Drive pavement/gutters. Therefore the existing pipe is believed to be adequate for the runoff quantity captured by inlets and discharged into the storm sewer system. Village staff have noted street flooding to be a problem along North Bay Shore Drive between Mill Road and Sunset Drive, a distance of approximately ¼ mile with only one set of inlets between on what is essentially very flat terrain.

100-Year Event Pond System Analysis. As noted above, computer model results indicate that the Scandia Village storm water detention pond (4002A) would be at capacity during the 10-year storm event. Its storage volume would be exceeded during more intense storms such as the 100-year event.

The NCD north of East Mill Road has a volume of runoff that exceeds the volume of storage below the 585 foot contour elevation. The area will flood to an elevation above the overland escape elevation (between 585 and 586 feet) in order to discharge. Runoff volume (0.98 acre-feet), storage volume below 585 contour (0.41 acre-feet).

Watershed Recommendations. Since the system is new, it has not been tested by time for rainfall events leading up to the 10-year event. Real world runoff characteristics and behavior must be observed to determine if the system needs additional infrastructure to meet the drainage system flooding goals.

The design for the Scandia Village detention pond should be reviewed. The design was probably done with more accurate topography and more detailed watershed modeling, but it should be checked to see what occurs during the 100 year event. A safe outlet should exist in the event of either overtopping or a plugged outlet.

The area northeast of East Mill Road should be monitored to see if overland flow from large events does reach the low area and cause problems. East Mill Road should act as a diversion to direct runoff downhill towards Bay Shore Drive. If flooding does pose a problem, it can be alleviated with minor grading to improve the hydraulic connection to the NCD of Subwatershed #6301. The Storm Water Storage Zone for this area should be at least at elevation 585 feet. All development should be required to have a low space elevation in excess of elevation 586 feet.

The excess runoff generated by Watershed #4000 that routes along the street curb and gutter system to North Bay Shore Drive can be captured in Watershed #6300 with additional inlets in the flat stretch of North Bay Shore Drive.

12.6.3.19 Watershed #4400

Watershed Description. This 160 acre watershed has a current land use that is primarily agricultural along with the majority of the remaining area being low density residential. It is expected that the area will fully develop at a medium residential density.

The watershed discharges away from Green Bay and is not contributing to the Sister Bay watershed. Figure 12-19 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm sewer system.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. Development already exists in the vicinity of the #4401 NCD. The top elevation contour is at 684 feet USGS, and the existing condition modeled flooded elevation is 683 feet USGS.

Similarly, development is already encroaching on the NCD in Subwatershed #4402. The surface route escape elevation contour is 674 feet USGS, the flooded elevation is 673.4 feet USGS for the existing condition.

Watershed Recommendations. It is apparent that the NCDs cannot be used for the added flood storage required when the watersheds are in the developed condition. It will also be necessary to create an outlet. It will be important that all future development accommodate all increases in runoff.

For the NCD in Subwatershed #4401 some flood proofing may be necessary around the structures on the parcels of Leslie Boden and the parcel owned by JM Northwoods Properties on the corner of STH 57 and Northwoods Road.

The Subwatershed #4402 NCD covers 16 acres and represents a considerable area to designate as unbuildable. The alternative to upland site development flood control BMPs is for <u>any</u> development within the watershed to make a legal arrangement with landowners downstream.

These NCDs should be designated as **storm water storage zones**.

12.6.3.20 Watershed #5200

Watershed Description. This 11 acre agricultural watershed drains to an NCD with no known outlet except for road overtopping to the west outside of the Green Bay watershed. Figure 12-20 illustrates the location of the watershed boundaries and surface water flow direction.

Storm System Description. There is no storm sewer system.

10-Year Event Storm System Analysis. There is no storm water system within the watershed (other than roadside ditches). Therefore, the 10-year event storm water system analysis was not performed.

100-Year Event Pond System Analysis. The top ground elevation contour is at 732 feet USGS and the modeled flooded elevation for the existing condition is 731.6 feet.

Watershed Recommendations. The NCD crosses out of the planning area study. This area should be designated as a **storm water storage zone**. The flooded elevation under future conditions is at or above the containment elevation of the NCD. Upland development should be required to control storm water for flooding and, as in the case of Watershed #4400, be prepared to make legal arrangements with downstream landowners if necessary.

12.6.3.21 Watersheds #5800 and #5900 – Sunnyside, Admiral, and Sunny Road Area

The Sunnyside, Admiral, and Sunny Road area does not have adequate drainage for future development. A neighborhood drainage plan should be developed and adequate drainage required as a condition of the building permits issued for this neighborhood. A ditch network with culverts under driveways would be adequate.

12.6.3.22 Watershed #6300 – South Spring Road and STH 42 (North Bay Shore Drive)

Watershed Description. This watershed is largely composed of commercial and dense residential development. A natural closed depression lies within Subwatershed #6301. It is reported that this area receives groundwater from the wetland of Subwatershed #3101 due to the development of an artesian condition (water is visibly flowing vertically out of the ground). The source area is known to infiltrate water at a high rate and there is an elevation difference of over 20 feet. Figure 12-21 illustrates the location of the watershed boundaries and surface water flow direction.

The area between Scandia Road and Mill Road, Bay Shore Drive and South Spring Road is defined by 1 foot contours from a survey specifically for that area. Datum for the STS survey was not provided. It is assumed to be consistent with the County furnished contours.

Storm System Description. The storm system consists of a 36 inch x 22 inch arch feeding into a 30 inch CMP discharging to the bay according to the 1973 Robert E. Lee drawings. The upstream pipe invert at Casperson's pond is 581.75. The system drains the basin just west of South Spring Road and the only other feed into the system are two inlets at North Bay Shore Drive.

10-Year Event Storm System Analysis. The system has capacity in excess of the 100-year event for the Watershed #6300 contributing area. As discussed under the description of Watershed #4000, bypass from #4000 is probable and likely to flow along North Bay Shore Drive which is flat with few inlets. As described by Village staff, there are insufficient inlets to capture runoff without road flooding.

100-Year Event Pond System Analysis. The 1 foot contours show a pond bottom of 579 feet, or about 2.8 feet below the outlet elevation. The existing basin has a closed contour capacity that is reached at elevation in excess of 585 feet NGVD in Subwatershed #6301. The 100-year water surface or flood elevation reaches 582.4 feet NGVD. An outlet control structure exists on Casperson Pond which can be manipulated. The study assumed that the outlet pipe invert would control and that control structure stop logs are removed to allow maximum outflow and minimize flooding. There is no information available on the outlet structure.

Watershed Recommendations. The invert of the storm sewer as it crosses North Bay Shore Drive is 581.2 feet USGS. The GIS mapping 2 foot contours indicate a ground elevation of approximately

586 feet. Allowing 3 feet for inlet height and assuming a surface elevation of 585 feet (due to contour tolerances), the storm sewer falls 0.8 feet over a distance of 160 feet with a 0.5 percent slope. It is 600 to 800 feet to the nearest adjacent storm sewer systems. The system on Sunset Drive crossing North Bay Shore Drive should be at approximately elevation 581.5 feet, while the system in Watershed #4000 is already at capacity. It may be necessary to route piping directly to the bay in a manner parallel to the existing system. A separate system would also preserve the pipe system's capacity to drain the basin at the present rate.

The runoff from Watershed #4000 exceeding the modeled capacity of the storm sewer is estimated at approximately 25 cfs for the 10 year storm. With the runoff from the local area, the southwest system shown in Figure 12-21 should use a 30 inch RCP pipe main at 0.5 percent leading to the Bay with 24 inch diameter pipes leading from the inlets. The northeast system should be adequate with 24 and 18 inch diameter pipes, respectively.

Serious consideration should be given to establishing a Storm Water Storage Zone in Subwatershed #6301. Because information on the outlet structure is unknown, and unless there is a plan in place to remove the stoplogs during large runoff evens, it would be prudent to establish the Storm Water Storage Zone at the overland escape elevation, which exceeds elevation 585 feet. The attached Figure 12-21a shows the extent of the 585 foot contour by shading. Other unknowns are the rate of discharge into the pond from Subwatershed #3101 via underground flow and the rate of discharge through the ground towards the bay. The survey indicates a ponded elevation of 579.2 feet but the water surface of the bay on that date is not noted. The bay may have some control on the pond pool elevation should a cobble substrate be present. These factors may well over-ride the simple runoff/discharge results. All development should be required to have a low space elevation in excess of elevation 586 feet.

Presently the basin is drained near the bottom of the basin, which precludes using it as a wet retention pond. The outlet structure could be modified to provide the minimum depth of 5 feet of undrained permanent pool if the discharge rate prevents flooding adjacent homes. If an Operation and Maintenance plan that calls for an operator to remove stoplogs in the event of large storms is practical, added protection would be provided to adjacent development. But unless these measures are taken and with the minimal present capacity, it appears that creating a water quality BMP is not feasible at this location without compromising the 100-year event flood protection.

Eroding and undersized storm water flow channels are a common problem in the Sister Bay area. Many existing channels have eroded to the underlying bedrock or flood routinely. As impervious surface area and the associated storm water runoff volumes upstream of the channel sections increase with future development, the existing problems will be intensified and new problems will occur in channels that are currently adequate. The following channel improvements are recommendations:

Public Capital Improvement Cost Estimate

New Storm Water System	$143,000

12.7 SUMMARY OF STORM WATER IMPROVEMENT RECOMMENDATIONS

Table 12-1 summarizes the recommended storm water management planning capital improvements for the Sister Bay planning area over the planning period. The improvements are listed by watershed.

TABLE 12-1

RECOMMENDED STORM WATER PLANNING IMPROVEMENTS

STORM WATER MANAGEMENT PLAN
SISTER BAY, WISCONSIN

Watershed No.	Improvement Description	Budget Estimate
2600	New Storm Sewer along Waters End Road	$125,000
2700	North Spring Road Culverts; New Lift Station Pump; Subwatershed #2702 Retention Basin; Lift Station Storm Sewer Outlet	$1,196,000
2800	Replace Storm Sewer System with Larger Pipe	$100,000
2900	New Storm Sewer and Retention Pond	$530,000
3000	New Storm Sewer with Underdrain	$100,000
3100	Channel Improvements; Subwatershed #3102 Retention Pond; Subwatershed #3105 Outlet Storm Sewer	$2,094,000
3600	**Private Improvements:** Floodproofing Structures; Golf Hazard Retention Pond Improvements; Channel and Culvert Replacement and/or Reconstruction	$487,000
	Public Improvements: Culvert Replacements; Subwatershed #3601 and #3603 NCD Capacity Expansion	$3,920,000
3900	Gateway Drive Retention Pond; Larson Road Retention Pond; Storm Sewer Capacity Improvements	$232,000
6300	New Storm Sewer Improvements	$143,000
Total		**$8,927,000**

Note

1. Estimates include engineering and contingency costs.

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The recommended first steps before implementing the proposed improvements is to enact zoning, secure easements, and purchase property necessary before additional development in the flood prone areas and BMP locations occurs.

12.7.1 Natural Closed Depressions

The NCDs need to be treated as outfalls receiving runoff. To protect development from flooding, development should be prohibited within the Storm Water Storage Zone unless other provisions are made to prevent flooding of both the proposed development and others hydrologically and hydraulically connected to the NCD.

This study provides the mapping necessary to create the Storm Water Storage Zones. The boundary of the zones is recommended to be at a flood protection elevation of 2 feet above the ponded depth given in Appendix C. The figures in this chapter show the approximate area of the zones at the 2 foot elevation contour above the ponded elevation which is not necessarily the same as the 2 foot freeboard.

Due to the uncertainty of the contour data, which is plus-or-minus 1 foot accuracy, it is recommended that each Storm Water Storage Zone be determined based on the process outlined below. The investigation of NCDs is also discussed in Chapter 13 of this report in the context of water quality.

1. Conduct a topographic survey up to an elevation of at least 2 feet above the currently modeled ponded elevation.
2. Survey to identify existing development by use (dwelling, garage, outbuilding, commercial business, etc.), including the low adjacent grade and floor elevations.
3. Convert the survey data into a contour CAD drawing.
4. Re-execute the H&H models to determine the ponded depth for the 100 year events for existing and future development, using the updated, accurate, topographic data.
5. Map the area at ponded depth, 1 foot of freeboard, and 2 feet of freeboard with corresponding elevations and area values.
6. Village to review the results to determine how existing development is affected and review possible alternatives such as:
   a) Can the existing development be flood-proofed?
   b) Can the NCD be regraded to increase storage to minimize the ponded elevation?
   c) Can storage be created in the upland contributing area to supplement the available storage of the NCD?
   d) Can an outlet be created to reduce the ponded elevation without causing flood damage downstream?

12.7.2 Ditches

The roadside ditches should continue to be the primary means of conveying storm water for runoff reaching road right-of-ways. Ditches have greater conveyance capacity than pipes at a lower capital cost and do not need to be as low in elevation which is an important consideration due to shallow bedrock. They have the added benefit of acting as water quality swale BMPs.

12.7.3 Storm Sewer

In existing urbanized areas where storm sewers are necessary their conveyance capacity is limited by a combination of size, slope, and the inlet characteristics. They are typically designed for a 10 year storm, but the surface topography will affect the efficiency of transferring surface runoff in ditches or gutters into the pipe below. Ditches and gutters are both the primary and tertiary conveyance system. They collect water, directing it to catch basins or inlets which capture some of the water and drain it into the underground pipe system. But their efficiency is determined by whether or not they lie on a slope or at a low point. Inlets on slopes typically allow a significant quantity of flowing water to bypass the inlet. Therefore the gutter or ditch continues to carry runoff supplementing the pipe system.

Recognizing this means that water will continue to be on the surface during large events and will accumulate at low points in the system. These sump areas will act as dry detention basins until the system can drain it down. Development in low areas will be flooded during extreme events unless they are above a surface "escape route" that allows water above the "escape elevation" to drain off. For development along the Bay Shore Drive, this may mean finding opportunities between existing developments to allow water to drain away from the street to the Bay. To determine this will require elevation information with accuracy to the nearest 0.1 foot vs. the 2 foot contour information available for this study.

The reconstruction of STH 42 provides an opportunity to adjust grades enough to optimize drainage as much as possible. Inlets should be located at low points. Escape routes can be situated so they are higher than inlets to avoid becoming the primary runoff route, but low enough to protect existing development.

12.7.4 Outfalls

Lake Michigan ranges in elevation (International Great Lakes Datum 1985) from 576.05 to 582.35 feet over the course of the historical record since 1918. The listed normal range is from 578.5 - 579.5 feet IGLD, but it was only a relatively short time ago in 1986 that it reached the high level noted above. To maximize the capacity of a storm sewer it should have a free outfall. For pipes with a low slope it is even more important to have a free outfall, otherwise the lake level will reach a significant distance up the pipe and decrease its conveyance efficiency.

This is of concern for Bay Shore Drive between Mill Street and Sunset Drive where the street elevation is in the vicinity of 586 feet USGS. The depth of an inlet structure alone can require 2.5 – 3 feet of height when a 12 inch pipe is used, higher for larger pipes. Special inlet structures such as the existing drainage pipe bisecting this area will be necessary.

This is also of concern for the development surrounding the wetland NCD of Subwatershed #2703 where it appears there are low adjacent grades below the 584 foot elevation contour, or within less than 2 feet of the high water level of Lake Michigan. This is why the lift station is in place.

The elevation differences in this area are so tight that even the datum becomes an issue. As noted above, the Lake Michigan water surface elevations are in International Great Lakes Datum 1985. There is a datum difference of 0.43 feet between IGLD 1985 and the NGVD 29 datum used for the flight to develop the 2 foot contours used in this study. In other words, the high water elevation of 582.35 feet IGLD 1985 converts to 582.78 feet NGVD 29.