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Ludlowville Stormwater Control Project
Tompkins County Planning Department

Technical Report 1: Existing Ludlowville Stormwater Conditions

December 2008

Barton & Loguidice, P.C.
Engineers • Environmental Scientists • Planners • Landscape Architects

290 Elwood Davis Road
Box 3107
Syracuse, New York 13220

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Prepared for:

Tompkins County Department of Planning
121 East Court Street
Ithaca, New York 14850

Prepared by:

Barton & Loguidice, P.C.
Engineers • Environmental Scientists • Planners • Landscape Architects
290 Elwood Davis Road
Box 3107
Syracuse, New York 13220

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Executive Summary

On behalf of the Ludlowville Stormwater Control Project Team, the Tompkins County Planning Department retained the services of Barton & Loguidice, P.C. (B&L) to prepare a Drainage Study for the Ludlowville area in response to resident requests to address the historical flooding which has impacted the area for many years. The Project Team includes the County Planning and Highway Departments, the Town of Lansing Zoning, Planning, Code Enforcement and Highway Departments and the Tompkins County Soil and Water Conservation District. The focus of this Technical Report #1 is to model the existing drainage patterns and determine the limiting components of the existing stormwater system. Future reports will further evaluate recommendations for proposed stormwater controls as part of this drainage study.

The Ludlowville watershed study area is broken into four drainage basins with a critical design point located at the downstream end of each basin (Figure 1). Three of the basins are located in series and are considered the primary study area (Basins A, B and C). The Lansingville Road (Basin A), Ridge Road/New York State Route 34B (Basin B) and Ludlowville Road (Basin C) drainage basins are connected when an upstream controlling drainage structure overtops and sends a surcharge flow into the next downstream basin. Basin A is 70 acres and terminates at a 24" steel cross-culvert located 0.4 miles north of the intersection of Ridge Road. Flows not conveyed by the culvert overtop the earth embankment in the ditch and remain on the west side of Lansingville Road to Ridge Road. Basin B is 97 acres and terminates at the 57" x 38" corrugated metal pipe-arch crossing Ludlowville Road. This crossing has historically overtopped, flooding residents on Ludlowville Road. Even the flow conveyed by this structure has caused significant erosion downstream and is a key design point for the study. Basin C is 16 acres and terminates at the 36" culvert crossing under Salmon Creek Road. The secondary study area consists of the Salmon Creek Road (Basin D) drainage basin which is 48 acres and terminates at a 36" culvert crossing Salmon Creek Road.

Haested Method's PondPack modeling software was used to create runoff hydrographs within the primary and secondary study areas for the 1-, 5-, 10-, 25- and 50-year storms (TR-55 Based). The model has determined the limiting components of the existing system and provided focus points for areas that require improvements. Additional hydraulic modeling including HY-8 (culvert hydraulics) and StormCAD (closed drainage system hydraulics) were utilized to calibrate the PondPack stormwater model. The results indicate that the peak runoff rates exceed the carrying capacity of the culverts at the downstream end of Basins A and B, which is a major contributor to the drainage issues in the area. Overtopping of these structures sends an overflow surcharge to the next downstream drainage basin and overloads the existing stormwater system ultimately overtopping the culverts crossing Ludlowville Road and Salmon Creek Road.

This Report summarizes the watershed study area, previous studies, existing stormwater infrastructure and modeling, and conceptual opportunities for stormwater improvements. Subsequent reports will expand upon the findings presented herein to develop recommended stormwater improvements.

1.0 Introduction

1.1 Background

The Hamlet of Ludlowville is located in the northwestern part of Tompkins County, just off the eastern shore of Cayuga Lake in the Town of Lansing. Residents of Ludlowville in the vicinity of Salmon Creek Road, Ludlowville Road, Ridge Road (New York State Route 34B) and Lansingville Road have experienced recurring flood events over the past several years due to spring thaws and significant rainfall events that produces drainage that exceed the capacity of the existing stormwater system. This results in the existing drainage system overtopping, which allows uncontained flows to travel overland causing damage to basements, landscapes, driveways and other personal and public property.

B&L has been retained by the Tompkins County Planning Department, on behalf of the Ludlowville Stormwater Control Project Team, to develop a drainage study and design a solution to mitigate the recurring flooding and sediment loss in the Ludlowville area. The project is sponsored by the Tompkins County Planning Department on behalf of the County's Highway Department and Soil & Water Conservation District, and the Town of Lansing's Highway Department and Zoning/Code Enforcement Office.

The first phase of this study is to develop a watershed based approach for analysis of the existing drainage conditions and to determine the limiting components of the existing stormwater system. The total study area begins in the agricultural fields west of Lansingville Road and extends southeastward to the confluence of Salmon Creek, just downstream of Ludlowville Falls. Approximately 230 acres was included in the model as being the areas that contributed to the existing Ludlowville stormwater conditions. The study includes the watershed hydrology for the project area and analyses of the existing driveway culverts, road cross-culverts, roadside ditches and closed drainage systems along Lansingville, Ridge and Ludlowville Roads.

A previous drainage study was completed by Milone & MacBroom, Inc. in October, 2004 which evaluated the hydraulic capacity of the culvert crossing Ludlowville Road near the intersection of Ridge Road. The study was completed in response to a storm event that overtopped the culvert and caused significant flood damage to private and public property along Ludlowville Road. The results of the study showed that the Ludlowville culvert was a limiting component of the stormwater system. Although the study concluded that the culvert was undersized, it appears to have underestimated the flows contributing to the Ludlowville culvert. The 2004 report did not include all of the runoff from Lansingville Road nor did it account for the runoff from the south side of Ridge Road that is conveyed to the north side via a closed drainage system. These areas account for approximately 40 acres of additional drainage, and substantially higher peak storm flows. The 2004 study was also limited to the capacity analysis of the Ludlowville Road culvert, and did not analyze other upstream drainage structures in the watershed or the existing stormwater system along the lower section of Ludlowville Road.

The primary objectives of this drainage study are to evaluate and model the contributing watersheds along Lansingville, Ridge and Ludlowville Roads and to evaluate the existing drainage system infrastructure including identification of its limiting components. The results of this effort will include preparation of an "existing conditions" model of the watershed which will be used as a tool to plan and design future drainage system improvements intended to mitigate the periodic flooding currently experienced in this area.

2.0 Study Area

2.1 Study Area Description

2.1.1 Primary Study Area

The primary study area begins at the confluence of the unnamed tributary watercourse and Salmon Creek located just downstream of Ludlowville Falls. The watershed area above the confluence totals 183 acres and consists of three major drainage basins that are connected in series as shown in Figure 1. The basins are analyzed separately because at the outlet of each basin, there is a controlling drainage structure that depending upon flow rates either routes stormwater to the next downstream drainage basin or diverts flow outside of the study area watershed. If the capacity of the controlling structure is exceeded and overtopped, the flow does not leave the study area watershed and is added as a surcharge load to the next downstream basin.

The primary study area consists of Basins A, B and C. The basin lowest in elevation is Basin C, which extends from the confluence of Salmon Creek up Ludlowville Road to the existing 57" x 38" corrugated metal pipe-arch. The flow through the existing pipe-arch is directed outside of the watershed to converge with Salmon Creek approximately 150 feet downstream of the Ludlowville Road bridge. A separate study focus of this report is the erosive conditions at the Ludlowville Road culvert which is discussed in Section 4.2.2.4. Basin C totals 16 acres in area and is primarily single family residential developments, woodlands and some agricultural fields. The land consists of moderate to steep terrain with slopes ranging from 10% to areas of 20% or greater.

The second basin is Basin B, which extends from the existing Ludlowville Road 57" x 38" corrugated metal pipe-arch northwest along Ridge Road to the top of the hill just before the intersection of Beckwith Lane. The basin also extends 0.4 miles north along Lansingville Road to an existing 24" steel cross-culvert. The flow through the Lansingville Road cross-culvert is directed outside of the watershed study area to converge with Salmon Creek. Basin B totals 97 acres in area and is composed primarily of agricultural fields and single family residential developments with some paved road surfaces and scattered woodlands. Excess flows from the Basin B flow to Basin C. The land consists of moderate grade with slopes ranging from 5 – 10%.

The last basin in the series of three is Basin A, which is the area west of Lansingville Road from the 24" steel cross-culvert northward to the intersection of Davis Road. The basin totals 70 acres in area and is composed primarily of agricultural land with scattered woodlands and single family residential developments. Drainage that exceeds the capacity of the 24" steel cross-culvert flows from Basin A flow into Basin B and ultimately to Basin C. The land consists of moderate grades with slopes ranging from 3 – 5%.

2.1.2 Secondary Study Area

A separate watershed area was established for a secondary study area that analyzes the 36" culvert that crosses Salmon Creek Road in front of the residence at 34 Salmon Creek Road (see Figure 1. Basin D is not linked to any other drainage basins in the study area. The basin totals 48 acres in area and is primarily woodlands and agricultural fields with slopes averaging 10%.

2.2 Drainage Sub-Area Descriptions – Basis for Hydrologic Modeling

The entire study area drainage basins were divided into a total of 23 sub-catchments for the purposes of completing the watershed model as shown on Figure 2. Sub-catchment boundary lines were developed using Light Detection and Ranging (LIDAR) contour maps provided by the County, detailed field survey conducted by T.G. Miller, and field reconnaissance. As with the larger drainage basins, surface runoff within each sub-catchment is tributary to a single outlet point for that sub-catchment, defined by a culvert pipe, swale/ditch, or closed drainage system.

Individual sub-catchments are summarized in Table 1, generally progressing from the upper-most end of a drainage area, downstream toward the study design point. Land use and soil types within each sub-catchment were determined from aerial mapping and the USDA Soil Conservation Service (SCS) digital soil survey which were used for establishing runoff curve numbers for the model (see Figure 3).

Table 1 – Summary of Drainage Sub-Catchment Areas		
Sub-Catchment	**Area, Acres**	**General Land Use**
Basin A	69.8	
A1	**15.5**	**Primarily agricultural, some wooded**
A2	**14.3**	
A3	**9.4**	
A4	**7.3**	
A5	**23.3**	
Basin B	96.7	
B1	**32.4**	**Primarily agricultural, some wooded**
B2	**32.4**	
B3	**17.9**	**Primarily residential, some agricultural**
B4	**4.6**	
B5	**1.9**	
B6	**5.4**	
B7	**2.1**	**Mix of grass and light forest**
Basin C	**16.4**	
C1	**0.1**	**Primarily residential, some wooded**
C2	**0.2**	
C3	**0.3**	
C4	**0.2**	
C5	**0.3**	
C6	**13.7**	
C7	**0.5**	
C8	**1.1**	
Basin D	**48.0**	
D1	**15.1**	**Mix of agricultural and wooded**
D2	**27.6**	
D3	**5.3**	
TOTAL	**230.9**	

Note: Detailed subarea cover types (land uses) and soil types are provided in the Hydrologic/Hydraulic modeling output of Appendix A.

3.0 Existing Stormwater Infrastructure

As shown on Figure 2, the following is a summary of existing infrastructure within the primary and secondary basins, respectively. The location, size and type of structures were determined by detailed field survey by T.G. Miller and field visits/data collection by B&L personnel conducted on August 12 and October 29, 2008. Several area residents accompanied B&L personnel on October 29 to point out areas of concern and share information regarding existing drainage patterns. This infrastructure was incorporated into the modeling to evaluate the capacity of each respective segment of the existing ditches, culverts, and closed drainage systems.

3.1 Basin A

The upper portion of Basin A begins at the Davis Road intersection and flows south along Lansingville Road to the 24" steel cross-culvert located 0.4 miles north of the intersection of Ridge Road. The stormwater runoff travels overland within sub-catchments down the hillside to the roadside ditches along the west shoulder of Lansingville Road. The runoff is conveyed southward in the grass-lined ditches until intersection one of the five cross-culverts. Earth embankments block the ditch at the culvert inlets and convey the runoff approximately 45 degrees to enter the 24" diameter steel cross-culverts. The cross-culverts outlet to the east side of Lansingville road into another grass-lined ditch that continues to flow south along the road. The network of ditches and cross-culverts convey the stormwater from north to south to converge with a hedgerow stream that diverts the runoff eastward outside of the study area watershed to Salmon Creek. The hedgerow stream begins at the outlet of the 24" cross-culvert which is the design point of Basin A. Should the flows exceed the capacity of the last cross-culvert, the stormwater overtops the embankment in the ditch and continues on the west side of Lansingville Road to Basin B.

3.2 Basin B

The upper portion of Basin B begins 200 feet south of the intersection of Beckwith Lane Road where stormwater runoff travels overland to the roadside ditch along the north shoulder of Ridge Road. The runoff is carried along the shoulder until entering the closed drainage system at the intersection of Lansingville Road. At this point, the flow from Ridge Road combines with runoff from Lansingville Road.

The Ridge Road Basin includes a 0.4 mile segment of Lansingville Road that consists of the area between the 24" steel cross-culvert and the intersection of Ridge Road. Stormwater runoff travels overland to the roadside ditch along the west shoulder of Lansingville Road. Additional flows from Basin A are input into Basin B during large storm events. Runoff then enters a catch basin located 600 feet north of the intersection of Ridge Road where the flow is split to each side of the road. The main outlet consists of a 36" pipe with the same invert as the inlet pipe which keeps a majority of the flow on the west side of Lansingville Road. A secondary outlet consists of a 30" pipe with an invert 3 feet higher than the other inverts to divert some flow to the east side of Lansingville Road when the drainage structure experiences high flows. The runoff that remains on the west side of the road travels through a roadside ditch and enters the closed drainage system to meet the runoff from the western segment of Ridge Road. The runoff that is diverted to the east side of the road flows through a roadside ditch and through two 24" driveway culverts before entering the closed drainage system at the intersection of Ridge Road. The stormwater from both sides of Lansingville Road combine in the closed drainage system at the intersection of Ridge Road.

Stormwater travels from the intersection of Lansingville Road down the north side of Ridge Road for 560± feet in a closed drainage system consisting of

36" corrugated high density polyethylene (HDPE) pipes. The closed drainage system then outlets into an open channel for 750± feet before entering the 57" x 38" corrugated metal pipe-arch crossing Ludlowville Road. This open channel is deeply incised with steep unvegetated banks and cluttered with dense undergrowth and fallen trees. A second closed drainage system outlets into the channel via a 36" HDPE pipe approximately 350 feet from the beginning of the channel. This closed drainage system brings runoff from the sub-catchments south of Ridge Road and diverts them to the north side of the road. The channel then outlets at the invert of the 57" x 38" pipe-arch crossing Ludlowville Road which is the design point of Basin B. Should the flows exceed the capacity of the pipe-arch, the stormwater overtops the culvert and continues down the north side of Ludlowville Road into Basin C.

3.3 Basin C

Basin C consists of the area north of Ludlowville Road and beings east of the 57" x 38" pipe-arch that crosses Ludlowville Road. The runoff from the top of the basin is directed to an 18" HDPE pipe on the north side of Ludlowville Road approximately 100 feet below the pipe-arch. Additional flows from the overtopping of the existing pipe-arch are added during significant storm events. The culvert marks the beginning of a 185 foot segment of closed drainage that includes one manhole. The runoff is then carried in an open ditch for 190 feet to an 18" HDPE pipe that begins a 340 foot segment of closed drainage that includes three manholes. The closed drainage system outlets into 400 feet of roadside ditch that contains two 24" driveway pipes. Midway along this ditch, a large volume of runoff enters the ditch from a sub-catchment that begins just east of Ludlowville Road and travels through the yard of 199 Ludlowville Road. The ditch then outlets to a 36" HDPE pipe which crosses under Salmon Creek Road. This 36" HDPE extends approximately 400 feet beyond Salmon Creek Road and then outlets to Salmon Creek.

3.4 Basin D

The basin consists of one 15-acre sub-catchment flowing to a 36" corrugated metal pipe crossing under Salmon Creek Road. The remaining 33 acres is conveyed through a separate 36" HDPE pipe located approximately 180 feet south of the corrugated metal pipe. This culvert has had no history of overtopping and therefore was not included in the model.

4.0 Existing Stormwater Infrastructure Model

4.1 Methodology and Assumptions

4.1.1 Soil Classifications

The various soil classifications within the Ludlowville study area are based on the USDA SCS, digital soil survey for Tompkins County, New York. For modeling purposes the various soil classifications were divided into four (4) Hydrologic Soil Groups; A, B, C, and D. Soils are grouped based on profile characteristics that include depth, texture, organic matter content, structure and degree of swelling when saturated. These groups range from Group A - "well drained soils", to Group D - "poorly drained soils". Runoff from Group D soils, therefore is high; while runoff from Group A soils is low. The soils identified within the study area are B and C which are moderately drained soils. The overlay on Figure 3 shows the limits of the associated Hydrologic Soil Groups for existing soils.

Although the soils within the study drainage basins are moderately well-drained, the effect of infiltration losses through the bottom of a channel or ditch were not applied to the model. The infiltration rate would be impacted significantly by the shallow depth to bedrock in many areas and reliable water table depths were not available. Further, it was assumed that in a worst case situation the available infiltration capacity would be reduced by a preceding wet or frozen period (i.e. spring runoff). Excluding the infiltration option from the model provides a conservative approach that will reduce the possibility of underestimating the modeled runoff volume and peak runoff rates.

4.1.2 Times of Concentration

The time of concentration was determined for each sub-catchment within the project area. The time of concentration is the time at which a sub-catchment area begins to contribute to runoff at its outlet node; this is calculated as the time taken for runoff to flow from the most hydraulically remote point of the drainage area to the design point or outlet. For modeling purposes, the flow path is divided into multiple sections based on three (3) flow types; Sheet Flow, Shallow Concentrated Flow, and Channel Flow. The time required to travel through a given section is determined by three (3) different equations associated with the TR-55 method. Each of these equations determines the travel time through a section incorporating watercourse length, the average watercourse slope of that section, and a coefficient representing the type of groundcover or channel material.

4.1.3 Design Storms

The watersheds of the primary and secondary study areas were modeled in PondPack for the 1-, 5-, 10-, 25-, and 50-year 24-hour storm for Tompkins County, New York. The 100-year storm event was not included in the analysis since all components of the existing drainage system overtop at the 50-year storm event. Rainfall data utilized in the analysis are derived from USDA SCS Technical Release 55. The design storms are based on a Type II, synthetic 24-hour rainfall distribution curve as shown in Appendix A. Table 2 summarizes rainfall for these storm frequencies.

Table 2 Summary of Design Storm Rainfall	
Storm Recurrence Interval	**Rainfall Quantity (inches)**
1-year	2.3
5-year	3.4
10-Year	3.9
25-year	4.6
50-year	4.9

4.1.4 Hydrologic & Hydraulic Modeling – Primary and Secondary Study Areas

The hydraulic model for the primary and secondary study areas were developed using PondPack from Haestad Methods. A link and node type hydraulic model was constructed for the entire study area based on the existing conditions within the watershed and the existing stormwater infrastructure. The models generate a runoff hydrograph for each sub-catchment based on the TR-55 method as described below.

The hydrographs from the individual sub-catchments are applied to nodes where they combine with runoff hydrographs from other sub-catchments, reach routes or detention areas. The hydrographs are routed through modeled channel and ditch sections (reach routes) using the Modified Pulse Method which uses channel geometry and characteristic information to determine channel capacity and the affect of attenuation (reduction of peak flow rate) on the runoff hydrographs. Reach routing allows the model to transform a sub-catchment runoff hydrograph from its initial point of discharge in a system through the system to a downstream location. At the downstream location the initial hydrograph has combined with other hydrographs and traveled through multiple channel reaches, all with differing characteristics. As the hydrograph moves through the system it undergoes changes in shape (often a reduction in individual peak flow) due to the effects of storage associated with conveying channels.

The model determines the peak runoff through culverts using culvert hydraulic calculation methods which use culvert slope, length, geometry, and losses associated with the inlet and outlet configurations to determine pipe capacity. This calculation method also accounts for the variations in culvert capacity based on inlet and outlet control conditions (i.e., surcharge at the inlet or full pipe flow with free discharge at the outlet). The culverts for the Ludlowville area are inlet controlled since the grades are steep throughout the project area, which provides no opportunity for water to pond at the outlet. The culvert hydraulics were calibrated with a separate HY-8 model.

The model determines peak runoff through the closed drainage systems by modeling the drainage structures as small ponds to account for storage within and around the catch basins when the systems surcharge. Attenuation of flow through catch basins is calculated by the model based on the volume of the catch basin and the capacity of outlet structures. Once the incoming flow rate to the catch basin exceeds the outlet capacity, stormwater is stored in the structure and the water level rises. The closed drainage system overtops once the water level exceeds the rim elevation of the structure. The closed drainage hydraulics were calibrated with a separate StormCAD model.

Flow across roadways at culvert crossings and overtopping of drainage structures were calculated using suppressed weir calculations to approximate the variable conditions observed in the field. Key channel and culvert elevations were obtained through an elevation survey and one foot digital LIDAR contours provided by Tompkins County.

Table 3 summarizes the peak runoff rates that reach the design points at the downstream end of each drainage basin during each of the five (5) design storms. The runoff rates include the stormwater surcharge that may enter the system from overtopping upstream design points. Relevant PondPack model input/output is included in Appendix A.

Table 3 – Summary of Peak Runoff Rates, PondPack Model

Storm Recurrence Interval	Basin A (cfs) [1]	Basin B (cfs) [2]	Basin C (cfs) [3]	Basin D (cfs) [4]
1-year	17	38	5	9
5-year	37	107	20	21
10-year	47	141	51	27
25-year	62	197	100	37
50-year	68	237	131	41

[1] The peak runoff rate is determined at the 24" steel culvert crossing Lansingville Road.
[2] The peak runoff rate is determined at the 57" x 38" corrugated metal pipe-arch crossing Ludlowville Road.
[3] The peak runoff rate is determined at the 36" HDPE crossing Salmon Creek Road.
[4] The peak runoff rate is determined at the 36" CMP crossing Salmon Creek Road.

4.2 Modeling Results and Observations

The modeling results for the primary and secondary study areas are summarized below:

4.2.1 *Basin A*

4.2.1.1 Roadside Ditches

The ditches along the west and east side of Lansingville Road are in fair condition and not limiting factors in the drainage basin. The PondPack model indicates that the ditches along the west side of the roadway provide sufficient capacity up to the 50-year storm event. The ditches along the east side of the roadway were not included in the model, since if they were to overtop, the stormwater would be lost into the agricultural fields and out of the drainage basin with no effect to residences.

4.2.1.2 Steel Cross-Culverts

A series of five 24" steel cross-culverts carry runoff from the west side of Lansingville Road to the roadside ditch on the east side of the roadway. The flow is then carried southward to the outlet of Clvrt 5 where it is diverted along a hedgerow and out of the drainage basin. The results from the PondPack model indicate that the four northernmost cross-culverts (Clvrt 1 thru Clvrt 4 on Figure 2) convey up to the 50-year storm event without overtopping. Stormwater from the sub-catchments along the west side of Lansingville Road down to Clvrt 4 is carried to the ditch on the east side of the road and out of the watershed study area through the "hedgerow stream".

According to the PondPack model, the southernmost 24" steel cross-culvert at the head of the hedgerow stream (Clvrt 5) becomes surcharged during significant runoff events. Flows carried by the cross-culvert are discharged into the hedgerow stream and removed from Basin A. Excess flows are conveyed in the roadside ditch on the west side of Lansingville Road and are routed into Basin B drainage conveyance system and are ultimately routed through the Ludlowville Road cross culvert. Previous studies did not account for this excess flow to the Ludlowville Road culvert. The condition is summarized in the Table 4.

Table 4 Summary of PondPack Modeling, Lansingville Road Clvrt 5 (Flow to Hedgerow Stream) Capacity			
Storm Recurrence Interval	**Peak Runoff Rate to Clvrt 5 (Inlet, cfs)**	**Peak Runoff Rate Passed by Clvrt 5 (Outlet, cfs)**	**Excess Peak Flows to Ridge Road System (cfs)**
1-Year	17	17	0
5-Year	37	26	11
10-Year	47	27	20
25-Year	62	28	34
50-Year	68	28	40

As shown in the table above, it is estimated that the 24" steel cross-culvert can convey the 1-year runoff without surcharge (i.e., full pipe flow at culvert inlet). Further, the maximum flow conveyed by the culvert to the channel east of Lansingville Road ranges between approximately 26 to 28 cfs for the 5- and 50-year runoff events, respectively. The culvert becomes surcharged during the peak of the 5-year runoff event. Once the backwater builds to an elevation of 18" over the top of the inlet pipe, the flow begins to overtop the earthen berm at the inlet and continue along the west side of the road. This condition creates an additional surcharge loading to Basin B and C as outlined above. The PondPack results were confirmed using the HY-8 model capacity curve and the results are included in Appendix B.

4.2.2 *Basin B*

4.2.2.1 Driveway Culverts

Two 24" driveway culverts on the east side of Lansingville Road near the intersection of Ridge Road were included in the PondPack model. It was reported that debris blocked one of the driveway pipes in the past and caused localized flooding of the area. The results of the model indicate that the driveway culverts sufficiently convey the 25-year storm event. The driveway pipes are overtopped at the 50-year storm event which causes runoff to flow over the ditch banks and through private property. It is concluded that the driveway pipes are adequately sized and that the previous flood event was caused by the blockage of the culvert pipe.

4.2.2.2 Closed Drainage System

Basin B consists of two closed drainage systems, one on each the north and south sides of the road. The closed drainage system on the north side of the road is approximately 560 feet long and consists of four catch basins and 36" diameter pipes. The peak runoff rates at the inlet of the closed drainage system include the surcharge from the overflow of Basin A (as described in section 4.2.1.2) along with stormwater from upstream subareas. The results are summarized in Table 5.

Table 5
Summary of PondPack Modeling, North Closed Drainage System (Ridge Road MH-3) Capacity

Storm Recurrence Interval	Peak Runoff Rate to System (Inlet, cfs)	Peak Runoff Rate Passed by System (Outlet, cfs)
1-Year	31	31
5-Year	94	94
10-Year	131	104
25-Year	185	107
50-Year	248	109

As shown in the table above, it is estimated that the closed drainage system can convey the 5-year storm event without surcharge. The culvert becomes surcharged during the 10-year storm event where the water elevation in the drainage structure exceeds the rim elevation. Once this condition is reached, the stormwater is directed along the north shoulder of Ridge Road to the open ditch at the outlet of the closed drainage system (RR Swale1 from Figure 2). Even though the closed drainage system is overtopped during significant storm events, the stormwater remains within the highway boundary and does not impact adjacent private properties. The PondPack results were confirmed using the StormCAD software.

The closed drainage system on the south side of the road is approximately 540 feet long and consists of four catch basins and 36" HDPE pipe. This system collects runoff from the sub-catchments south of Ridge Road and carries it to the north side to RR Swale 2. The results from the PondPack model show that the closed drainage system south of Ridge Road is adequately sized to convey the 50-year storm event.

4.2.2.3 <u>Roadside Ditches</u>

The primary conveyance ditch within Basin B is the earth ditch from the outlet of the closed drainage system on the north side of Ridge Road to the invert of the 57" x 38" pipe-arch crossing Ludlowville Road (RR Swale 1 and RR Swale 2 in Figure 2). The outlets of the two closed drainage systems within the drainage basin combine at the roadside ditch which then carries the flow to the pipe-arch. The PondPack model indicates that the ditch provides sufficient capacity to convey the 50-year storm event.

The other ditches within the drainage basin are along the north side of Ridge Road. These ditches carry runoff from the sub-catchments to the catch basins and also divert overflow to the downstream ditch when the closed drainage system is overtopped. The model shows that these ditches are also sufficient to convey the 50-year storm event.

4.2.2.4 <u>Culverts</u>

The primary design point in the Ridge Road drainage basin is the 57" x 38" corrugated metal pipe-arch crossing Ludlowville Road (Clvrt 12 in Figure 2). This culvert has overtopped in the past and sent overflow down the north side of Ludlowville Road. The peak runoff rates at the inlet of the culvert include the surcharge from the overflow of Basin A as described in section 4.2.1.2. The results from the PondPack model are summarized in Table 6.

Table 6 Summary of PondPack Modeling, Ludlowville Road Clvrt 12 Capacity			
Storm Recurrence Interval	**Peak Runoff Rate to Clvrt 12 (Inlet, cfs)**	**Peak Runoff Rate Passed by Clvrt 12 (Outlet, cfs)**	**Overflow to North Side of Ludlowville Road (cfs)**
1-Year	38	38	0
5-Year	107	84	21
10-Year	141	88	52
25-Year	197	93	103
50-Year	237	96	138

As shown in the table above, it is estimated that existing pipe-arch sufficiently conveys the 1-year storm event, but overtops during the peak of the 5-year storm event. The maximum flow conveyed by the culvert to the south side of Ludlowville Road ranges between 84 and 96 cfs for the 5- and 50- year runoff events, respectively. These results of the culvert analysis were confirmed using the HY-8 model capacity curve. When the peak runoff rate exceeds the capacity of the culvert, the backwater elevation builds until overtopping the stream bank and sending a surcharge flow down the north side of Ludlowville Road into the Ludlowville Road drainage basin.

The outlet velocity of the culvert was also determined at Clvrt 12 by the HY-8 model which ranged from 11.9 ft/s for the 1-year storm to 15.6 ft/s at the capacity of the structure. The large computed velocities at the outlet substantiate the significant amount of erosion of the unprotected stream channel downstream. Additional erosion of this stream section is anticipated without future corrective measures.

4.2.3 *Basin C*

4.2.3.1 Closed Drainage System

Basin C consists of two closed drainage systems on the north side of the road between the Ludlowville Road culvert and Salmon Creek Road. The peak runoff rates at the inlet of the closed drainage system include the surcharge from the overflow of Basins A and B. The results from the PondPack model are summarized in Tables 7 and 8.

Table 7
Summary of PondPack Modeling, Capacity of Western Segment of Ludlowville Road Closed Drainage System

Storm Recurrence Interval	Peak Runoff Rate From Basin C (Inlet, cfs)	Peak Runoff Rate from Overflow (Inlet, cfs)	Peak Runoff Rate Passed by System (Outlet, cfs)	Excess Runoff (cfs)
1-Year	0.3	0	0.3	0
5-Year	0.7	21	19	2.7
10-Year	0.8	52	25	27.8
25-Year	1.1	103	27	77.1
50-Year	1.2	138	28	111.2

Table 8
Summary of PondPack Modeling, Capacity of Eastern Segment of Ludlowville Road Closed Drainage System

Storm Recurrence Interval	Peak Runoff Rate From Basin C (Inlet, cfs)	Peak Runoff Rate from Overflow (Inlet, cfs)	Peak Runoff Rate Passed by System (Outlet, cfs)	Excess Runoff (cfs)
1-Year	0.7	0	0.7	0
5-Year	1.6	21	18	4.6
10-Year	2.0	52	28	26.0
25-Year	2.6	103	31	74.6
50-Year	2.9	138	32	108.9

As shown in the tables above, the PondPack model indicates that the existing closed drainage system is sufficient when only handling runoff from Basin C subareas. The capacity of the closed drainage system is exceeded when the Ludlowville Road cross-culvert is overtopped and the surcharge flow is added to the system during the peak of the 5-year storm event. When the closed drainage system overtops, the additional flow is directed along the north side of Ludlowville Road and onto private properties.

4.2.3.2 Roadside Ditches

Three open channels, including Ldlwvl 1 thru Ldlwvl 3 from Figure 2, are located within Basin C on the north side of Ludlowville Road. The ditches primary function is to carry stormwater down the north side of Ludlowville Road to the culvert crossing Salmon Creek Road. The PondPack model shows that the ditches are sufficient to convey the 50-year storm event. However, as outlined above, the intermixed closed drainage system will not convey flows including and in excess of the 5-year storm event. The excess flow from the closed drainage system is routed onto adjacent private properties.

4.2.3.3 Culverts

The primary design point in Basin C is the 36" HDPE pipe crossing Salmon Creek Road (Clvrt 18 in Figure 2). This culvert has overtopped in the past and sent overflow onto private property. The peak runoff rates at the inlet of the culvert include the surcharge from the overflows of Basins A and B as described in sections 4.2.1.2 and 4.2.2.4, respectively. The results from the PondPack model are summarized in Table 9.

Table 9
Summary of PondPack Modeling, Salmon Creek Road
Clvrt 18 Capacity

Storm Recurrence Interval	Peak Runoff Rate To Culvert (Inlet, cfs)	Peak Runoff Rate Passed by Culvert (Outlet, cfs)	Overflow (cfs)
1-Year	5	5	0
5-Year	20	19	0
10-Year	51	36	14
25-Year	100	38	60
50-Year	131	39	91

As shown in the table above, it is estimated that existing 36" culvert pipe sufficiently conveys the 5-year storm event, but overtops during the peak of the 10-year storm event. The maximum flow conveyed by the culvert to the east side of Salmon Creek Road ranges between 36 and 39 cfs for the 10- and 50- year runoff events, respectively. When the peak runoff rate exceeds the capacity of the culvert, the backwater elevation builds until overtopping the channel and sends stormwater towards adjacent private property.

4.2.4 *Basin D*

4.2.4.1 <u>Culverts</u>

The primary design point in Basin D is the 36" corrugated metal pipe crossing Salmon Creek Road (Salmon Crk Clvrt in Figure 2). The peak runoff rates at the inlet of the culvert are generated from one sub-catchment that extends from Salmon

Creek Road to Lansingville Road. There is no potential for surcharge loading in Basin D due to the absence of upstream drainage structures that could overtop. The results from the PondPack model are summarized in Table 10.

Table 10
Summary of PondPack Modeling, Salmon Creek Culvert Capacity

Storm Recurrence Interval	Peak Runoff Rate To Culvert (Inlet, cfs)	Peak Runoff Rate Passed by Culvert (Outlet, cfs)	Overflow (cfs)
1-Year	9	9	0
5-Year	21	21	0
10-Year	27	27	0
25-Year	37	35	2
50-Year	41	36	5

As shown in the table above, it is estimated that existing 36" culvert pipe sufficiently conveys the 10-year storm event, but overtops during the peak of the 25-year storm event. The maximum flow conveyed by the culvert to the east side of Salmon Creek Road is approximately 35 cfs. When the peak runoff rate exceeds the capacity of the culvert, the backwater elevation builds onto private property and into the driveway of 34 Salmon Creek Road. The velocity of the runoff that travels parallel to the driveway is significant due to the volume of water and the slope of the drainage basin. The modeling substantiates the issues that the adjacent resident has reported regarding their driveway washing out.

4.3 Design Storm Summary

The following shall serve to generally summarize stormwater flow routing within the primary and secondary study areas for the 1-, 5-, 10-, 25- and 50-year design storms. Descriptions of flooding characteristics are based on the hydrographs and PondPack modeling of Appendix A, discussions with area residents, and field observations. The summaries are based on the assumptions that all channels, culverts and closed drainage systems are maintained free of obstacles.

1-Year Storm:

- The culverts and closed drainage systems within both the primary and secondary study areas convey all modeled runoff through the structures.

5-Year Storm:

- Basin A - The culvert at the downstream end of the drainage basin (Clvrt 5) overtops, sending 11 cfs to Basin B.
- Basin B - The closed drainage system along the north side of Ridge Road conveys all of the flow to the culvert at the downstream end of Basin B. The 57" x 38" pipe-arch crossing Ludlowville Road (Clvrt 12) overtops, sending 22 cfs to Basin C.
- Basin C - The closed drainage system along the north side of Ludlowville Road overtops, but the culvert at the downstream end of the basin (Clvrt 18) conveys all of the runoff through the structure.

- Basin D - The culvert at the downstream end of the drainage basin conveys all of the stormwater runoff.

10-Year Storm:

- Basin A - The culvert at the downstream end of the drainage basin (Clvrt 5) overtops, sending 20 cfs to Basin B.
- Basin B - The closed drainage system along the north side of Ridge Road is overwhelmed, sending 27 cfs along the north drainage ditch/shoulder down to the culvert at the downstream end of the basin. The 57" x 38" pipe-arch crossing Ludlowville Road overtops (Clvrt 12), sending 53 cfs to Basin C.
- Basin C - The closed drainage system along the north side of Ludlowville Road overtops as well as the culvert at the downstream end of the drainage basin (Clvrt 18). The structure is overwhelmed by 14 cfs.
- Basin D - The culvert at the downstream end of the drainage basin conveys all of the stormwater runoff

25-Year Storm:

- Basin A - The culvert at the downstream end of the drainage basin (Clvrt 5) overtops, sending 34 cfs to Basin B.
- Basin B - The closed drainage system along the north side of Ridge Road is overwhelmed, sending 78 cfs along the north drainage ditch/shoulder down to the culvert at the downstream end of the basin. The 57" x 38" pipe-arch crossing Ludlowville Road (Clvrt 12) overtops, sending 104 cfs to Basin C.

- Basin C - The closed drainage system along the north side of Ludlowville Road overtops as well as the culvert at the downstream of the drainage basin (Clvrt 18). The structure is overwhelmed by 62 cfs.

- Basin D - The culvert at the downstream end of the drainage basin overtops, sending 2 cfs onto private property and onto Salmon Creek Road.

50-Year Storm:

- Basin A - The culvert at the downstream end of the drainage basin (Clvrt 5) overtops, sending 40 cfs to Basin B.

- Basin B - The closed drainage system along the north side of Ridge Road is overwhelmed, sending 139 cfs along the north drainage ditch/shoulder down to the culvert at the downstream end of the basin. The 57" x 38" pipe-arch crossing Ludlowville Road (Clvrt 12) overtops, sending 140 cfs to Basin C.

- Basin C - The closed drainage system along the north side of Ludlowville Road overtops as well as the culvert at the downstream end of the drainage basin (Clvrt 18). The structure is overwhelmed by 92 cfs.

- Basin D - The culvert at the downstream end of the drainage basin overtops, sending 5 cfs onto private property and onto Salmon Creek Road.

The following table identifies structures that are unable to design storm flow rates, along with discharge locations of excess flows.

Table 11 – Summary of Drainage StructureLimitations		
Design Storm	**Structure**	**Excess Flow Routed to:**
1	All modeled structures pass design storm flows	None
5	Basin A Clvrt 5 Basin B Clvrt 12	Basin B Drainage System Basin C Drainage System
10	Basin A Clvrt 5 Basin B Clvrt 12 Basin C Clvrt 18	Basin B Drainage System Basin C Drainage System Private Properties
25	Basin A Clvrt 5 Basin B Clvrt 12 Basin C Clvrt 18 Basin D Salmon Creek Rd Clvrt	Basin B Drainage System Basin C Drainage System Private Properties Private Properties
50	Same as 25-year storm	Same as 25-year storm

The locations of structure overtopping/surcharging and associated design storms are depicted on Figure 4.

5.0 Stormwater Infrastructure Improvement Opportunities

5.1 Improvement Opportunities

This study has examined in detail and determined the limiting components of the existing stormwater system along Lansingville, Ridge, Ludlowville and Salmon Creek Roads and has provided focus points for areas that may warrant improvements. The existing stormwater system is complex with many drainage structures connected in series. The overtopping of one upstream structure can have cumulative effects on downstream structures.

The peak runoff rate exceeding the capacity of the culverts at the downstream end of Basins A and B is a major contributor to the drainage issues in the area. Excess flows from these areas have caused downgradient issues, specifically at the Ludlowville Road culvert. This culvert has overtopped and caused several localized drainage issues along Ludlowville Road.

This study examined the limitations of the existing drainage system. Further evaluation of potential improvements is the next phase of the study. Several concepts may be considered to improve the existing stormwater system including:

- Increasing the capacity of Clvrt 5 (at the downstream end of Basin A) to eliminate some of the surcharge flow to Ridge Road and ultimately to Ludlowville Road. This may require improvements to the downstream channel on private property and require easements.

- Modifying existing drainage patterns to divert stormwater runoff away from Clvrt 12 (Ludlowville Road) and convey excess flows along Ridge Road to follow the "natural" drainage pathways.
- Constructing detention basin(s) to store runoff and regulate flows through the watershed.
- Channel improvements such as stabilization and check dams.
- Evaluation of above alternatives on the impacts of erosive velocities within Salmon Creek and its tributary.

Further discussion and detailed evaluation of these alternatives, and potentially other alternatives, along with supporting documentation will be provided in the next phase of the study.

Written comments regarding the subject of this report should be directed to:

Scott Doyle, AICP, Senior Planner
Tompkins County Department of Planning
121 East Court Street
Ithaca, New York 14850