ENGINEERING REPORT

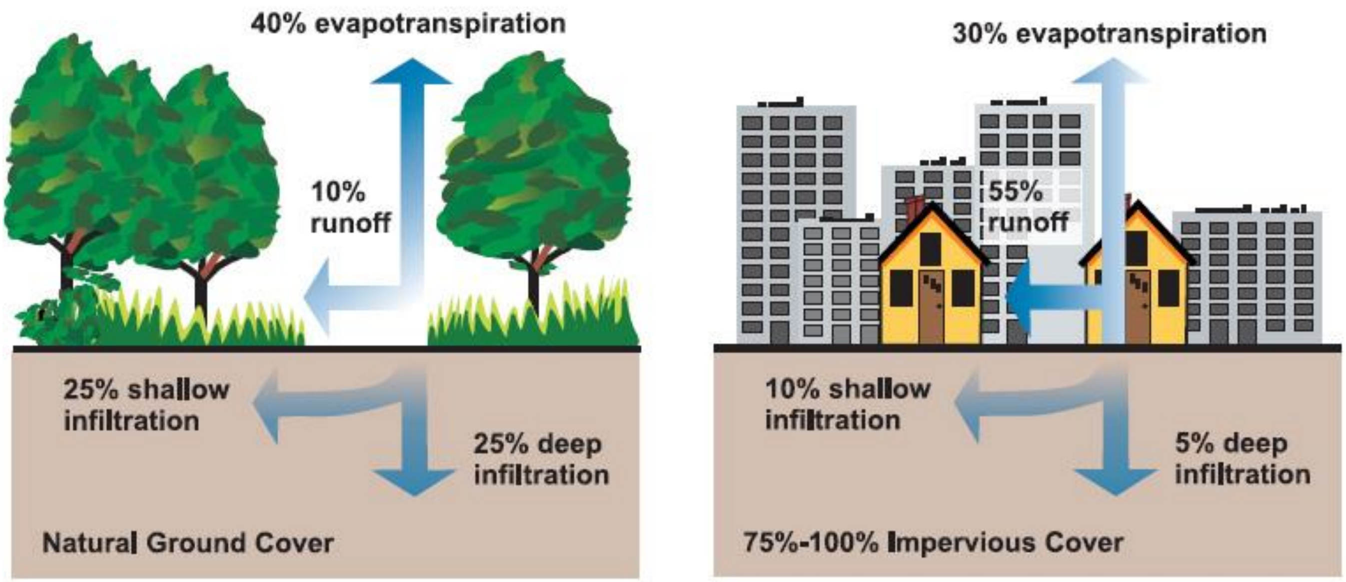


Illustration Source: EPA

January 2022

Calypso Storm Drainage System

The purpose of this report is to assess the condition and adequacy of the Town's existing drainage system and to recommend general improvements for consideration by the Town. The report also proposes a plan for devel.oping a priority system for adding the recommended improvements, offers recommendations for the management and maintenance of the Town's stormwater drainage system, and proposes for consideration and adoption a Town Stormwater Ordinance.

Appian Consulting Engineers, PA
PO Box 7966
Rocky Mount, NC 27804
252.972.7703
BLN: C0562
www.appianengineers.com

1/7/22

NORTH CAROLINA PROFESSIONAL SEAL 8421 ENGINEER BOBBY L. JOYNER

TABLE OF CONTENTS

CALYPSO STORM DRAINAGE SYSTEM
ENGINEERING REPORT

Engineering Report

CALYPSO STORM DRAINAGE SYSTEM

SCOPE OF REPORT | PART 1

The scope of our work, as introduced in this report, covered field data collection, base mapping, hydrologic and hydraulic analysis, and the development of a model stormwater ordinance for the Town of Calypso. Since all roadway drainage outside the corporate limits up to the ETJ comes under the jurisdiction of the NCDOT, the bulk of our detail investigation and analysis covered primarily the area within the corporate limits of the Town of Calypso; the area of Town maintenance responsibility. See Exhibit A-2 in the Appendix for map of NCDOT maintained streets within the Corporate Limits of the Town Calypso.

To carry out our objectives, we began our investigation by first meeting with both Town staff and the public, at a public meeting, to locate and document specific areas of drainage concern. With that information, we broke into two field crews to document and locate all readily accessible existing drainage pipe and drainage structures. Those areas identified in the field were then flown by drone to develop an aerial data base and the pipe inverts, as well as some drainage outfalls, surveyed by GPS. From the field work, we developed a map base to aid in hydrological and hydraulic analysis of the Town's existing drainage system. Subsequently, drainage base mapping and data spreadsheets were developed that both describe the existing system and provided general recommendations for upgrades to the system to improve system efficiency and eliminate point flooding problems. Where additional pipe capacity is needed, new pipe sizes were recommended based on the following assumptions:

1. If the existing pipe can be utilized and if it is in good condition, it will remain in service.
2. Not all buried or partially buried driveway pipe was noted in the report to be replaced as pipe can either be modified or replaced at time street ditches are regraded.
3. The new pipe will be laid at approximately the same grade as the existing pipe or at a slope that allows the storm water runoff to have a minimum velocity of 2 feet per second; where possible. Two-feet per second is the "self-cleaning" velocity typically used in stormwater conduit design (with the pipe flowing full).
4. The proposed and existing pipes are not surcharged at the influent end or subject to discharge control conditions at the effluent end.

A list of specific problem areas along with general recommendations for improvement are provided in this report.

To minimize the negative impact of future development on the Town's existing drainage infrastructure, we have provided a stormwater ordinance for the Town's consideration and adoption. This ordinance as recommended would provide drainage guidelines for future development that will help to prevent negative impacts to the existing drainage system as well as ensure that future development will adequately address drainage on site; not sending it to downstream property owners.

DATA COLLECTION

All of the Town's streets are shoulder section streets (i.e., typically referred to as "strip paved streets"). Curb and gutter streets within the Town's corporate limits exist primarily on NCDOT maintained system streets.
All visible pipe, buried pipe (reasonably located by probe or by other detectable means), catch basins, junction boxes, etc., within the corporate limits of the Town of Calypso and up to the ETJ were field surveyed (obtaining x,y,z coordinates location and determination of pipe slope). Only pipe ends that could not be located or were within inaccessible concrete structures were not surveyed. The top of the pipe ends were painted so that the pipe ends could be visually detected on scaled drone aerial imagery. Both the painted pipe ends captured by

aerial imagery and the GPS x and y coordinates of pipe ends were found to coincide. Our GPS coordinates of pipe ends landed directly on top of the painted pipe ends shown in the aerial imagery. Pipe size, diameter, and the condition of the pipe were also noted in the field notes.

Due to a lack of routine roadway ditch maintenance, a very large number of driveway pipe on Town maintained streets had one or both ends buried. Similarly, a significant number of pipe ends were also found to be buried on some on the NCDOT maintained streets within the study area. A list of inaccessible areas and buried pipe ends (requiring DOT assistance on State maintained Roads), was provided to the Maintenance Department. As of this date, none have been uncovered/exposed. Accordingly, for the study, assumptions as to grade were made based on field observations and engineering judgement.

Pipe/Structures on NCDOT Roads: The NCDOT secondary and primary roadway facilities surveyed and evaluated in this report are those that were deemed to possibly have an impact or affect upon the Town's storm drainage facilities. Recommendations for pipe sizes on NCDOT system roadways/highways, where deemed necessary, are shown in the report Data Tables. However, since these specific systems are maintained exclusively by the NCDOT, any improvements that may be desired by the Town based on impact to the Town will require concurrent approval for an upgrade or replacement. Accordingly, a more detailed hydrological and hydraulic design will be required for verification of the pipe structure using a FHWA and/or NCDOT culvert design methodology. Refer to the latest revision of the NCDOT *Guidance in the methods, procedures, policies, and criteria for Drainage Studies and Hydraulic Design* manual; link below.
https://connect.ncdot.gov/resources/hydro/Pages/Guidelines-Drainage-Studies.aspx

Area Along US-117 By Pass: The storm drainage facilities shown along the new US 117 By Pass were taken from NCDOT construction plans provided by the District Engineers' office. Due to the sparseness of the area and inexact topographical contour mapping, every culvert, and the field ditches at principal points east of US 117 By Pass was field surveyed to determine the relative direction of stormwater flow. The area in question and topographically mapped is bounded by N. Fourth Street on the east, US 117 By Pass on the west, N. Trade Street on the south, and the Town's northern corporate limit line on the north. Some of the pipe(s) shown on NCDOT's US 117 By Pass drawings were found not to exist (as forewarned by the District Engineer's office). It appeared to us that some pipe had likley been relocated by a field change at the time of construction. No as-builts of this area were found by the District Engineer's office of US 117 By Pass in this vicinity.

It is noteworthy that some of the NCDOT culverts in this area were found to be laid on reverse grade when it was clear, after broadly topographically mapping the area, that the predominate tributary flow was from east to west (towards US 117 By Pass). Furthermore, some pipe along and below old US 117 is thought to have existed prior to the construction of US 117 By Pass and was, therefore, not replaced.

DOT Data Collection Assistance:

We were unsuccessful in coordinating the NCDOT's assistance in opening/uncovering a few of the junction boxes or buried/missing pipe ends on their system street. However, considering that all driveway and cross-drain pipes on DOT roads are solely the responsibility of the NCDOT, other than the collective runoff from a series of driveway tile leading to a stream or pipe crossing of Town importance, no detailed drainage analysis was performed on such systems parallel to or crossing a DOT maintained street/roadway. When it comes to maintenance of such streets, the Town can report problems to the DOT or otherwise request or propose improvements where such improvements would aid or improve the Town's drainage infrastructure.

LIMITATIONS OF PIPE EVALUATION (HYDRAULIC ANALYSIS)

This study uses the Manning equation to compute full flow for both existing pipe and proposed pipe replacements. The flows provided are "preliminary" and are deemed sufficient at this level of evaluation to find weaknesses in the system and to estimate pipe sizes for future replacement. The limitation of the Manning equation is that it assumes full flow but does not take into account the impact of elements that can marginally either increase or decrease pipe flow capacity; elements such as: headwater and tailwater depth, pipe length, losses due to the pipe inlet or the pipe outlet condition, losses at pipe junctions and through structures (i.e., catch basins), difference in pipe-in/pipe-out grades, etc. Inlet Control tends to govern pipe capacity for short pipe segments whereas Outlet Control tends to govern pipe capacity for longer pipe segments (retarding flow due to pipe friction losses). That type of advanced level of hydraulic analysis would typically be engaged with any future design in determining the size and capacity of a new pipe or pipe system; or the replacement of same.

IDENTIFIED AREAS OF STORMWATER CONCERN

Prior to beginning the Town-wide study, a community public meeting was held on November 10, 2020, at the Calypso Fire Department. The purpose of the initial community public meeting was to gather input from the public regarding specific areas of stormwater concern. The primary areas of stormwater concern noted by those citizens in attendance, with input from some of the Town officials as well, are noted below. See map of Town showing *"Location of Stormwater Concern"* (map located at end of this section).

1. **Significant high water/flooding in vicinity of NW Center at Warren Street**:
   Observations:
   a. Absence of a localized drainage interception system on NW Center St. sufficient to receive stormwater runoff. The collection system that exists close to this area (between north-south between N. Fourth and NE Center St.) is significantly undersized and deficient in capacity.
   b. See item 2; next, as it relates to this flooding problem.

2. **Localized flooding along a ditch parallel to and situated between NW Center St. and N. Fourth St; primarily between Carolina St. and W. Church St.**:
   Observations/Considerations:
   a. The existing drainage ditches and pipe are grossly undersized. Some of the existing pipe create choke points, clogging issues, and some pipe has been laid on reverse grade. See ditch profile in Appendix A-7.
   b. Downstream pipes receiving this runoff are also undersized.
   c. A drainage system pinch point is located at the pipe crossing below the railroad. The rail pipe crossing is located approximately midway between E. Church and E. Cameron. The pipe begins as a 24" diameter steel pipe on the west side and transitions to an 18" diameter concrete pipe on the east side. This line is also laid on an opposing grade (opposing the flow direction).
   Tributary drainage area to the pipe inlet (west side) is 29.35 acres. The pipe size should be a minimum of either a 42" diameter reinforced concrete pipe (RCP) or twin 30" RCP's.
   d. Future Improvements Considerations:
      i. The entire deficient drainage ditch/pipe system both upstream and downstream of the rail crossing needs to be rehabilitated/upgraded as part of a single storm drainage improvement project as funds permit. Such a project would involve regrading ditches, pipe replacement/upgrade, and permanent easement acquisition. If funds permit only partial upgrade, work should progress from the low end (S. First St.) and move upstream. Otherwise, upgrading some point upstream could potentially burden or cause localized flooding conditions at corresponding downstream properties. Existing pipe and ditch restrictions have, in effect, created isolated detention ponds that provide some relief to downstream properties but at the expense of impacting some upstream properties.
      ii. Prior to making any isolated improvements to the drainage corridor from W. Carolina St. to S. First St., a drainage study should be performed to determine:
         1. If improving the current route from W. Carolina St. to S. First St. is the most economical and practical route, or
         2. If there is an alternate more economical route(s) to convey the tributary drainage from west of the railroad tracks to the south toward Goshen Swamp. Doing so will relieve a substantial burden along the drainage corridor between SE Center St. and S. First St.

That determination is beyond the scope of this project as it would require more extensive surveying (due to the relative flatness of Calypso), a more detailed drainage analysis considering one or more possible alternate route options, and preliminary design.

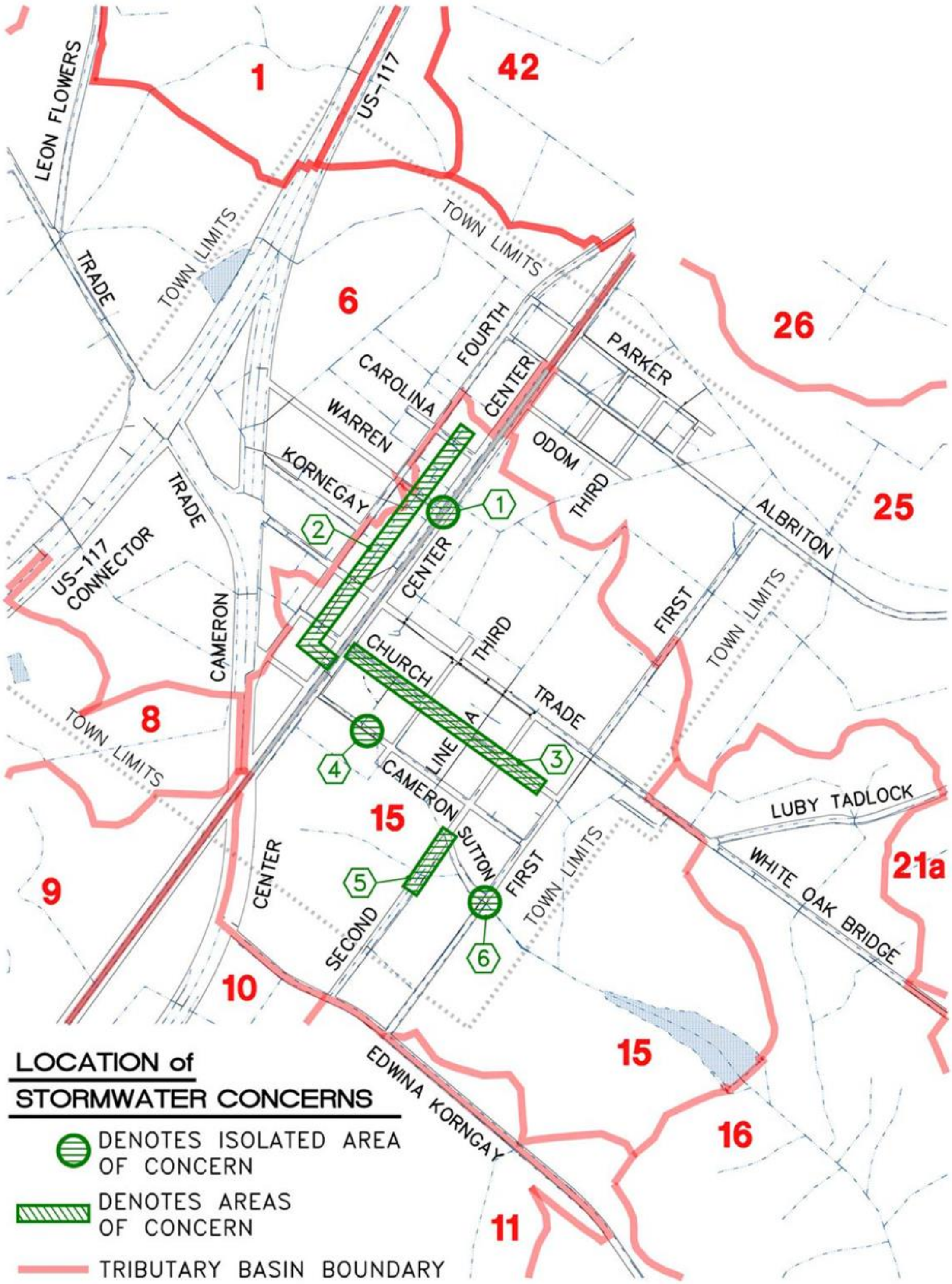
3. **Localized ponding of runoff along E. Church St. from SE Center to the Line "A" Crossing (existing 36" corrugated pipe crossing)**:
   Observations/Considerations:
   a. Absence of road ditches and a subsurface drainage system to collect and transport runoff east to Line "A" cross drainage.
   b. What driveway piping was found along E. Church St. for the most part was either partially or completed buried. Some driveway piping is 8" corrugate plastic pipe. Also, some pipe ends could not be found/located.
      Note: Small diameter pipe (pipe less than 15 inches in diameter,) typically has a short conveyance life and, as such, tends to fill in with silt. Plastic pipe tends to collapse/crush when not properly placed.
   c. A new drainage system is needed from SE Center St. to First St.; both ends of E. Church St. tying to cross-drainage "Line A" (an existing 36" corrugated pipe).
   d. Concurrent with and/or after a new drainage collection system is installed, road ditch reshaping/grading (with replacement of existing driveway pipe [or new pipe]; on grade) will be needed.

4. **On E. Church St., approximately 300 feet west of S. Third St.**: An existing garage is located on top of an existing 15" concrete drainage pipe (pipe #15D10-2). The pipe drains to south.
   Observations/Considerations:
   a. Garage structure has been constructed on top of an existing 15" concrete pipe.
   b. The minimum recommended pipe size for this reach of pipe is a 24" reinforced concrete pipe. If it is determined that the line needs to be upgraded (as part of a street drainage system improvement [see item 3, above], we recommend *realignment* of the existing lateral line; locating the line to a side lot line. When and if that is performed, the existing line beneath the garage can be grouted with lean concrete to prevent silt infiltration and development of sink holes above the pipe (to avoid damaging the garage).
   c. If the line is realigned, a permanent easement should be acquired for line maintenance purposes.

5. **South Second Street (Pipe No. 15D51-1)**:
   Observations/Considerations:
   a. In the vicinity of this pipe, there is a depression/low area that tends to accumulate runoff. Runoff tends to fill in the road ditches until sufficiently high enough for runoff to flow to the north to pipe 15D49-1 (a 30" RCP). The tributary drainage area is primarily agricultural field consisting of approximately 26 acres.
   b. To mitigate the problem, either a pipe or open ditch can be run parallel to the roadway; extending from Pipe 15D51-1 north to pipe 15D49-1; a distance of approximately 700 ft. There is sufficient grade.
6. **S. First Street Ditch Crossing; floodwater overtopping S. First St.**: The existing drainage outfall ditch just upstream of S. First St. and running parallel to Cameron Street is the downstream end of the drainage system addressed in item 2, above. This road crossing is the last road crossing prior to conveying drainage to the Calypso Club Pond. See Appendix A-7 for profile of ditch alignment leading to pond.
   Observations/Considerations:
   a. The existing pipe (15D82-1) beneath S. First Street is a 54" corrugated metal pipe; not as efficient in flow capacity as would be a smooth-walled pipe.
   b. The existing 54" CMP culvert is undersized; carrying approximately 55% of the required Q_{10} flow (inlet control governing). As such, roadway overtopping can be an issue with high intensity storm events exceeding the Q_{10} event. Typically, secondary road crossings are designed for a Q_{25} storm event with the balance of flow exceeding the culvert capacity permitted to over top the street provided the

street at the crossing is stable and properly shaped to accommodate the overtopping flow. Obviously, any pipe crossing can be increased in size to reduce the frequency of road overtopping.

c. Tributary drainage area to this pipe crossing at S. First St. is 186.7 acres producing an estimated Q_{10} flow of 245 cfs and an estimate Q_{25} flow of 290 cfs. The recommended minimum crossing pipe here should be either twin 60" diameter reinforced concrete pipes or triple 48" diameter reinforced concrete pipe (to replace the existing single 54" CMP).



UNFAVORABLE PRACTICES AND CONDITIONS IDENTIFIED

Excluding apparent pipe size deficiencies, we observed a number of storm drainage issues and/or unfavorable practices occurring within the Town of Calypso's drainage system. The most apparent are noted below.

1. **Driveway and lateral piped lines installed with a mix of pipe sizes and/or pipe materials**: It was common to find a single drainage conduit comprised of two or more pipe diameters or made up of two or more pipe materials (e.g., a single line made up of both 12" CPP and 15" RCP). We found 20 to 30 of these type systems throughout the Town. One such system is located beneath the railroad and is a mix of both two different pipe diameters and two different materials. Such systems can lead to pavement failure or collapse of the soil above the pipe (causing sink holes). Both can be hazardous to the public.

2. **Pipe Joint Failures**: A few areas exhibited the tell-tale sign of pipe joint failure. Water moving through a culvert creates a negative pressure that can pull sandy or silty sand backfill through open pipe joints or cracks. The resulting voids can lead to pavement failure or the development of sink holes (see example in photo at right). Such failures can only be repaired by opening the pavement, removing backfill, and correctly sealing the pipe joint.

3. **Improperly laid Corrugated Plastic Pipe**: Finding egg-shaped plastic pipe or plastic pipe with crushed ends was quite common. When corrugated plastic pipe (CPP) is laid too shallow and/or improperly bedded at the haunches of the pipe, it is common for the pipe to develop an oval shape or to be crushed. For this reason, most municipalities do not permit the use of CPP except for driveway applications and only then with strict adherence to bedding, haunching, backfill materials, and minimum backfill controls.

4. **Use of small diameter pipe as driveway or drainage pipe**: We observed a number of shallow 4-, 6-, 8- and 10-inch diameter pipe tying into catch basins; some used as driveway pipe. The small diameter pipe observed was found to be a mixture of solid wall PVC pipe, solid wall ABS pipe, small diameter CPP (some with interior corrugations; some with smooth wall interior), cast iron, and steel pipe. Small pipes retard flow and quickly silt up. Ninety percent of the small diameter pipe found/observed was filled with silt. The conveyance life of small diameter pipe is short.

5. **Lack of Routine Street Maintenance**: We saw no evidence of routine street maintenance in the form of periodic pulling or reshaping of road ditches and/or shoulder grading; maintenance needed to both protect the pavement and extend its life. Consequently, a surprisingly large number of the existing road ditches and driveway pipe in the Town were found to be either partially or wholly filled in with sediment; many buried. We spent a considerable amount of field work locating buried pipe and catch basins (example of buried DI on Parker Street, photo at right). Throughout most of the Town, there is little to no road ditch on existing shoulder-section (strip paved) streets.

   <u>Surficial Alluvial Soils Predominate the Town</u>: The predominant surficial soils in the Town of Calypso are alluvial fine sandy] ☐ & ☐ $

stormwater runoff slows and the transported silt tends to settle out. In road ditches, established groundcover can further reduce stormwater velocity causing sediment to settle in the road ditches. With time, the ditch soon begins to fill in and driveway conduit opening shrinks. Thus, the need for routine ditch and shoulder maintenance.

6. **Pond (Calypso Club Pond)**: In Basin 15, the study terminated at a private pond located approximately 2,100 feet east of S. First St. The approximate tributary drainage area to this pond is 228.4 acres yielding an estimated Q_{25} flow of 338 CFS (68 min Time of Concentration; average basin C=0.503 [composite]). The dam has not been maintained according to conventional and acceptable practices and guidelines. Some deficiencies observed were:

   A. Large trees growing on the dam. Trees blown over during high wind events can lead to a sudden dam breach. Dead tree roots can also lead to piping failures in the dam.
   B. Loose debris fill placed at both emergency spillways and dumped at the downstream (toe side) of the dam. See photo at right.
   C. Base flow water flowing over the northern emergency spillway.
   D. Irregular shaped emergency spillways and poor spillway maintenance.
   E. Absence of a "qualified" trash rack, improperly maintained riser. This can lead to frequent emergency spillway overflows. A drain valve was not readily apparent on the riser.
   F. Poor vegetation cover.

Pond Dam Upstream Hydraulic Impact – A Brief Discussion:
The bottom (flowline) of the lowest emergency spillway at the dam is at about the same elevation as the invert of the existing 54" CMP at S. First Street. By analysis, that yields a 3-foot tail water depth at the outlet end of the S. First St. culvert for a Q_{10} or Q_{25}, storm event. However, with inlet control governing (i.e., the pipe will not accept more water into the pipe than what the inlet will allow), the capacity of the 54" CMP is not be reduced by having a 3 ft high pipe tailwater depth. Also, with inlet control governing, any flow in excess of 135 cfs (i.e., the capacity of the existing 54" CMP based on inlet control) will overtop the street and continue downstream. Only by increasing the cross-sectional area of the pipe culvert and improving the entrance condition, can we increase the flow through the culvert crossing. We are therefore proposing to replace the existing 54" CMP at S. First St with twin 60" RCP's.

For the proposed twin 60" RCP's, analysis indicates inlet control will also govern pipe flow. The 3-foot tailwater depth did not impact the outlet control condition sufficiently to create a headwater depth greater than the top of the road (the inlet control headwater criteria). The proposed twin 60" RCP's will accommodate the Q_{25} storm. It should be noted that the NCDOT requires that culverts crossing secondary roads be designed to accommodate a Q_{25} storm. Flow in excess of the Q_{25} storm is permitted to overtop the road and should be expected.

Once runoff passes through the new S. First St. twin 60" RCP culvert, storm runoff can continue, as it has in the past, to be temporarily stored/detained downstream of S. First St. in the woods, open farm fields and pond with significantly less backwater impact in the future to properties upstream for up to the Q_{25} storm event.

Consequently, there is little justification for either removing the pond dam or modifying the pond dam to lower the tail water depth though any such improvements would be beneficial. If there is a desire by the Town to further reduce overtopping frequency beyond that of a Q_{25} storm event or to reduce the headwater elevation to some degree lower than the top of S. First St. (upstream of the twin 60" RCP's culvert), lowering headwater elevation can be accomplished by adding a third parallel pipe and designing the culvert to account for a 3-foot tail water depth (should the flow conditions change from inlet control governing to outlet control governing).

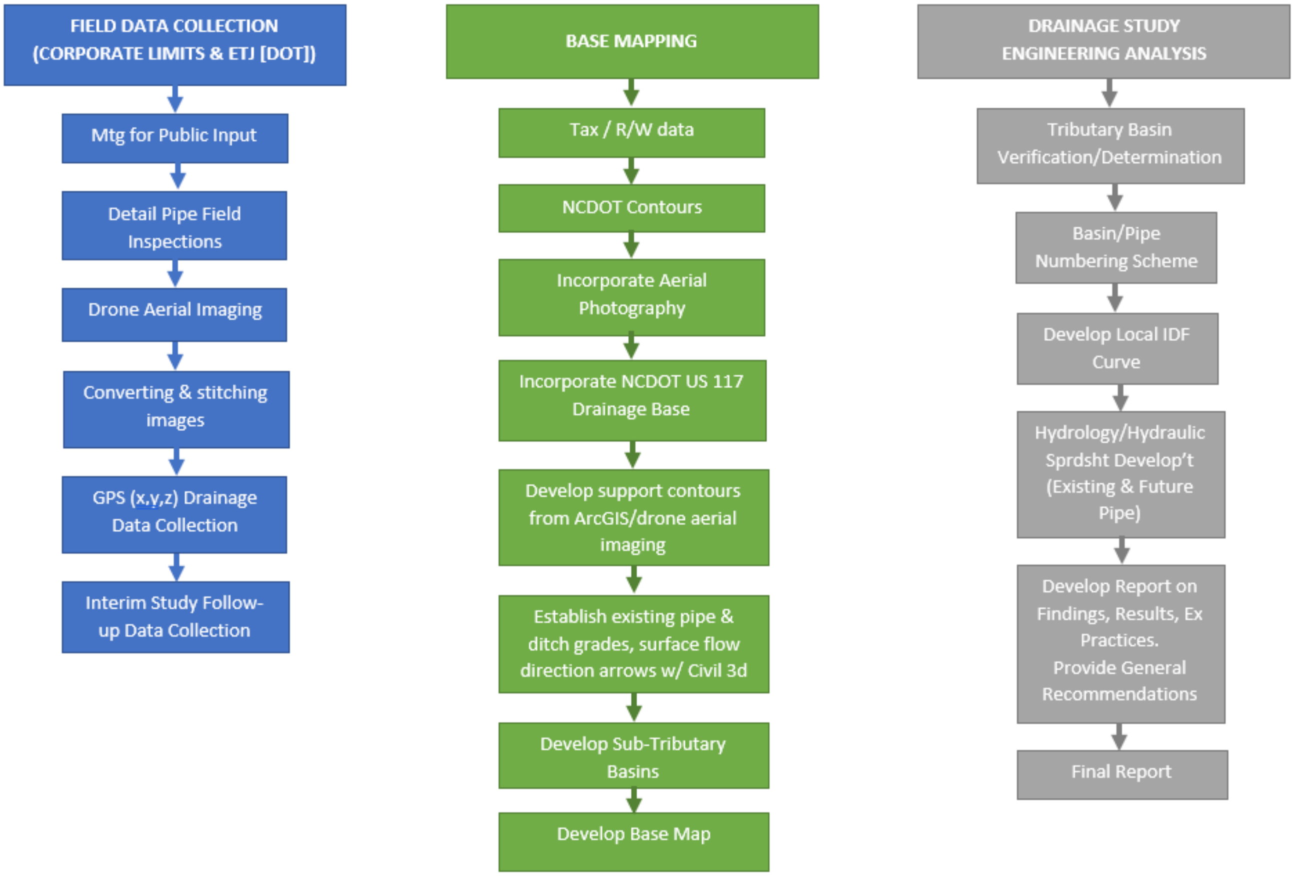
We would also like to point out that lowering the water elevation in the pond to create temporary storage prior to a forecasted severe storm event is unlikely offer any appreciable benefit as the pond would refill rather quickly under high flow conditions.

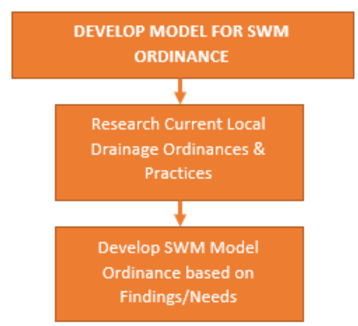
FINANCIAL ANALYSIS

The proposed pipe sizes shown in the Report Data Tables can be used to create "preliminary" cost estimates for pipe replacement. However, due to the current dynamic construction climate, materials costs, and materials availability, we recommend that the Town consult with a Civil Engineer, a Roadway Contractor, or both to obtain a more accurate and detailed projected cost estimate for a specific project(s) of interest. Any unit prices we would put forth at this date would soon become obsolete. Furthermore, municipal stormwater rehabilitation or pipe replacement is affected by too many variables to put forth a unit price for specific pipe diameter. A small project, for example, can tend to be more heavily weighted on the labor and equipment side which, by using a *one-price-fits-all* per pipe diameter, would tend to yield a low estimate.

STORMWATER SYSTEM EVALUATION & DESIGN CONSIDERATIONS | PART 2

1. STORM DRAINAGE STUDY FLOW CHART | OUR APPROACH





2. STORMWATER RUNOFF:

Stormwater runoff determination consists of the study of rainfall events (in terms of inches or inches per hour) and runoff (cubic feet per second; CFS) as related to the engineering design of conveyance features such as ditches and culverts; the latter being the primary emphasis of concern herein. These conveyance features are typically designed to a particular storm event or storm frequency (e.g., a Q_{10} storm event).

In the study of any existing storm drainage culvert or a system of ditches and culverts, it is always important to visit the actual project site and identify problems that may be encountered or that could impact the study. Existing culverts always seem to be a problem and have to be looked at carefully. To perform this drainage study, Appian's general approach and process followed the aforenoted flow chart.

What follows herein in Part 2, is a brief explanation of the approach and considerations taken in the performance of this study. The explanations are intended to inform the reader and to help the reader understand why such measures were applied.

Runoff Determination – First Step:

Once all field data is gathered and mapped accordingly, the first step in the design or analysis of an urban storm drainage system is to determine the stormwater runoff. That determination is the most important aspect of drainage design. The customary approximate methods were used for estimating stormwater runoff in Calypso. There are Civil Engineering software platforms/methodology's available that assist in both field data collection and tributary basin determination. At this level of analysis, and due primarily to the small size areas of the tributary basins involved, the Rational Formula was used for determination of peak flow based on a Q_{10} storm event. The Rational Method has typically yielded satisfactory results when applied to basin study areas of less than 200 acres.

Drainage Area Determination - Methods:
When performing a site-specific study, depending on the tributary area of the drainage basin, soils, etc. under study, Engineers will select a specific method to compute peak flow runoff. Acceptable methodologies for computing the stormwater runoff volumes and peak discharge should be consistent with those noted in the latest revision of the NCDOT *Guidance in the methods, procedures, policies, and criteria for Drainage Studies and Hydraulic Design* manual. Those methodologies may include one or more of the following with the Rational Method the most commonly used for small tributary basins:

1. The Rational Method,
2. Dr. H. Rooney Malcolm, P.E., Small Watershed Method,
3. The Peak Discharge Method as described in USDA Soil Conservation Service's (SCS) Technical Release Number 55 (TR-55)

The Rational Method Approach:

Q= CIA, in which:

Q = Peak flow from the drainage basin (in cubic feet per second)
C = Runoff coefficient (dimensionless)
I = Rainfall intensity (in inches per hour)
A = Contributory drainage area (in acres)

The Rational Formula is based upon the assumption that in a rainfall of uniform intensity, the peak stormwater runoff flow at the outlet of a given area occurs at the time of concentration, T_c, which is the time that stormwater flow is received at that outlet from the most remote point in the basin. It has been observed that the rainfall intensity of a given recurrence interval decreases as the duration of the storm increases. Thus, the appropriate rainfall intensity for use in the Rational Formula is that intensity associated with a storm duration equal to the time of concentration for that tributary area/basin.

The procedure for calculating area, rainfall intensity and the runoff coefficient are as follows:

A. **Area**: The boundaries of drainage areas can be determined from field surveys or by analysis of topographic maps often with the assist of Civil drainage software platforms.

B. **Rainfall Intensity**: The information on rainfall is divided into the following groups:

1. **Storm Frequency**: The selection of a design storm frequency establishes the interval at which the storm drainage facility is expected to be fully loaded. For this reason, governmental agencies will establish design storms based on a return frequency for the type of development or condition under consideration. To illustrate, the selection of a Q_{10} storm event is based on the acceptance of the

risk that a facility(ies) will be overloaded by large storms on the average of once in 10 years. The consequence of such overloading is usually limited to street and lowland flooding of yards and small streams. Areas which incur extensive damage from this sort of flooding should receive special attention or a higher designation. It is rarely justifiable to design all stormwater collection systems to accommodate highly improbable storm events. See an example of typical design storms, below.

a.	Undeveloped areas, agricultural	10-year storm
b.	Partially developed area	10-year storm
c.	Residential areas	10-year storm
d.	Business district-trunk lines	25-year storm
e.	State secondary road crossings	25-year storm[1]
f.	State/Federal Primary Road crossings	50-year storm[2]

Though evaluated based on a Q_{10} contribution to the Town of Calypso, with the subsequent recommendations shown in this report based on Q_{10}, the storm frequencies for storm drainage piping crossing NCDOT secondary and primary roads must meet the requirements of the North Carolina Department of Transportation. Any improvements proposed in this report to the NCDOT system are the minimum recommendations based on the Town's needs but are subject to review and concurrent approval by the NCDOT. See "Scope of Report | Part 1", page 2, paragraph 1 for study limits.

What is a Q_{10} storm?
A 10-year storm (Q_{10}) has a 10% chance of occurring in any given year, a 50-year storm has a 2% probability of occurring in any given year and a 100-year storm return period has a 1% probability of occurring in any given year. Is it possible or likley that one can experience back-to-back 10-year storms in the same year? The answer to that question is YES. The return frequency of a particular design storm, such as the Q_{10}, is based on past hydrological experience with frequent data updates by NOAA. Since man cannot control the weather, back-to-back storm events, or even an event with a lower return frequency (e.g., a Q_{50}) following a Q_{10} is also certainly possible.

2. **Time of Concentration**:

The time of concentration to the point under consideration, is estimated so that the average rainfall rate may be determined. For urban storm drainage, the time of concentration consists of the time required for the storm runoff to flow overland to the nearest established drainage channel and the time required to flow along that channel and, possibly, through a pipe system to the study point under consideration.

Flow within a pipe system may be closely estimated from the hydraulic properties of the pipe. However, the time required for overland flow and the time required for flow in an open channel are more difficult to estimate since those times vary with the slope, the nature of surface cover, and the length of the flow path.

The formula below, which was used in our analysis, calculates the time of concentration in terms of minutes for runoff to travel in well-defined channels, overland on bare earth, and in mowed grass

[1] Analysis of the NCDOT pipe systems was not performed in this study except with regard to runoff contribution to the Town's existing drainage system and that was based primarily upon a Q_{10} storm event. Otherwise, all drainage within NCDOT rights-of-way is required by analysis to meet the latest revision of both the NCDOT's *Subdivision Roads Minimum Construction Standards* and the *Guidelines for Drainage Studies and Hydraulic Design;* with concurrent approval by the NCDOT.
[2] id.

roadside channels. For other flow conditions, modification factors are employed to adjust the time of concentration (see Modification factors below). Designers can opt to use either the formula method or a nomograph[3] to determine times of concentration.

$$= \frac{\left(\frac{3}{\;}\right)^{0.385}}{128}$$

where,
T_c = Time of Concentration (minutes)
L = Maximum length of travel (feet)
H = Height of most remote point above outlet (feet)
T_c Modification Factors:

- Natural Basins w/ well defined channels or overland flow on bare earth or mowed grass roadside channels, use the computed T_c (i.e., multiply by 1.0)
- Overland Flow (grassed surfaces:) Multiply T_c by 2
- Overland Flow (concrete or asphalt surfaces): Multiply T_c by 0.4
- Concrete Channels: Multiply T_c by 0.2

3. **Rainfall Intensity:**

Once the time of concentration has been determined, the rainfall intensity of the design storm frequency is found. The peak stormwater runoff occurs when the storm duration is equal to the time of concentration. Storms of shorter duration do not allow the entire area to contribute runoff and storms of longer duration have a smaller rainfall intensity.

Data for intensity-duration-frequency (I-D-F curve) relationships are gathered from the records of rainfall from NOAA's *Hydrometeorological Design Studies Center* (Precipitation Frequency Data Server (FPFS). The records of actual rainfalls show that the intensity corresponding to a given duration and frequency may occur at any time during a storm. The intensity duration curves for different storm frequencies are prepared by statistical analysis. The rainfall intensity curve used in this study, commonly referred to as an I-D-F curve, was developed by Appian specifically for the Town of Calypso. The curve and the associated rainfall data are included in Appendix A-6 (ref: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html).

C. **Runoff Coefficient:**

The runoff coefficient, C, in the Rational Formula is the term least susceptible to precise determination. Selection of the runoff coefficient "C" requires great care, experience, and good judgment. The coefficient reflects losses due to interception of rainfall by vegetation, infiltration into soil (which can vary depending on the soil type and whether the soil is dry or saturated from preceding rainfall), retention in surface depressions, evaporation, transpiration, and other losses. What is left is referred to as excess precipitation value as determined by the C coefficient selection. Since these losses decrease with time, it may be expected that the coefficient of runoff will increase with time. But since the time of concentration begins after an appreciable amount of rainfall has fallen, the increase in value of the coefficient with time is not very significant. The use of an average coefficient of runoff which is assumed to remain constant through the storm is sufficient. The most commonly used runoff coefficients are shown in Appendix A-4.

[3] A nomograph is a graphical calculating tool; a two-dimensional diagram designed to allow the approximate graphical computation of a mathematical function.

Frequently, it is necessary and/or desirable for Engineers to develop a composite runoff coefficient "C" based on the weighted values of various types of surfaces, development density, soils, etc., within a drainage area under consideration. The runoff coefficients are applied to representative sections and then a composite C value for the tributary basin understudy is determined. The values for various surfaces (e.g., such as pavement, lawns, roofs, etc.), are also included in Appendix A-4.

It is possible that less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. In such instances, the runoff coefficient values may be adjusted as deemed applicable by the Town's Engineer and/or the project design Engineer for the area under consideration.

3. STORMWATER COLLECTION:

The stormwater collection system includes the system of gutters, small channels, inlets, pipes, and manholes which convey stormwater to a point of release. The point of release may be in a natural stream, a lake, or in an artificial channel or impoundment. These systems are typically designed in small area increments of 50 to 100 acres. The design sequence is typically separated into two activities: the location of inlets and the sizing of pipes. For design requirements and methodology for future development or Town improvement projects, we recommend that the Town of Calypso adopt a Stormwater Ordinance that references within that document the design criteria for a stormwater collection system with references to recognized design manuals (e.g., the NCDOT *Guidance in the methods, procedures, policies, and criteria for Drainage Studies and Hydraulic Design* manual, latest revision, and NCDEQ's *Erosion and Sediment Control Planning and Design Manual, latest revision,* for structural stormwater controls).

A WORD ABOUT INLET LOCATION:

To minimize the investment in pipes and inlets, and in their maintenance, surface flow through open ditches and channels should be used where practical. Inlets should be installed at depressions where water would otherwise have no outlet, and at points where the surface channel reaches capacity at design storm flow. For the small drainage areas involved in inlet location, the Rational Formula is satisfactory for flow estimates.

Starting at the top end of an Interbasin, for example, and moving towards the interbasin outlet, the design process proceeds through each subbasin, locating inlets in depressions and where surface channels are loaded to capacity. Inlet locations may be influenced by the pipe network pattern which emerges in the design process. It should be noted and emphasized that the economy of the system is significantly affected by inlet location.

Curb inlets on curb and guttered streets can be located on the design plans by trial-and-error adjustment of the inlet position in such a way that its drainage area approximates the allowable area or flow with the desired precision. In most cases, the curb inlet will not capture the full gutter flow. The intercepted fraction is a function of the flow, street grade and the hydraulic characteristics of the inlet. Programs, charts, and nomographs are available to relate these parameters and to estimate intercepted flow. The useful capacity of the gutter downstream from an inlet must be reduced by the quantity of flow which passes by the inlet when determining the allowable drainage area for the next inlet downstream.

PIPE SIZING:

Conventionally, pipes are sized in an analysis independent from that which located the inlets. Flows contributory to each inlet are recomputed by the Rational Formula. The time of concentration is the flow time from the most remote inlet in the drainage area to the point of design, plus the time of travel in pipe to the point of design. For small drainage areas, however, the time of travel in a pipe is negligible and is usually not included. The runoff coefficient is typically a composite of all contributory drainage areas.

Normally, one proceeds from the upland boundary towards the outlet, setting pipes at minimum depth consistent with profile constraints. For this study, pipes were generally sized to flow just full, according to the Manning equation, at design peak flow. In determining the estimated design pipe size for undersized pipe found within the Town by this study, the Manning equation was conveniently rearranged as follows:

$$= 16 \left(\frac{}{^{\frac{1}{2}}}\right)^{3/8}$$

in which:

- D = Minimum pipe diameter (in.)
- Q = Design flow (cfs)
- n = Manning roughness coefficient (dimensionless)
- s = Pipe slope (ft/ft)

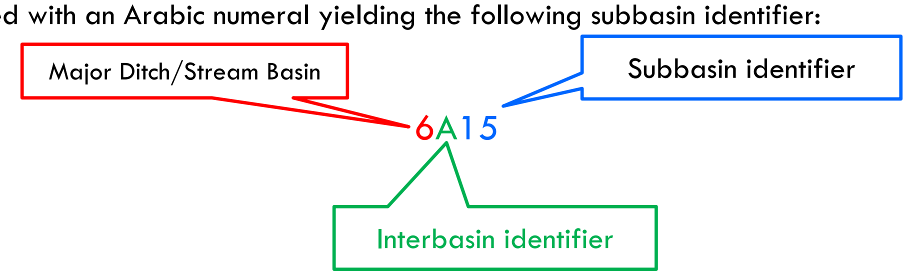
Typical Manning roughness coefficient following values:

Concrete Pipe	0.013
Clay Pipe	0.012
Corrugated Steel Pipe	
Plain with 2 2/3" x ½" corrugations	0.021
Plain with 3" x 1" corrugations	0.023
Plain with 6" x 2" corrugations	0.026
Concrete Box Culverts	0.014
Brick Culverts	0.014
Concrete Lined Channels	0.015
Dredged Earth Channels	0.030

The Manning Equation has been adapted to nomographs[4] for ease of use for various pipes and for various pipes (e.g., circular concrete corrugated metal pipe, etc.). Similarly, nomographs are available for both Inlet and Outlet control; again, for various pipe materials and shapes.

AND, DRAINAGE BASIN ANALYSIS:

Drainage Basin Identity: Each major ditch or stream basin in the study area was identified with an Arabic numeral. Within the major drainage basin, that area was further divided into "interbasins," a subbasin of the major basin; identified by an alphabetic letter. Within those "interbasins," smaller tributary "subbasins" were identified with an Arabic numeral yielding the following subbasin identifier:



Pipe Identity: Each pipe culvert associated with a particular subbasin carried the subbasin identifier. The subbasin identifier was appended with an Arabic numeral. The pipe was identified by subbasin contributing

[4] Id.

flow; typically to the inlet end of the pipe. Where there were 2 or more culverts associated with a single subbasin, the numeric pipe suffix increased a numeric digit. See example below.

6A15 -1 — Numeric Pipe (1, 2, …)

Order of Basin Numbering/Analysis: The order of the numbering of the subbasins within an interbasin started with the subbasin at the highest elevation in the drainage basin. Each successive subbasin downstream has the next higher Arabic subbasin number. For example, 15A1 represents the upper most contributing subbasin in interbasin 15A, which is part of major drainage basin number 15.

4. REPORT | PIPE DATA TABLES:

The data tables list the area pipe identification numbers and the analysis of the flow for the existing pipe. Where the existing pipe was determined to be inadequate, the additional capacity required is given under the column "Proposed Pipe." If an additional pipe (parallel to the existing) is proposed by the analysis, the pipe diameter in the "Proposed Pipe" column is noted with *. If a pipe replacement is proposed by analysis, the pipe diameter in the "Proposed Pipe" column is noted with **. All pipes shown in the column "Proposed Pipe" are proposed to be concrete pipe unless noted otherwise.

Where pipe evaluated is under NCDOT maintenance responsibility, the proposed pipe, with or without a single * or double **, will also include or show a ++.

TABLE 2.4-1

PIPE DATA TABLE LEGEND	
HEADING	**UNITS**
Pipe Identification Number	--
Area	Acres
Σ Area (Accumulated Area)	Acres
C (Runoff Coefficient)	Dimensionless
T_c (Time to Concentration)	Minutes
Storm Frequency	Years
I (Rainfall Intensity)	Inches/Hour
Q (Runoff Rate or Pipe Capacity)	Cubic Feet per Second
Σ Q (Accumulated Runoff Rate)	Cubic Feet per Second
Dia. (Diameter)	Inches
S (Slope)	Percent

TABLE 2.4-2

ELEMENT NAME	ABBREVIATION USED IN TABLES AND DRWGS
Cast Iron Pipe	CIP
Concrete Pipe (Plain or RCP)	C
Corrugated Metal Pipe	CM, CMP, CMAP
Corrugated Plastic Pipe	CPP
Ductile Iron Pipe	DIP
Polyvinyl Chloride Plastic Pipe	PVC
Terra Cotta (Clay Pipe)	TC
Steel Pipe	Stl
Catch Basin	CB
Drop Inlet (Yard Inlet)	DI
Junction Box	JB
Manhole Junction Box	MHJB
Open Throat Catch Basin	OTCB
Box Culvert	Box
Drop Inlet	DI
Flared End Section	FES
Headwall	HW

The pipe/area identification numbers given in the data table are presented on a set of the Town of Calypso topographic maps along with an outline of the corresponding drainage area. That mapping, not included in this report because of its size, is included in a separate package.

For each drainage area, a short introduction describes some of the area's topographic and hydrologic characteristics. Then the data tables are presented.

Because the topographical features of Calypso are so flat with many of the pipe systems laid shallow and on very flat grade, and in an effort to reduce headwater depth thereby reducing overland flow, a number of the proposed larger pipe shown in the Data Tables were sized to accommodate larger flows. We have also shown recommended pipe slopes where the existing pipe grade is so flat. When replacing any of the individual or piped systems shown in the Data Tables, the final pipe diameter will need to be determined by design by a Licensed NC Professional Engineer taking into account the location, allowable headwater depth above inlets and/or pipe invert, allowable storage depth, tailwater conditions, etc. all in accordance with accepted practices and the requirements of both the Stormwater Ordinance and the NCDOT *Guidelines for Drainage Studies and Hydraulic Design.*

RECOMMENDATIONS FOR CONSIDERATION | PART 3

1. CONSTRUCTION DESIGN AND DRAWINGS – FUTURE CONSTRUCTION

Drainage Improvements: Before construction of any improvements to the storm water drainage system can commence, detailed field surveys will have to be made for the preparation of construction drawings. The data gathered by those field surveys will enable the designer to include economy in his/her design of the planned site and drainage improvements. For example, in the upper part of a drainage basin, it could be possible to let the storm water runoff flow overland. In those areas, shallow ditches along each side of the street, which are more economical than piped systems, can be used. This may require regrading or upgrading existing road ditches. When the storm water runoff becomes too great for road side ditches to be practical, curbs and gutters can be added to transport the surface runoff water to a storm drainage pipe system. This is particularly applicable to street rehabilitation programs.

New Development Streets: Unless dictated otherwise by the Town's zoning ordinance, the design of new development streets, where the maintenance responsibility of that street will ultimately lie with the Town, should follow the applicable requirements of the Town's Stormwater Ordinance and the NCDOT's *Subdivision Road Minimum Construction Standards*, latest revision.

2. ORDER OF CONSTRUCTION

Undertaking all the recommended pipe improvements at one time is impractical because of the great cost and the huge scope of the work involved. Therefore, staging or phasing the improvements over a period of years should be planned in any effort to resolve the most critical areas of concern. The order of construction should follow a logical priority scheme, such as the following:

1. Construct storm sewers in those areas which are the most subject to localized flooding.

2. Install downstream pipes in a drainage area first. By installing downstream pipes first, flow restrictions in any drainage course are prevented.

3. Install drainage in the commercial or business districts.

4. Complete drainage system in residential areas and in the upper portion of drainage basins.

3. MAINTENANCE:

A. **Maintenance Recommendations**:

1. **Bi-Weekly or Monthly Drainage Inspection**: Adopting the general practice of keeping catch basins, curb inlets and pipe entrances free of leaves, trash, and other debris will enable the drainage system entrance to function properly and not restrict flow. Also, the practice of keeping natural drainage courses free of weeds, trees, and debris along their bank or across the ditch bottom will prevent flow restrictions and enable storm water runoff to move more efficiently.

2. **Routine Scheduled Drainage Inspection**: A routine scheduled inspection of the entire storm water drainage system should occur at least once a year. Areas that have frequent problems should be inspected often enough to prevent reoccurrence.

3. **Inspection of Critical Points in Drainage System**: All critical points in the drainage system should be inspected in the fall before the winter rains. Those same critical points should be inspected after each major storm to remove any debris build-up that occurred.

4. **Reshaping Road Ditches and Regarding Shoulders:** Routine municipal road maintenance should include periodic reshaping of roadway ditches and regrading the shoulders. Routine roadway maintenance has the benefits of:

   A. Ensuring roadway and lot runoff is intercepted and conveyed to intercepting cross-drainage ditches and streams.

   B. Prolonging the life of the roadway pavement section. The life and strength of every roadway or parking lot pavement section is heavily dependent upon the integrity and condition of the base and soils upon which they bear.

> **NOTE:** Surface water standing or accumulating in road ditches leads to a weakening of the road base and subgrade. Flat shoulders with periodic wetting can cause weakening of the pavement edge leading to pavement edge raveling. Both conditions accelerate pavement deterioration and reduce pavement life.
>
> Refer to Appendix A-1; A Guide for Routine Maintenance of Stripped Paved Streets.

5. **Annual Inspections/Inventory:** Locally maintained streets should be scheduled for an annual inspection to note areas of specific repairs needs; needs such as isolated pavement failure (e.g., pot holes, depressions, alligator cracking, failed pavement cuts, etc.) and roadway ditches in need of regrading to typical section (to ensure removal and conveyance of surface runoff). This could be performed in conjunction with the preparation for the annual Powell Bill Fund report. As the Town is aware, Powell Bill funds can be used for routine street maintenance, street related drainage maintenance, street rebuilding, and street resurfacing.

6. **Pond:**

   A. This appears to be a private pond; likely originally constructed for agricultural purposes. The dam would fall under the jurisdiction of NC DEQ, Division of Energy, Mineral and Land Resources, Dam Safety Section "*Dam Safety Program, Subchapter 2K – Dam Safety*." The dam would likley be classified as a Class A dam under these rules. Class A includes dams located where failure may damage uninhabited low value non-residential buildings, agricultural land, or low volume roads. However, under HB 119, dams constructed for agricultural use, are exempt provided they are not determined to be of high hazard classification (regardless of size). Such ponds of this age were typically designed by and constructed according to the USDA Soil Conservation Services (probably as an irrigation pond). The final determination of for exemption, which may already have been obtained by the owner, would need to be made by a qualified Licensed Engineer and confirmed by Division of Energy, Mineral and Land Resources, Dam Safety Section.

   B. Regardless of an exemption, the Owner should perform an informal periodic safety and assessment inspection (02K .0301) after each severe rainfall event. Periodic or severe rainfall event inspections should include checking for dam seepage, wet areas on toe drain, trash rack debris, slides/erosion, settlement, tree growth, rodent activity, and vandalism. Emergency spillways should typically be mowed at least twice a year.

   C. See previous comments pertaining lack of justification to modify the pond dam.

4. EASEMENTS:

In areas where no drainage easements exist, it is recommended that the Town of Calypso consider trying to acquire drainage easements along all natural drainage channels and along all underground storm drainage pipe systems that are located outside street rights-of-way. Those easements are needed to ensure access for maintenance purposes as well prevent permanent structures from being built either over or too close to underground pipe systems and natural drainage channels. Easements acquired through existing developed areas should not affect existing structures; grandfathering existing structure encroachments.

5. FUTURE DEVELOPMENT:

The Town of Calypso should consider adopting a local Stormwater Ordinance that outlines criteria for acceptable storm water drainage design for all new development within the Town's jurisdictional area. Until primary drainage outfall lines are upgraded, the Stormwater Ordinance should also require the detention of storm water runoff for future development. Typically, for such a plan, post-development peak flow runoff storm runoff should not exceed the pre-development peak flow runoff for the same return period storm. Stormwater detention requires that stormwater runoff be held temporarily and released gradually. Gradual release will minimize flooding in sensitive downstream tributary areas, will prevent high velocity flows in stream channels which would erode unprotected channels, and will prevent the release of unusually high sediment in downstream channels.

See the *Stormwater Ordinance* proposed by Appian for the Town’s consideration and adoption.

6. A DISCUSSION OF DESIGN & CONSTRUCTION CONSIDERATIONS; AND TO HELP UNDERSTAND “WHY”

A. Drainage pipe is usually sloped at the same grade as the ground. Pipe slopes significantly steeper than the surrounding natural slope are to be avoided to prevent excessive depth of the pipe, to prevent erosion at the discharge end (Figure 102, below right), and to prevent deposition of sediment in flatter sloped pipes downstream. Pipe slopes flatter than the surrounding natural slope are also to be avoided since larger diameter pipes would be required to carry the same quantity of water.

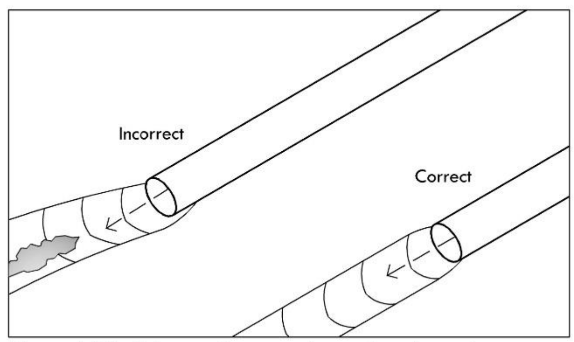


Figure 102: Culvert alignment for reduced erosion

B. Similarly, successive culverts (e.g., driveway pipe) placed in either a road ditch or drainage outfall should be laid with a uniform longitudinal grade. See Figure 101 in Appendix A-1.

C. **Maintenance Recommendation**: To reduce clogging problems, for future pipe installation, the minimum pipe size for storm drainage should be a 15” diameter pipe. Existing 12” diameter pipes may be left in service, but existing pipes smaller than 12” should be replaced. There should be no reduction in pipe size in the downstream direction, even if steeper slopes indicate that the flow would be carried in a smaller pipe.

D. **Maintenance Recommendation**: To reduce sedimentation problems, all pipe should be laid at a slope such that the velocity will be at least 2 feet per second when the pipe is flowing full. Those self-cleaning velocities will reduce maintenance on the pipe(s). In the absence of engineering analysis, and where the longitudinal grade of the existing street permits, the minimum longitudinal grade for driveway tile should be 0.5%. That is equivalent to an inch of fall for a 16-foot driveway tile.

E. Pipes laid on steep slopes have higher velocities of flow. Those high velocities can cause erosion of the pipe particularly where sandy soils are present. Pipe velocities should be kept below 10 feet per second. But, since storm flows are intermittent and of relatively short duration, pipe velocities are often not a major consideration where the pipe outlet ends have stable vegetation.

F. Manholes should be provided at pipe junctions, bends, and in straight sections such that the maximum distance between points of access is 400 feet. Inlets are appropriate points for pipe junctions. At junction points the mainline pipe culvert invert should be dropped to account for losses due to bends and convergent flows. Junction boxes should have formed inverts to minimize turbulence and reduce friction loss.

G. For short culverts under roads where open channel flow exists upstream and downstream of the culvert, and at points where open channel flow enters culvert or pipes, the designer must look at inlet control and outlet control. Often, one or the other will restrict the capacity of a culvert.

1. **Inlet Control**: Inlet control exists in cases where the culvert is not flowing full; most often seen in short pipe segments. The inlet of the culvert restricts flow, and the water at the inlet is deeper than the culvert height. That depth of water is called the headwater depth. The maximum allowable headwater depth is limited by either the controlling flood elevation (e.g. not exceeding the top of the pavement) or by existing or proposed development (to prevent flooding).

2. **Outlet Control**: Outlet control exists in cases where the culvert is flowing full and quite often exists in longer culvert segments (as opposed to short culvert segments). A controlling criterion for outlet control is the tailwater depth. Tailwater depth is the depth of the water at the outlet end of the culvert. The difference in the elevation of the water surface on the upstream side of the culvert and the downstream water surface is known as "head." The "head" is dependent upon the tailwater elevation. The tailwater elevation is determined by downstream conditions. In any case the tailwater elevation should not be above a selected flood elevation at the outlet. If no flood data is available, the simple assumption should be made that the tailwater elevation is the crown of the culvert.

7. OTHER OPTIONS TO CONSIDER FOR MITIGATING DRAINAGE CONCERNS

A. Below are some things for the Town to consider that would aid the areas with the direst need for improvement and allow time for the Town to take a systematic approach to mitigating some of the less impactful drainage concerns or pinch points in the drainage system.

1. **Area 1**: Localized Flooding in vicinity of NW Center Street and Warren St.
   a. **Buyout Property Subject to Frequent Flooding**: The Town can possibly apply for Grant assistance for either a potential buyout or relocation of the affected/flooded home(s). The Town could either convert the new vacant land to a Public Park or create a detention pond on the property as part of a drainage improvement program. A detention pond would help mitigate downstream drainage impact.
   b. **Elevate Impacted Homes**: The town can look into applying for Grant Assistance to elevate the impacted home(s).

2. **Areas 2, 3, 5, and 6**: With the major citizen concerns mitigated as noted in above, the Town can perform upgrades to other areas prioritized based on impact and availability of funds.

3. **Existing Detention Basins**: As previously stated in this report, Area 2 (as well as other areas in the Town), intermittent small detention ponds have been created by the presence of undersized pipe, adverse pipe and ditch grade, inlet obstructions (e.g., trash accumulating at pipe inlets), pipe partially filled with silt, etc. Such unplanned detention has the unintended positive benefit of

providing a degree of flooding protection to downstream properties during short duration storm events (that is, provided such small impoundments are not causing property damage). To a degree, this concept can reduce the immediacy of addressing some areas in the areas of concern noted. However, larger infrequent storm events (Q_{25}, Q_{50}, etc.) can easily nullify the benefit/concept depending on location and the degree of flooding impact to property.

B. A systematic annual line item can be added to the Town's budget to tackle prioritized areas. Powell Bill funds for example, can possibly be applied to drainage improvements directly related to street improvements. However, drainage outfall improvements unrelated to streets would not typically qualify for reimbursement under the Powell Bill program.

C. Based on public impact and need, the Town may qualify for a drainage improvements Grant.

Back to Top

APPENDIX

A-1
A GUIDE FOR ROUTINE MAINTENANCE OF STRIPPED PAVED STREETS

1. **Road Ditch Shape**

   The shape of the road ditch and slope of its front and back slopes will determine the road ditches long-term stability. Hydraulically, the most efficient cross section for road ditches is parabolic. However, the most common and practical shape for road ditches is the rounded-bottom V-shaped profile. Often, the front and back slopes, for ease of mowing maintenance is a 3:1 front and back slope (3 units horizontal to 1 unit vertical) though in rural applications, the backslope is sometimes laid back at a 2:1 slope provided with suitable groundcover that provides stabilization to the soil; seed species matching the soil type and flow velocity.

   Road ditch front and back slopes should never be vertical as in a U-shape as such ditches are unstable and tend to erode and slough off.

2. **Roadway Ditch Maintenance**: Roadway ditch maintenance requires attention to the shoulder grade, ditch bottom depth (to provide roadbed protection from near surface groundwater), and front and back slope shaping.

   A. **Strip Paved Street Shoulder Grading**:

   1. **Shoulder Grading**: Because sediment can build up on roadway shoulders over time, unpaved roadway shoulders periodically require regrading to allow the pavement runoff to reach the roadway ditch without accumulating on the shoulder and adjacent to the pavement edge. Built-up, flat, or low-sloped shoulders encourage surface water to infiltrate the pavement subgrade which can lead to pavement deterioration. Routine street maintenance of municipal stripped paved streets involves blading the shoulder from the edge of pavement to the shoulder point (typically 8 feet for urban streets; but dependent upon the Town's standard roadway section). Therefore, unpaved roadway shoulder grading is essential to the longevity of the stripped paved street.
   2. **Shoulder Slope**: Normal outside shoulder slopes are -0.08 ft/ft (12:1 slope). For example, for an 8-foot shoulder, the drop below the edge of pavement at the outside shoulder point would be 0.67 feet.

   B. **Roadway Ditch Maintenance**:

   1. **Transverse Grading**: Road ditches are graded in cross-section to meet a typical ditch section and to ensure that adequate depth below the edge of pavement is developed to protect both the pavement surface course and the roadway stone base course (see Figure 100). Typically, the front and back slopes should match.

ROAD DITCH TYPICAL SHAPE (Fig 100)

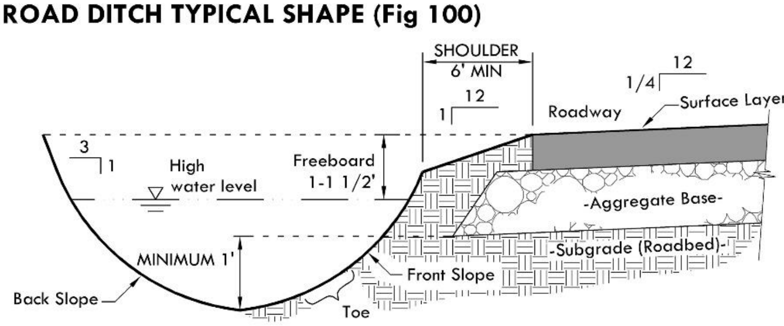


Figure A: A ditch profile and some basic features

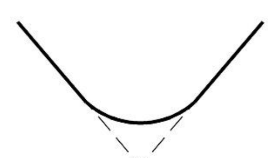


Figure B: Rounded-bottom, V-shaped ditch

NOTE: Min long ditch grade = 0.5%

   2. **Shaping**: Routine roadway ditch maintenance involves use of either a road grader, an excavator with an articulating bucket, or a *Gradeall* excavator.

3. **Longitudinal Roadway Ditch Grading**: Roadway ditch grading also needs to ensure that an adequate longitudinal grade is achieved; typically, no less than 0.5% to achieve a velocity that is self-cleaning and unconducive to sediment deposition if conditions permit. As such, a Professional Surveyor or Licensed Roadway Contractor should perform the evaluation and establish the grade that reasonably matches the existing conditions and existing cross drainage depths/inverts. Unless the existing driveway culverts were originally established on a uniform longitudinal grade for the full block length, it is likley that grading will require removal and replacement of existing driveway tile; placed at a uniform grade. See Figure 10, below, for clarification of for establishing successive culvert inverts.

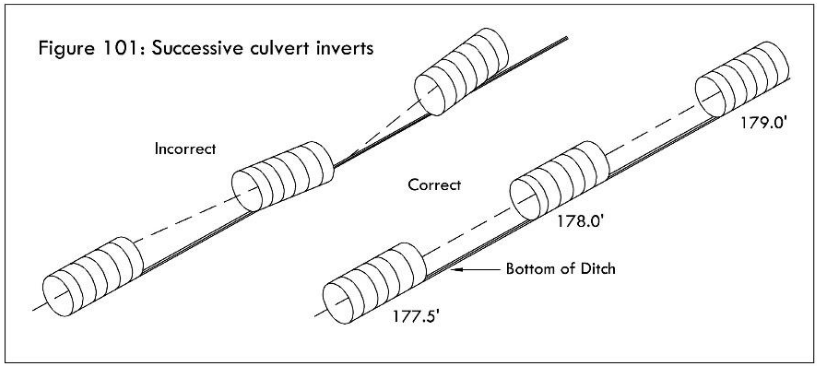
   

   Figure 101: Successive culvert inverts

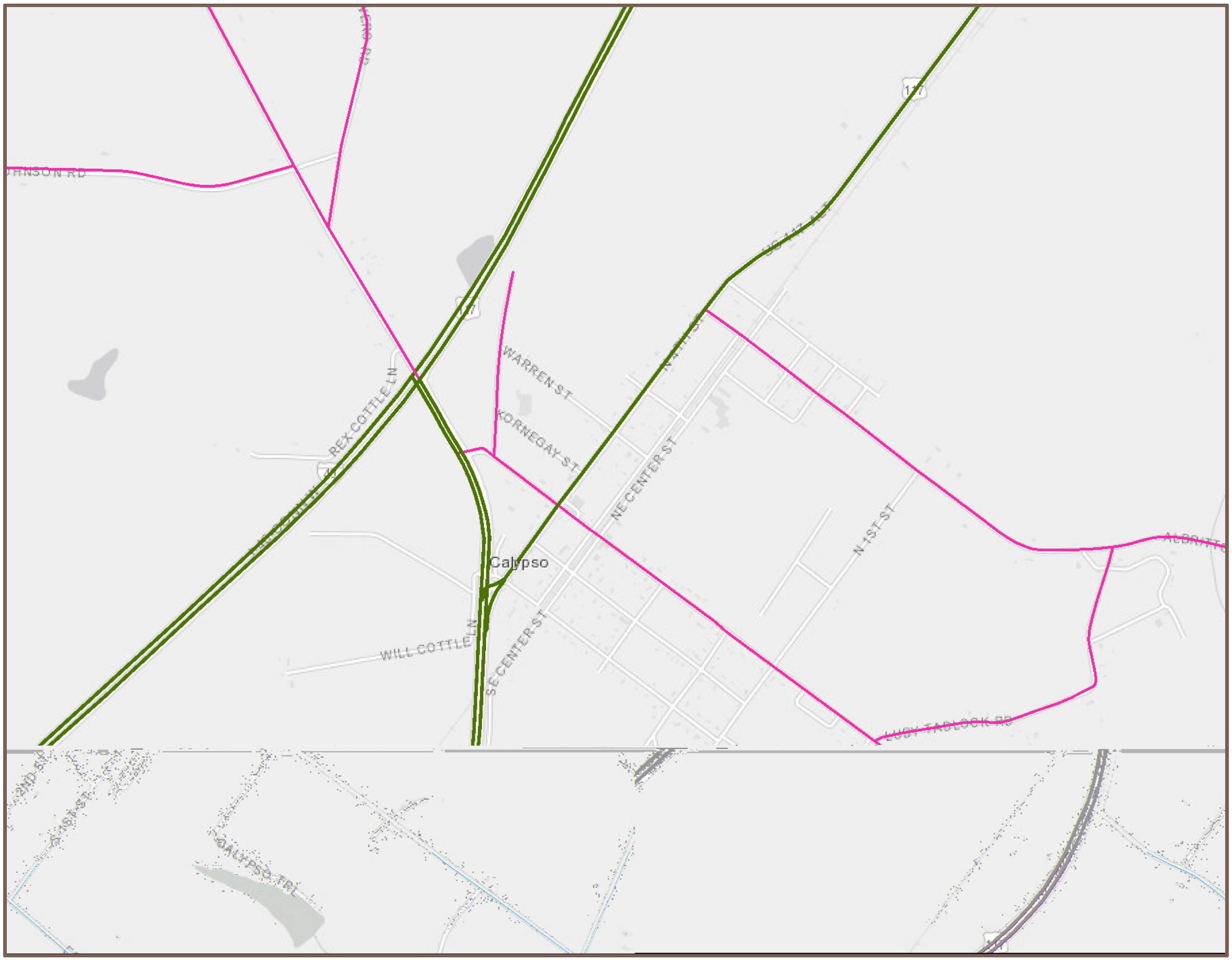
   Existing driveway tile that is either materially averse to the Town's standard or undersized will need to be replaced to the Town's minimum driveway pipe standard (i.e., material, diameter, minimum longitudinal grade). We recommend as a minimum standard for new driveway pipe the use of 15-inch diameter reinforced concrete pipe where cover from drive surface to top of pipe will be 12 inches or less. If the Town permits, corrugated plastic pipe (smooth wall interior) should be installed to NCDOT standards (with regard to material, cover, bedding, haunching and compaction requirements).

C. **Groundcover/Stabilization of denuded Areas**: As part of routine roadway maintenance, liming, fertilizing, seeding, and mulching should be applied to all new denuded surfaces. Seeding should be season appropriate. The NCDOT's *Minimum Design and Construction Criteria for Subdivision Roads*, latest edition refers to the NCDEQ *Erosion and Sediment Control Planning and Design Manual (*latest edition) for structural stormwater controls as part of a stormwater management plan. Unless exempted from the Sediment Pollution Control Act (SPCA), erosion and sedimentation control is required regardless of the size of the disturbance (ref NC State Sedimentation Control Law, chpt. 1). Typically, when the area of disturbance exceeds 1-acre, an ES&C plan will be required to be filed with NCDEQ's Division of Energy, Mineral and Land Resources, Land Quality Section, Wilmington Regional Office. For the development of such a plan, consult a Licensed Professional Engineer for assistance.

D. **Street Improvements Note:** It is not advisable to resurface or rebuild streets with significant signs of base failure without ensuring adequate drainage exists to protect the pavement; or drainage improvements to protect the street are made part of the street resurfacing or rebuilding project. This approach to street maintenance tends to yield a "least cost alternative" for the life of the street.

A-2

Exhibit A-2 NCDOT Maintained Streets/Highways within Corporate Limits of Calypso, NC



NCDOT State Maintained Roads

State Maintained Roads

- Interstate
- US Route
- NC Route
- Secondary Route
- Ramps
- Rest Areas
- Other State Agency Route

A-3

Table A-3 Predominant Surficial Soils within the Corporate Limits of the Town of Calypso		
Series	**Composition/Description**	**Groundwater Proximity**
GoA	0-12 inches; fine sandy loam 12-46 inches; fine sandy clay loam	2 ft to seasonal high groundwater Soil strongly acid (pH about 5.2)
NoA	0-48 inches; loamy fine sand	10+ ft to seasonal high groundwater, best soils in Duplin Co. for farming Soil strongly acid (pH is 5.2)
RAA	0-8 inches; fine sandy loam 8- 38 inches; fine sandy clay loam	½ ft to seasonal high groundwater, poorly drained soils and one of the more extensive soils in Duplin County. Rains soil needs drainage for cultivation. Rains soils are typically classified as a Hydric soil; found in or adjacent to wetlands. Soil strongly acid (pH is 5.3)
Source: Duplin County GIS; Soil Survey 1954, Duplin County, NC		

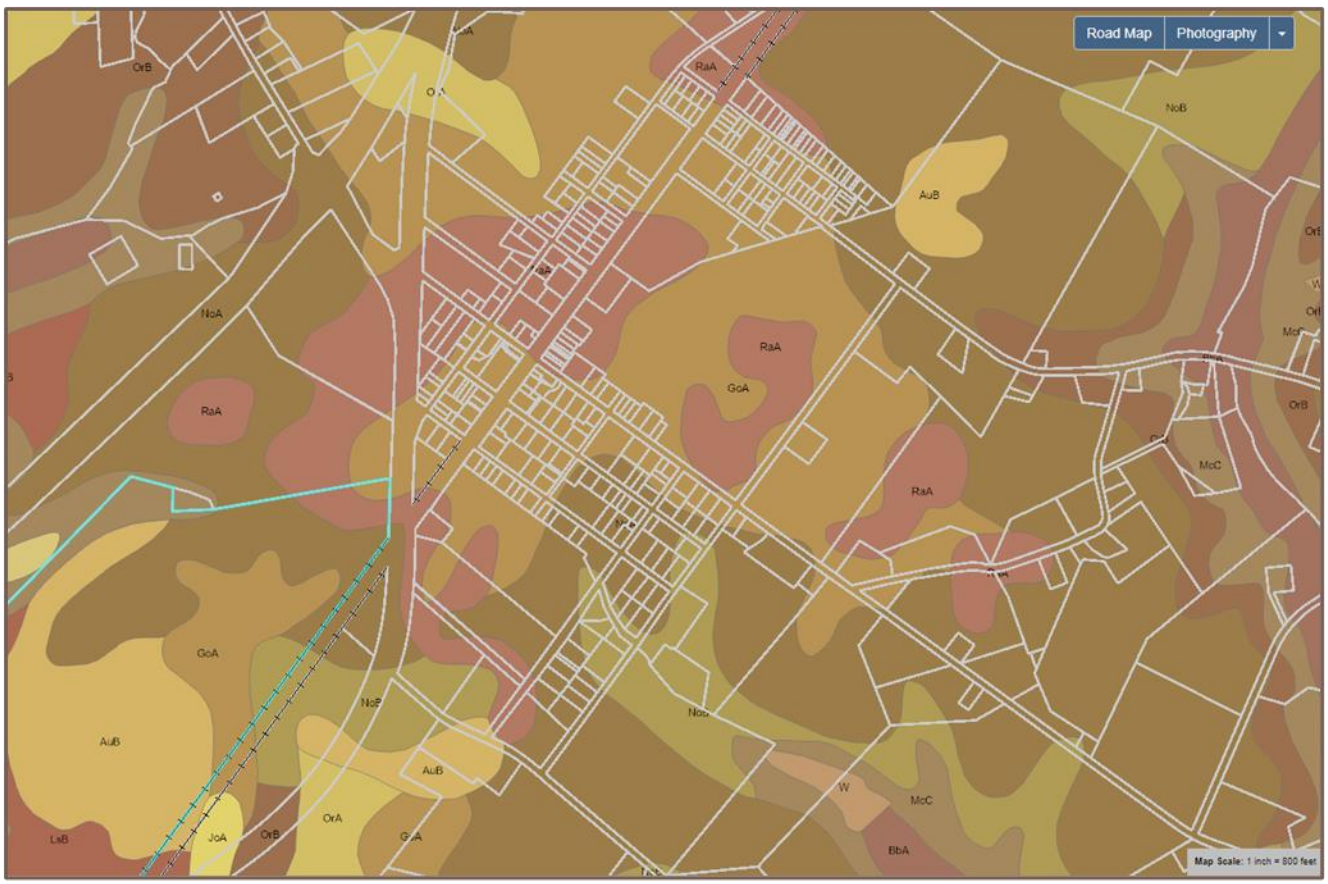


Exhibit A-3: Soils Mapped within Corporate Limits of the Town of Calypso

(Source: Duplin Co GIS)

A-4

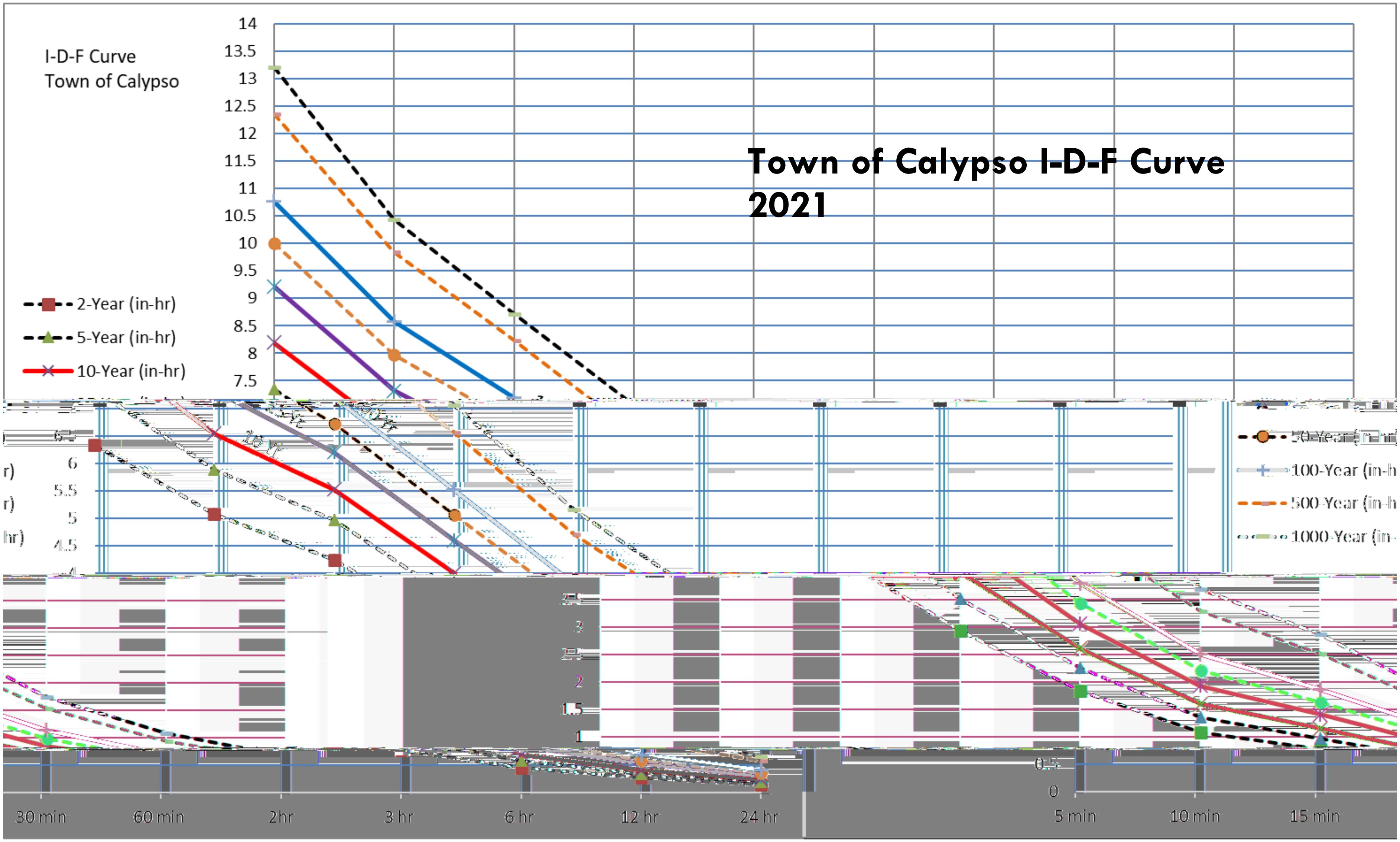
RUNOFF COEFFICIENTS

LAWNS:	(1) SANDY SOILS	FLAT	<2%	0.10
		AVERAGE	2% - 7%	0.15
		STEEP	>7%	0.20
	(2) HEAVY SOILS	FLAT	<2%	0.15
		AVERAGE	2% - 7%	0.20
		STEEP	>7%	0.30
WOODS, CEMETERIES, PARKS:				0.20
UNIMPROVED AREAS (PASTURE, CROP, ETC.):				0.25
PLAYGROUNDS:				0.30
RESIDENTIAL:	(1) APARTMENTS AND TOWNHOUSES			0.70
	(2) LOT SIZE <1/4 ACRE (R-6, R-9)			0.60
	(3) LOT SIZE <1/3 ACRE (R-15)			0.55
	(4) LOT SIZE <1/2 ACRE (R-20)			0.50
	(5) LOT SIZE <1.0 ACRE			0.40
	(6) LOT SIZE >1.0 ACRE			0.35
INDUSTRIAL:	(1) LIGHT			0.70
	(2) HEAVY			0.80
COMMERCIAL:	(1) DOWNTOWN, STRIP, MALL, PAVEMENT AREAS			0.95
	(2) CENTER			0.90
	(3) NEIGHBORHOOD			0.85
ROOF:				0.95
PAVEMENT:	(1) ASPHALT OR CONCRETE			0.90
	(2) BRICK			0.80
GRAVEL:				0.30

TABLE A-5: COMPARISON OF COMMON PIPE CULVERT MATERIALS[8]					
Property/Condition	**Corrugated Galvanized Steel[5,8]**	**Aluminized Corrugated Steel**	**Corrugated Aluminum Alloy**	**Corrugated HDPE, Smooth Wall Interior[6]**	**Reinforced Concrete**
Cost (material, transportation, installation)	$	$	$$	$$	$$$
Lifespan[7] (years)[8]	20 - 30	Type 2: 75+[9]	25 – 30 (75[10])	50 – 50	50 - 100
Shorter lifespan when always wet (ex. Wetlands)	X				
Ideal pH range	6 – 10.5	5.0 - 9.0	4.5 - 9.0	All	5.0 - 9.0
Bog Compatible (pH: 3 – 5)			X	X	
Swamp Compatible (pH: 7 – 8)	X	X	X	X	X
Light weight	X	X	X	X	
Ease of Installation	X	X	X	X	
Readily available	X	X		Small sizes	X
Smooth surface (good for heavy water flow)				X	X
Resistant to abrasion and corrosion		X	X	X	X
Easily punctured during backfill			X	Use granular backfill compact haunches properly	
Salt resistant		X	X	X	
Notes		Susceptible to corrosion if coating is compromised	Minimum of 1 ft. cover and proper backfill methods	Meet NCDOT Specs for cover and backfill	

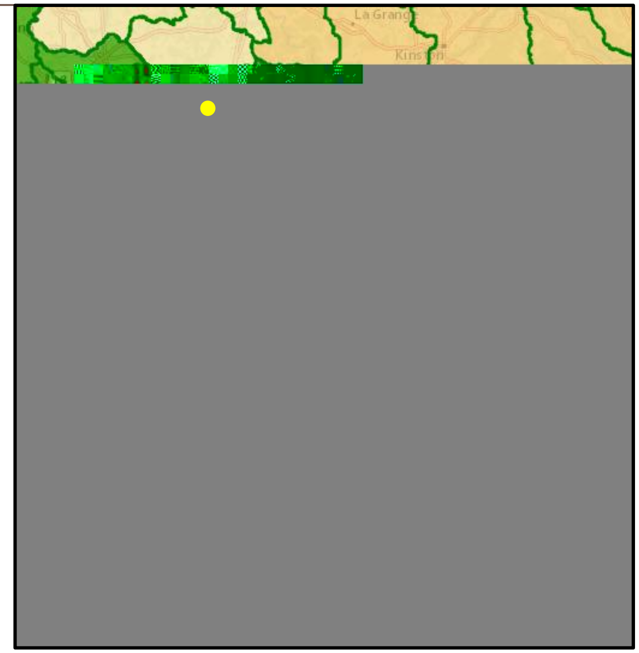
[5] Worst performing pipe material type, Gwinnett County, Georgia GIS Database.
[6] HDPE pipe is the second-best performing material. Concrete is in the middle of the pack, Gwinnett County, Georgia GIS Database
[7] Can vary depending on many factors such as acidity of soil, abrasive conditions, and installation practices.
[8] NCDOT allows only smooth inside wall in storm drainage systems (¶305-2). Galv. CMP is not recommended for Calypso as the soil is strongly acid (pH 5.2).
[9] MnDOT recommends using aluminized type 2 CMP because its service life is 3 to 8 times better than galvanized Steel Pipe. Top rated pipe material.
[10] Manufacturers Product Literature.
Table Source: *Field Guide for Maintaining Roadside Ditches*, Fortin Consulting, Inc.; University of Minnesota Sea Grant Program, 2014, w/ revisions by Appian.

A-6



Comprised of Upper Goshen Swamp (west of 117/40) and Middle Goshen Swamp (east of 117/40), Cape Fear River Basin

Calypso, North Carolina 35.1530° N 78.1079° W 160.07 feet*



Downtown Calypso, NC
Point Precipitation Frequency Estimates From NOAA Atlas 14
Extracted November 15, 2021

*Source: USGS
Precipitation Frequency Estimates
(inches)

Precipitation Frequency Estimates (inches)										
ARI* (years)	**5 min**	**10 min**	**15 min**	**30 min**	**60 min**	**2hr**	**3 hr**	**6 hr**	**12 hr**	**24 hr**
2	0.53	0.85	1.06	1.47	1.84	2.17	2.32	2.77	3.25	3.75
5	0.61	0.98	1.24	1.76	2.26	2.73	2.91	3.49	4.12	4.85
10	0.68	1.09	1.38	2.00	2.61	3.21	3.46	4.15	4.92	5.80
25	0.77	1.22	1.55	2.30	3.06	3.86	4.22	5.08	6.60	7.24
50	0.83	1.33	1.68	2.53	3.43	4.43	4.89	5.91	7.10	8.49
100	0.90	1.43	1.80	2.76	3.80	5.03	5.61	6.80	8.22	9.90
500	1.03	1.64	2.06	3.28	4.71	6.59	7.57	9.24	11.30	13.90
1000	1.10	1.74	2.18	3.53	5.15	7.39	8.60	10.50	13.00	16.00

*These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.

	Duration									
Return Period (years)	**5 min**	**10 min**	**15 min**	**30 min**	**60 min**	**2hr**	**3 hr**	**6 hr**	**12 hr**	**24 hr**
2-Year (in-hr)	**6.34**	**5.07**	**4.24**	**2.94**	**1.84**	**1.09**	**0.77**	**0.46**	**0.27**	**0.16**
5-Year (in-hr)	**7.34**	**5.88**	**4.96**	**3.52**	**2.26**	**1.37**	**0.97**	**0.58**	**0.34**	**0.20**
10-Year (in-hr)	**8.20**	**6.54**	**5.52**	**4.00**	**2.61**	**1.61**	**1.15**	**0.69**	**0.41**	**0.24**
25-Year (in-hr)	**9.22**	**7.32**	**6.20**	**4.60**	**3.06**	**1.93**	**1.41**	**0.85**	**0.55**	**0.30**
50-Year (in-hr)	**10.00**	**7.98**	**6.72**	**5.06**	**3.43**	**2.22**	**1.63**	**0.99**	**0.59**	**0.35**
100-Year (in-hr)	**10.76**	**8.58**	**7.20**	**5.52**	**3.80**	**2.52**	**1.87**	**1.13**	**0.69**	**0.41**
500-Year (in-hr)	**12.36**	**9.84**	**8.24**	**6.56**	**4.71**	**3.30**	**2.52**	**1.54**	**0.94**	**0.58**
1000-Year (in-hr)	**13.20**	**10.44**	**8.72**	**7.06**	**5.15**	**3.70**	**2.87**	**1.75**	**1.08**	**0.67**

A-7

DRAINAGE OUTFALL PLAN & PROFILE (CAROLINA ST TO CALYPSO CLUB POND)