# Wash Creek Watershed

## STORMWATER MASTER PLAN

May 2019

WR Job Number: 2180508

Jennifer Diaz, PE

WithersRavenel
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**WithersRavenel**
**84 Coxe Avenue, Suite 260**
**Asheville, NC 28801**

## INTRODUCTION

The City of Hendersonville has engaged WithersRavenel for the development of a stormwater master plan for the Wash Creek watershed. The Wash Creek Watershed is approximately 1378 acres. The goal of the stormwater master plan is to identify and prioritize capital improvement projects that will allow the City to plan and budget for improvements to its stormwater infrastructure.

## FIELD RECONNAISSANCE SUMMARY

The preliminary data analysis utilized existing GIS data provided by the City to determine the structures within the Wash Creek Watershed that would require additional inspection. Field data collection was done in the Fall of 2018. The field crews collected information on the stormwater structures by pulling lids and making visual observations from ground level. A total of 641 structures were surveyed for additional information (a total of 778 structures were identified but 137 of them were inaccessible). The team was able to obtain measurements and note the general condition, all of which is documented in the ArcGIS database. The condition of each structure was categorized as either Excellent, Good, Fair, Poor, or Needs Repair.

The observed conditions are defined as follows:

**Excellent** New infrastructure in perfect condition;

**Good** Infrastructure with no discernable flaws, in optimal working condition without much sediment or debris;

**Fair** Infrastructure is in working order but shows signs of age. There is a significant amount of wear and tear and/or debris and sediment is substantial;

**Poor** Infrastructure needs maintenance (signs of an active problem such as cracking, sedimentation, etc). These structures are visibly broken or in imminent danger of failure;

**Needs Repair** The infrastructure has failed and requires immediate maintenance action.

The table below tabulates the condition assessments of the structures:

**Table 1.** Field results of condition assessment

| Condition | Number of Structures |
|---|---|
| Excellent | 1 |
| Good | 281 |
| Fair | 241 |
| Poor | 103 |
| Needs Repair | 15 |

Additional comments are included in the ArcGIS data when the condition is considered to be Poor or Needs Repair.

### Inventory Analysis

The GIS inventory located inlets, manholes, and culvert endwalls/headwalls. The connectivity of these elements in the GIS interface determined pipe length and slope. The Wash Creek Watershed was determined to have 49,405 linear feet of storm drainage pipe; 1,671 linear feet of that is associated with culverts. Since the pipes themselves were not inspected, a condition is not directly attributed to them in the GIS database. For the purposes of this analysis, a condition was attributed to the pipe based on the worse condition of the connected structures. For instance, if the upstream inlet of the pipe was considered to be in “fair” condition and the downstream inlet was considered to be in “good” condition, the pipe was assigned a “fair” condition.

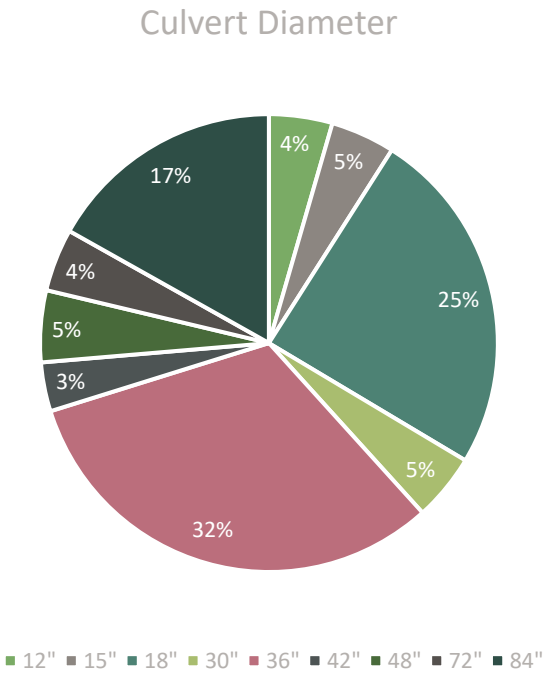



**Figure 1.** Diameter of culverts in inches by percentage of linear foot

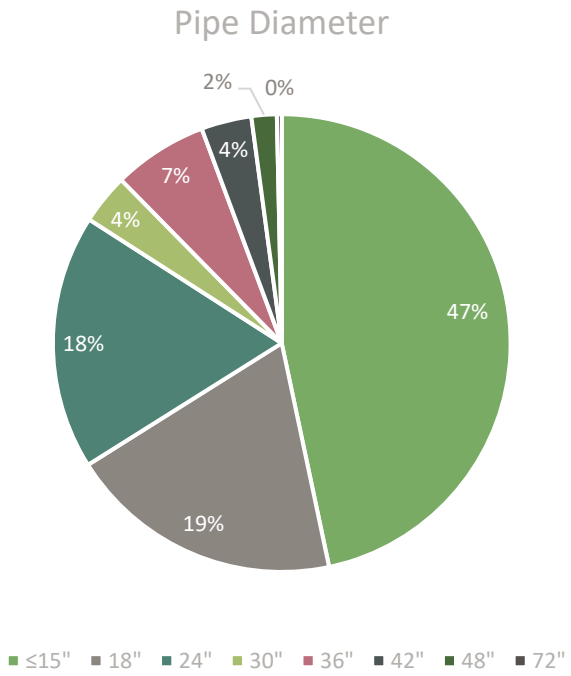



**Figure 2.** Diameter of pipes in inches by percentage of linear foot

Installation information of the infrastructure was not available. Therefore, age was estimated based on the material and likely timeframe that material was installed in this region. For instance, corrugated metal pipes were quite popular in the 1970s therefore metal pipes were assumed to between 40-49 years old.

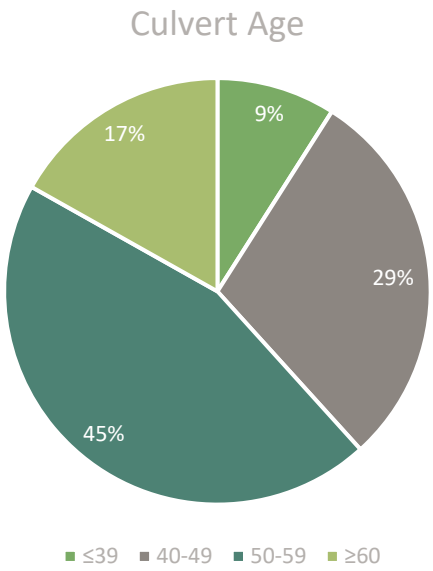



**Figure 3.** Estimated age of culverts in years by percentage of linear foot

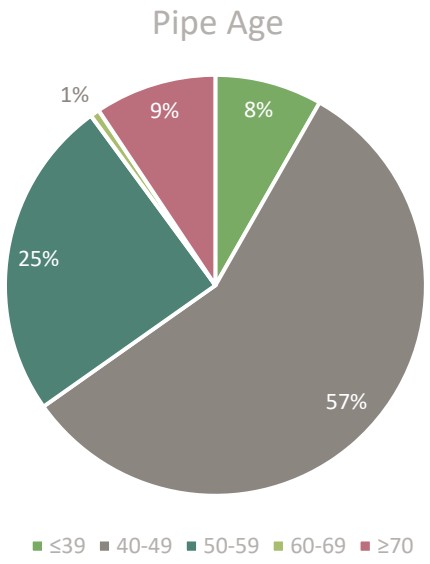



**Figure 4.** Estimated age of pipes in years by percentage of linear foot

## STORMWATER INFASTRUCTURE ASSESSMENT

Each of the elements of the surveyed stormwater network were evaluated in order to prioritize repair or replacement. Based on the stormwater inventory, the attributes stored in the GIS database were used to establish a "score". The score was based on the "Likelihood of Failure" (LoF) and "Consequence of Failure" (CoF).

Likelihood of Failure or LoF was based on condition, age, and material. Condition was determined from the field assessment. Age was estimated based on the material as described above. Material was determined from the field observations.

The CoF attempts to quantify the criticality of the infrastructure. The CoF was based on diameter and general location. Larger diameter pipes were assigned a higher score. Infrastructure located within a road was assigned a higher score than those located outside the roadway.

Lower scores for LoF and CoF indicate less risk, while higher scores indicate greater risk. Together, combining the condition and the consequence of failure of the structures allowed for a general prioritization score to be determined for each structure. The overall rating indicates the relative priority for repair/replacement of the stormwater infrastructure element.

The tables below illustrate the numeric score that was assigned based on the associated criteria:

**Table 2.** Likelihood of Failure (LoF) score based on estimated age of pipe.

| Pipe Age (years) | LoF Score |
|---|---|
| 60+ | 7 |
| 50+ | 6 |
| 40+ | 5 |
| 30+ | 4 |

**Table 3.** Likelihood of Failure (LoF) score based on material of pipe.

| Material | LoF Score |
|---|---|
| PVC | 0.25 |
| CMP | 0.5 |
| CPP | 0.25 |
| Concrete | 0.5 |
| Clay | 1 |
| Brick | 1 |
| DIP | 0.5 |

**Table 4.** Likelihood of Failure (LoF) score based on condition of pipe.

| Condition | LoF Score |
|---|---|
| Good | 0.5 |
| Fair | 1 |
| Poor | 2 |

**Table 5.** Consequence of Failure (CoF) score based on diameter of pipe.

| Diameter (inches) | CoF Score |
|---|---|
| 50+ | 8 |
| 40 - 50 | 7 |
| 30 - 40 | 6 |
| 20 - 30 | 5 |
| 15 - 18 | 4 |
| 6 - 12 | 3 |
| Unknown | 2 |

**Table 6.** Consequence of Failure (CoF) score based on location of pipe.

| Within a Roadway | CoF Score |
|---|---|
| Yes | 2 |
| No | 1 |

## Structure Prioritization

The LoF and CoF scores were tabulated for each individual structure. Each structure has been assigned this priority score in the GIS database. The scores range from 1-100, from least priority to most priority. The scores were gradated from low priority to extreme priority. The following charts summarize the results of the prioritization data analysis. Maps depicting the location of structures and identifying them by priority have been included in the Maps section of this report.

### Culverts

Medium Priority – 221 linear feet

Significant Priority – 1,411 Linear feet

High Priority – 39 Linear feet

| Consequence of Failure (Minor ----- Catastrophic) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 277 | 39 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 97 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 23 | 40 | 21 | 69 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 82 | 0 | 238 | 50 | 458 | 0 |
| 5 | 0 | 0 | 0 | 0 | 95 | 25 | 80 | 57 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Rare ---------- **Likelihood of Failure** ---------- Almost Certain

**Risk Scale Legend**

Low | Medium | Significant | High | Extreme

### Pipes

Medium Priority – 13,782 linear feet

Significant Priority – 33,075 Linear feet

High Priority – 877 Linear feet

| Consequence of Failure (Minor ----- Catastrophic) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 165 | 63 | 309 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 105 | 451 | 613 | 1,710 | 266 | 0 |
| 7 | 0 | 0 | 0 | 0 | 1,978 | 175 | 853 | 2,037 | 303 | 0 |
| 6 | 0 | 0 | 0 | 0 | 3,163 | 1,005 | 3,527 | 4,953 | 682 | 0 |
| 5 | 0 | 0 | 0 | 0 | 4,812 | 1,666 | 4,666 | 6,060 | 1,408 | 0 |
| 4 | 0 | 0 | 0 | 199 | 2,275 | 661 | 940 | 1,668 | 1,020 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Rare ---------- **Likelihood of Failure** ---------- Almost Certain

**Risk Scale Legend**

Low | Medium | Significant | High | Extreme

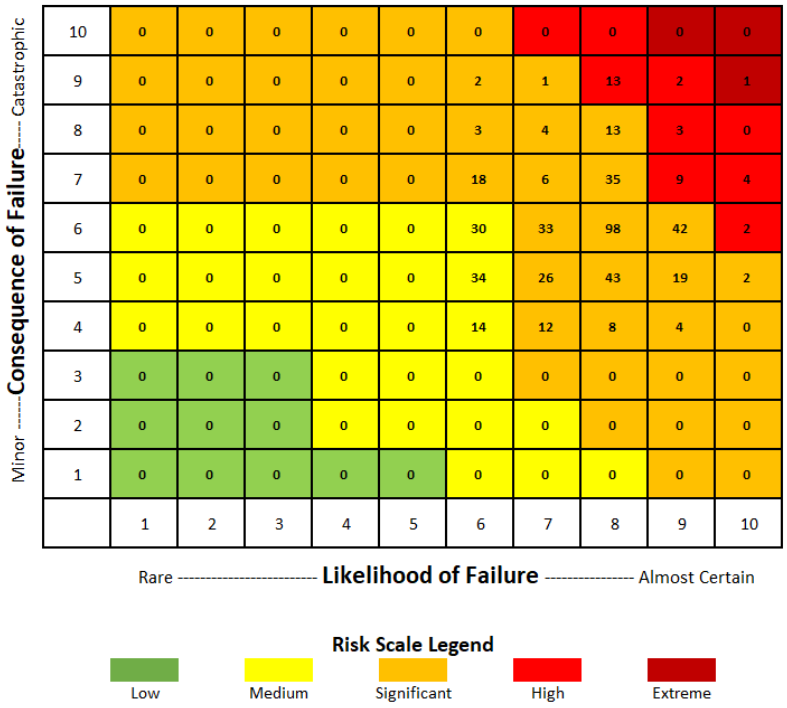
## Inlets

Medium Priority – 78

Significant Priority – 369

High Priority – 33

Extreme Priority - 1



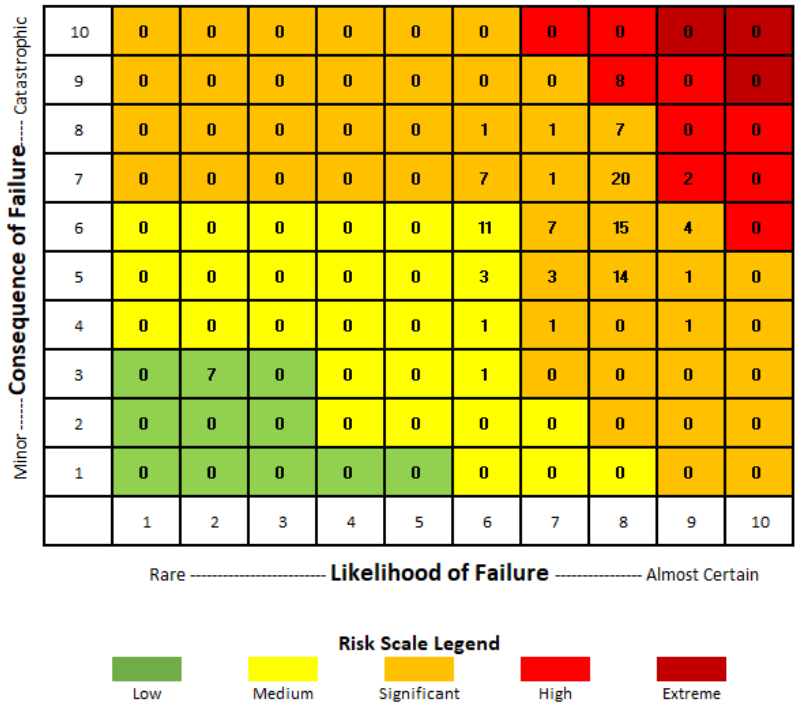

## Manholes

Low Priority - 7

Medium Priority – 16

Significant Priority – 98

High Priority – 10



# POTENTIAL PROJECT IDENTIFICATION

## Areas of Concern

From the field reconnaissance, with input from the City, five (5) areas of concern were identified. They are listed below. Please refer to the Area of Concern identification map for further information. From these areas of concern, with consideration of the prioritization analysis, five (5) project areas were identified for further study.

**Area of Concern #1** *Along 5th Ave W from Blythe Street and Ehringhaus St / Along Valley St from Holmes Street to 3rd Ave W*

This area is approximately 26.25 acres of the watershed. The following infrastructure was located within this area:

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" RCP | 1215 |
| 18" RCP | 1029 |
| 24" RCP | 1041 |
| 30" RCP | 450 |
| 36" RCP | 38 |
| 42" RCP | 24 |
| 48" RCP | 63 |
| Small Box Culvert | 1058 |
| Manholes | 7 |
| Inlets | 51 |
| Headwalls | 6 |

Of the infrastructure listed above 26 inlets were found to be in fair condition, 8 in poor condition, and 2 were in need of repair. The remaining inlets were considered to be in good condition. One of the inlets identified as in need of repair, INLEI 301, was noted as a potentially hazardous condition in its current state. The other in need of repair inlet, INLE302 was noted to have the grate cemented on.

There are 6 discharge points in this area. One was considered fair condition and 2 to be in poor condition. The remaining discharge points were found to be in good condition.

There are 7 manholes in this area. One was considered to be in fair condition and 3 were unknown. The remaining 3 were in good condition.

The prioritization analysis identified the infrastructure within this area of concern to be high priority. Three (3) areas were identified for further study; Project Areas #1A, #1B, and #1C were analyzed as potential improvement projects.

**Area of Concern #2** *Around Buncombe Street between 5th Ave W and Lily Pond Dr*

This area is approximately 29.28 acres of the watershed. The following infrastructure was located within this area:

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" RCP | 2233 |
| 18" RCP | 704 |
| 24" RCP | 577 |
| 30" RCP | 890 |
| 36" RCP | 675 |
| 48" RCP | 214 |
| Small Box Culvert | 596 |
| Large Box Culvert | 68 |
| Manholes | 13 |
| Inlets | 45 |
| Headwalls | 7 |

Of the infrastructure listed above, 17 inlets were found to be in fair condition, 10 in poor condition, and 8 were inaccessible and/or unknown. The remaining inlets were considered to be in good condition.

There are 7 discharge points in this area. Three were considered to be in fair condition and 3 were found to be in poor condition. One discharge point was considered to be in good condition. Of note, 2 of the discharge points identified as in fair condition, STD73 and STDP 74, appear to be conveying stormwater underneath houses.

There are 13 manholes in this area. One was considered to be in fair condition and 7 were unknown. The remaining 5 were in good or excellent condition.

The prioritization analysis identified the infrastructure within this area of concern to be high priority. Two (2) areas were identified for further study; Project Areas #2A and #2B.

### Area of Concern #3 *Near 5th and 3rd Ave West between Jordan St and Blythe St*

This area is approximately 10.97 acres of the watershed. The following infrastructure was located within this area:

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" RCP | 1137 |
| 18" RCP | 311 |
| 24" RCP | 215 |
| 30" RCP | 209 |
| 36" RCP | 64 |
| Large Box Culvert | 30 |
| Manholes | 6 |
| Inlets | 19 |
| Headwalls | 7 |

Of the infrastructure listed above, 5 inlets were found to be in fair condition, 6 in poor condition, and 3 were in need of repair. The remaining inlets were considered to be in good condition. The inlets in need of repair were identified as INLE426, INLE 439, and INLE 442.

There are 7 discharge points in this area. One was considered to be in fair condition and 3 were found to be in poor condition. The remaining three discharge points were considered to be in good condition.

There are 6 manholes in this area. Two were considered to be in fair condition, 2 in poor condition, and 2 were unknown.

The prioritization analysis identified the structures in this area to be medium priority in general. The prioritization analysis did identify one portion of the system (GRAV 429) as being high/significant priority in this area.

### Area of Concern #4 (PW #1) *Near Blythe Street between Pinecrest Drive and Glenbrook Drive*

This area is approximately 5.45 acres of the watershed. The following infrastructure was located within this area:

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" RCP | 117 |
| 18" RCP | 336 |
| Inlets | 5 |
| Headwalls | 1 |

Of the infrastructure listed above, one inlet was found to be in fair condition and one was in need of repair. The remaining inlets were considered to be in good condition. The inlet in need of repair was identified as INLE445. It was noted that the lid was stuck and possibly abandoned.

There was 1 discharge points in this area. It was found to be in good condition.

Evaluation of this area identified an open conveyance feature at the rear of residential lots and a pond. The prioritization analysis identified the structures in this area to be low priority.

### Area of Concern #5 (PW#2) *Between N Oak Street and N Justice Street from Florida Ave and 4th Ave West*

This area is approximately 2.86 acres of the watershed. The following infrastructure was located within this area:

| Structure | Quantity (pipes in lf) |
|---|---|
| 24" RCP | 149 |
| Small Box Culvert | 40 |
| Manholes | 1 |
| Inlets | 4 |
| Headwalls | 3 |

Of the infrastructure listed above, 2 inlets were found to be in fair condition and 1 was unknown. The remaining inlets were considered to be in good condition.

There are 3 discharge points in this area. One was considered to be in fair condition and 2 were found to be in good condition.

The condition of the manhole in this area could not be verified.

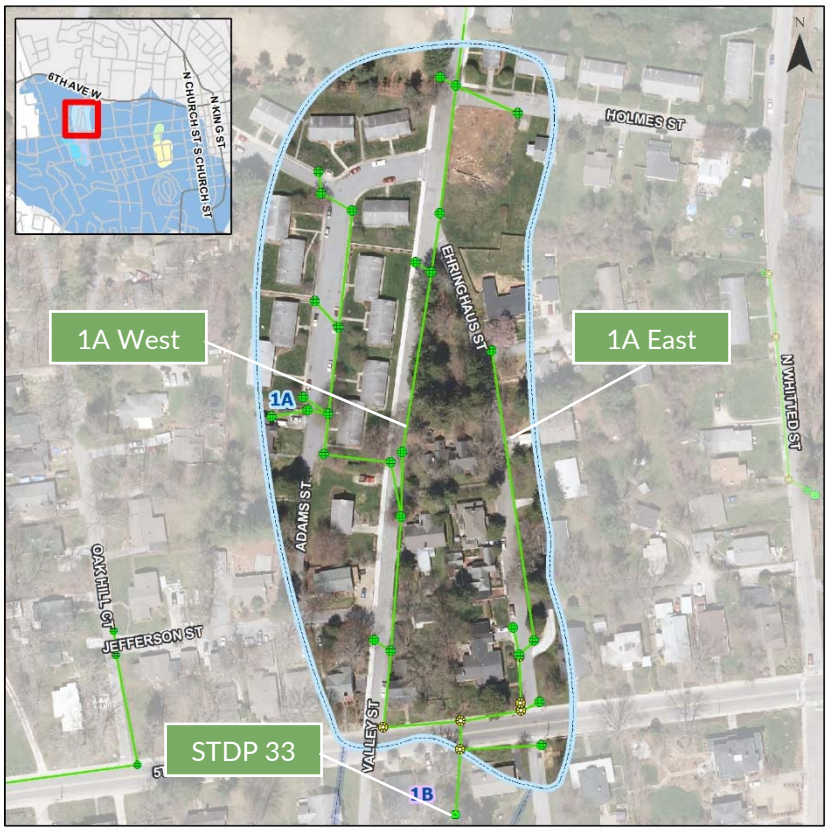
The prioritization analysis identified the structures in this area to be low priority.

## Project Area Analysis

Five (5) project areas were identified for further study. Simplified hydrologic and hydraulic models were created for each project area based on the collected survey information, estimated drainage area, and land use assumptions. Assumptions and adjustments were made for the purposes of this study for inverts where survey data was unknown or incomplete. PCSWMM was used to evaluate the project area drainage systems using modified rational for flows simulating the 10-year storm event. The purpose of this exercise was to understand the potential conveyance capacity of the existing system. This is for informational purposes only. Profile results are included in the Project Area Analysis section of the report.

### Project Area 1A

This system outlets to STDP 33. There are two main lines of storm drainage that contribute to this outfall: 1A West and 1A East. The drainage area to 1A West was determined to be 14 acres. The drainage area to 1A East was determined to be 7 acres. Both systems are piped systems without open channels. Each of these systems is located within the right-of-way.




The conveyance analysis results show that the storm drainage outfall where these two systems meet is adequately sized for the modeled flows however the condition may require replacement. The upstream systems are not sized to convey the design storm and should be upsized.

*Recommendation:* Both pipe systems 1A East and 1A West should be upgraded in order to convey the design storm. Site evaluation of the culvert at STDP 33 is recommended to determine if the pipe should be replaced.

### Project Area 1B

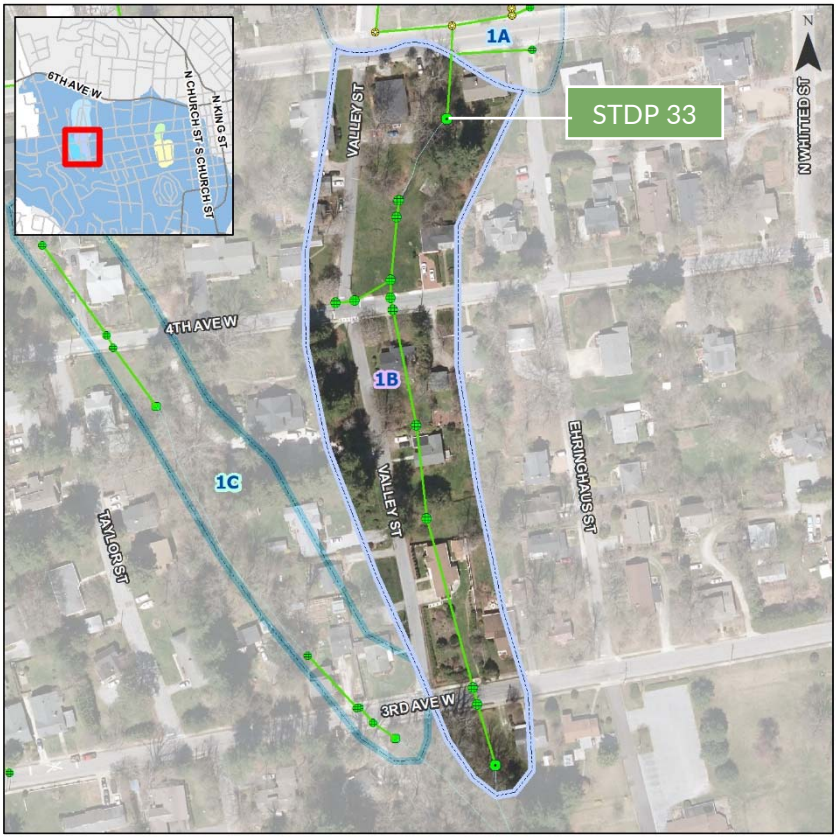
This system is just downstream of Project Area 1A. The drainage area totals 29 acres. The system is comprised of an open channel from discharge point at STDP 33 which then transitions to a subsurface network of 24" VCP and concrete box culverts. The system traverses through private property.

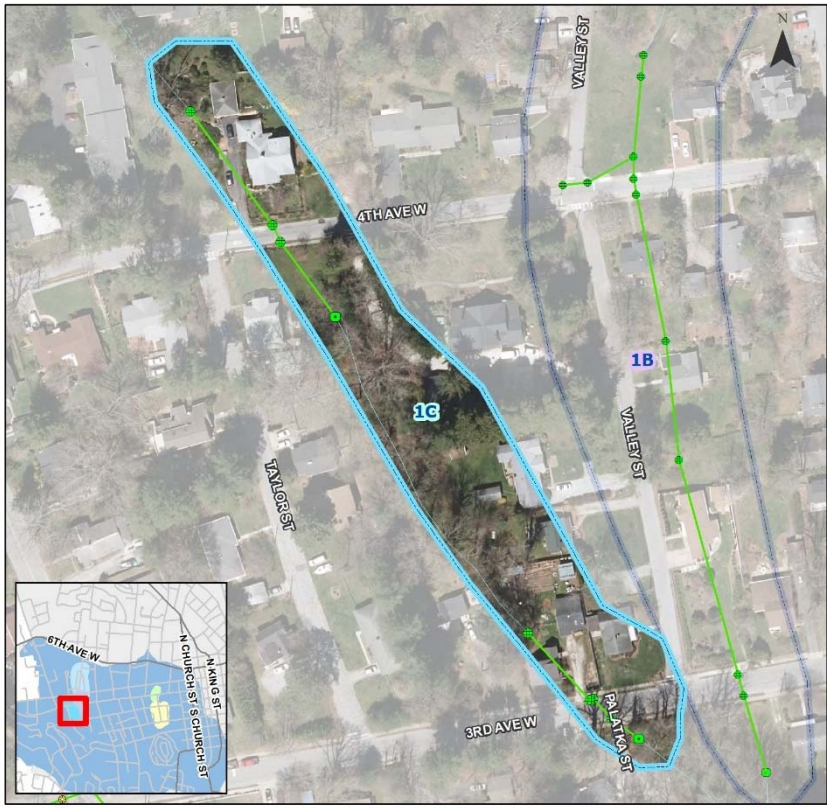
The system is not adequately sized to handle the design storm as modeled.

*Recommendation:*

It is recommended that the materials and pipe size be upgraded as well as rerouting the system to stay within the right-of-way.

This recommendation requires the addition of a minimum of 2 junction boxes as well as an additional 100 linear feet of storm drainage.




### Project Area 1C

This system receives a drainage area of 70 acres. The system is comprised of channel flow as well as a piped network. It is located primarily on private property.

The system is not adequately sized to handle the design storm as modeled.

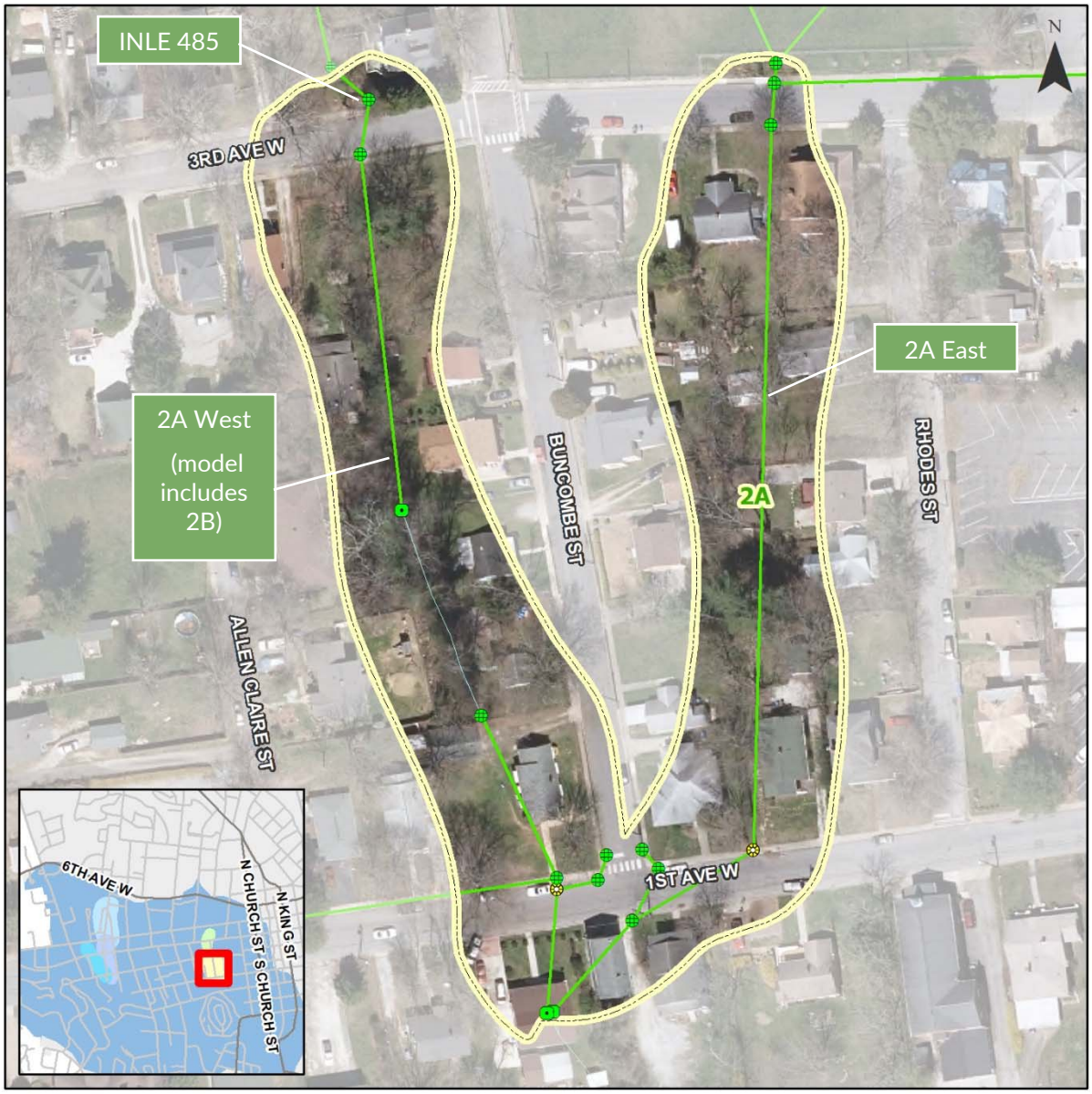
*Recommendation:*

It is recommended that the conveyance system be rerouted to stay within the right-of-way. This recommendation requires the addition of a minimum of 2 junction boxes as well as an additional 600 linear feet of storm drainage.

Alternatively, channel improvements could be made if approved by environmental permitting agencies and the channel system could be placed in an easement to be operated and maintained by the City. Improvements to the storm drain network associated with this project site would still be warranted if this alternative is explored.

### Project Area 2A

Similar to Project 1A, Project 2A is comprised of two main storm drain networks that converge at one outfall point. Each system was analyzed as 2 distinct systems; Project 2A East and Project 2A West. The drainage area to Project 2A East is 32 acres while the drainage area to Project 2A West is 38 acres. Project 2A East is a piped system where as the Project 2A West has portions of open channel. Both systems are located on private property with portions crossing the right-of-way.




Project 2A East is undersized for the majority of network. The pipe size is reduced midway through which restricts flow.

Project 2A West is undersized up until the stream. Then the stream and downstream infrastructure adequately handle the flow in the design storm. The undersized portion has been identified separately as Project 2B below.

*Recommendation:* Improvements to the 2A should include upgrading the pipe that is currently restricting flow. This 15" pipe goes through an open space area. It is recommended that the pipe size be upgraded throughout this network and that the pipe through the open area be realigned through the nearby parking lot that then ties into the right-of-way. Easements may be required.

It is also recommended that the drainage systems be located into the right-of-way. The west alignment is proposed to move into Buncombe Street. The East alignment is proposed to go into Rhodes Street. This adds approximately 195 LF and 4 structures for the realignment along Rhodes Street and 270 LF and 1 additional structure for the realignment along Buncombe Street

### Project Area 2B

Modeled as part of the west side of Project 2A, only a portion of this network was deemed inadequate. The portion of the network from INLE 520 to INLE 485 is considered Project Area 2B.

*Recommendation:* The culvert crossing the road, GRAV 612 is recommended to be upgraded up through manhole STMH18.

## PRELIMINARY COST OPINIONS FOR BUDGETING PURPOSES

In order to help the City of Hendersonville budget for the potential projects identified above, rudimentary cost opinions were developed for each project. The cost opinions were based on replacing the current infrastructure quantities only; costs associated with surveying, engineering design, environmental permitting, and land or easement acquisitions were not considered. Assumptions for proposed pipe size and location improvements were based on the conveyance capacity analysis and do not consider constraints such as existing utilities. Construction costs were assumed to be two times the materials cost. The unit pricing assumed concrete structures at 10-foot depth. All pipes were replaced with Class III Reinforced Concrete Pipe. Additional contingencies were added for budgeting purposes. Below is a summary of probable costs including these contingencies. Detailed costs assumptions are included with the project details section of this report.

| Potential Project | Probable Costs |
|---|---|
| Project Area 1A | $1,380,000 |
| Project Area 1B | $930,000 |
| Project Area 1C | $640,000 |
| Project Area 2A | $1,130,000 |
| Project Area 2B | $270,000 |

## RECOMMENDATIONS

Five potential project areas were identified based on the prioritization analysis and areas of concern identified through discussions with the City. Of the five areas of concern identified by the City, two contained the highest priority areas. Three potential projects were identified in Area of Concern 1 and two potential project areas were identified in Area of Concern 2. Our preliminary hydraulic analysis of these systems identified them as being undersized for the design storm. Therefore, it is recommended that the improvements to these areas also account for improvements to the hydraulic capacity of the systems as well. Preliminary budget information has been provided to help assist in the prioritization of these projects. Due to the nature of the high priority factors relative to the estimated costs, it is recommended that Project Areas be explored in the following order 1C, 2A, 1B, 2B, 1A.

Regular maintenance is recommended for individual structures considered to be in need of repair. Fifteen structures were identified during the field reconnaissance as requiring immediate attention. Not all of these structures were captured by the recommend improvement projects.

The prioritization analysis identified areas outside of the five areas of concern that could potentially require attention in the near future. These areas were identified in this study but were not analyzed as they were outside of the areas of concern. It is recommended that these areas be monitored and studied further to determine any deficiencies in the network and to determine possible improvements.

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# INVENTORY ANALYSIS MAPS

# WASH CREEK WATERSHED
# HENDERSONVILLE, NC
# STORMWATER SYSTEM
# BY DIAMETER

## Legend

- Channel
- Wash Creek

**Gravity Stormwater Drainage System**

**Diameter**

- 6" - 10"
- 12" - 18"
- 20" - 24"
- 30" - 36"
- 42" - 48"
- 72"

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Hendersonville
Lennox Park
Toms Park
Barker Heights

# WASH CREEK WATERSHED
# HENDERSONVILLE, NC
# STORMWATER SYSTEM
# BY ESTIMATED AGE
# (BASED ON MATERIAL)

## Legend

Channel

Wash Creek

**Stormwater Drainage System**

**Estimated Age (Years)**

- < 40
- 40 - 49
- 50 - 59
- 60 - 69
- > 70

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Hendersonville

Lennox Park

Toms Park

Barker Heights

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Path: C:\AMP\Hendersonville - Wash Crk MP\AMP\Storm_Gravity_by_Estimated_Age.mxd

Printed Date: 4/24/2019 Created By: DEV

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# PRIORITIZATION MAP

# WASH CREEK WATERSHED
# HENDERSONVILLE, NC
# STORMWATER SYSTEM
# BY PRIORITY SCORE

## Legend

Channel

Wash Creek

**Gravity Stormwater Drainage System**

**PRIORITY SCORE**

- 16 - 25
- 26 - 36
- 37 - 45
- 46 - 56
- 57 - 72

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# AREAS OF CONCERN

# Areas of Concern

WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr | Cary NC, 27511
t: 919.469.3340
license #: C-0832
www.withersravenel.com

0 200 400 800 Feet

1 inch = 400 feet

## Legend

- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- Stormwater Gravity Main
- Channel

**Project Areas of Concern**

- 1
- 1A
- 1B
- 1C
- 2
- 2A
- 2B
- 3
- PW1
- PW2

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# PROJECT AREA ANALYSIS

# Area of Concern 1A

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Engineers | Planners | Surveyors
115 MacKenan Dr | Cary NC, 27511
t 919.469.3340
license #: C-0832
www.withersravenel.com

0 50 100 200 Feet
1 inch = 100 feet

| Facility ID | Diameter | Material |
|---|---|---|
| GRAV275 | 15 | RCP |
| GRAV276 | 15 | RCP |
| GRAV277 | 18 | RCP |
| GRAV278 | 18 | RCP |
| GRAV279 | 18 | RCP |
| GRAV280 | 24 | RCP |
| GRAV281 | 24 | RCP |
| GRAV282 | 24 | RCP |
| GRAV283 | 30 | RCP |
| GRAV284 | 24 | RCP |
| GRAV285 | 24 | RCP |
| GRAV286 | 10 | RCP |
| GRAV287 | 12 | RCP |
| GRAV288 | 12 | CMP |
| GRAV289 | 24 | RCP |
| GRAV290 | 18 | RCP |
| GRAV291 | 15 | RCP |
| GRAV292 | 18 | RCP |
| GRAV293 | 18 | RCP |
| GRAV294 | 30 | RCP |
| GRAV295 | 30 | RCP |
| GRAV296 | 24 | RCP |
| GRAV297 | 24 | RCP |
| GRAV298 | 12 | VCP |
| GRAV299 | 36 | CPP |
| GRAV301 | 15 | RCP |
| GRAV302 | 15 | RCP |
| GRAV303 | 24 | RCP |
| GRAV304 | Other | Other |
| GRAV534 | 15 | RCP |
| GRAV588 | 18 | RCP |

| Facility ID | Condition |
|---|---|
| INLE302 | Needs Repair |
| INLE399 | Poor |
| INLE400 | Fair |
| INLE403 | Poor |
| INLE404 | Fair |
| INLE405 | Fair |
| INLE406 | Fair |
| INLE407 | Fair |
| INLE408 | Fair |
| INLE409 | Fair |
| INLE410 | Good |
| INLE417 | Fair |
| INLE418 | Fair |
| INLE419 | Fair |
| INLE420 | Fair |
| INLE421 | Fair |
| INLE422 | Fair |
| INLE423 | Good |
| INLE424 | Good |
| INLE458 | Fair |
| INLE459 | Fair |
| INLE460 | Fair |
| INLE461 | Poor |
| INLE462 | Good |
| INLE463 | Fair |
| INLE464 | Fair |
| INLE514 | Good |
| STMH20 | Good |
| STMH46 | Unknown |
| STMH47 | Unknown |
| STMH49 | Good |
| STMH72 | Good |
| STMH73 | Fair |

## Legend

- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- swGravityMain
- Channel

**Project Areas of Concern**

- 1
- 1A
- 1B

Path: K:\18\18-0500\180508-Hendersonville - Wash Crk MP\Geomatics\GIS\AreaOfConcern_1A.mxd

Aerial Date: 2015 Printed Date: 5/10/2019 Created By: BAG

HGL

Time: 4/5/2019 12:10:00 AM

Conduit GRAV301
Flow = -3.277 cfs

Conduit GRAV588
Flow = 26.824 cfs

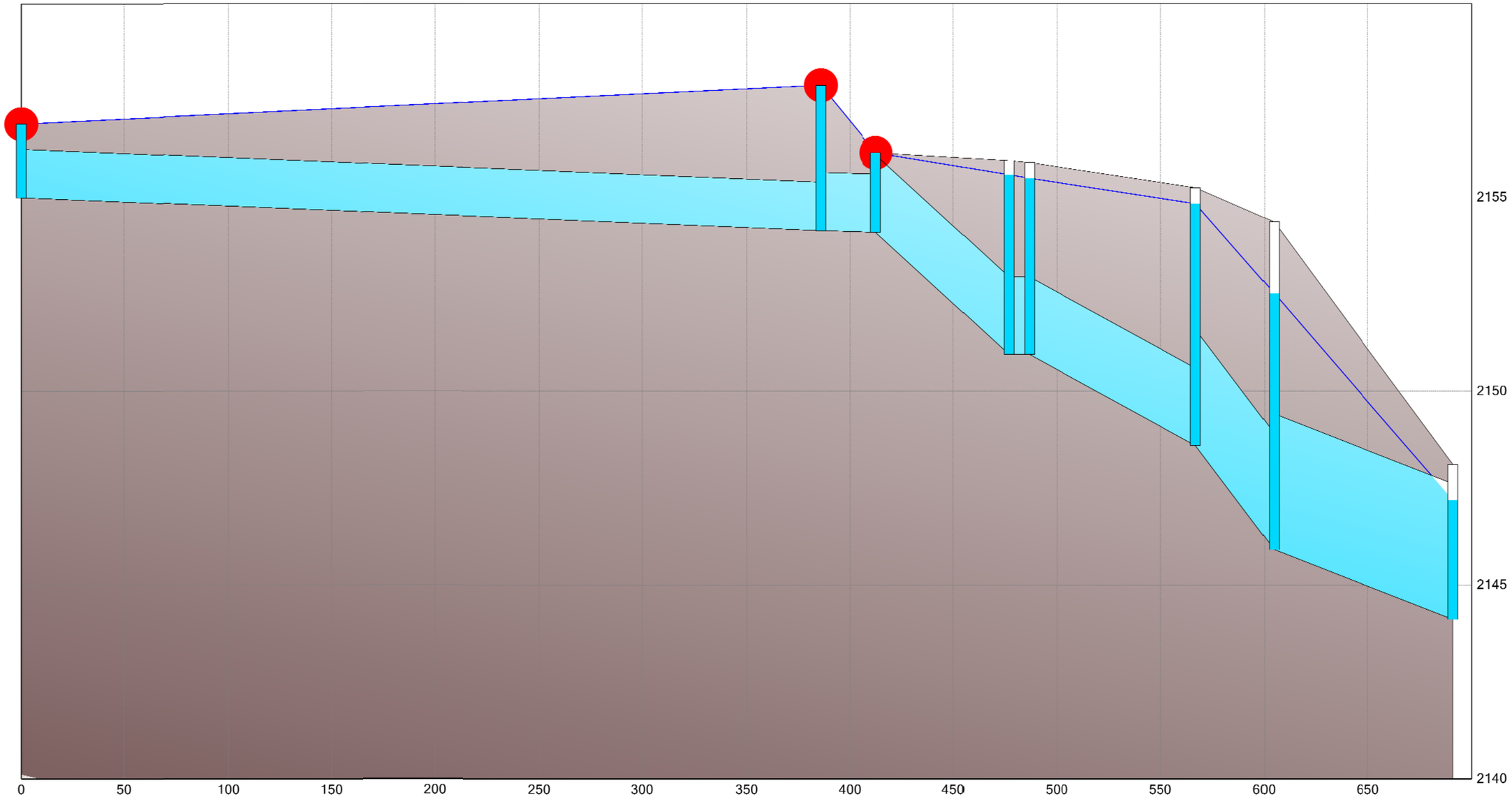
Conduit GRAV303
Flow = 21.286 cfs

Conduit GRAV297
Flow = 21.286 cfs

Conduit GRAV296
Flow = 20.477 cfs

Conduit GRAV299
Flow = 10.727 cfs

Conduit GRAV300
Flow = 17.474 cfs




Junction INLE461
CWSEL = 2156.9 ft

Junction INLE462
CWSEL = 2157.893 ft

Junction INLE464
CWSEL = 2156.15 ft

Junction STMH47
CWSEL = 2155.582 ft

Junction STMH20
CWSEL = 2155.494 ft

Junction STMH72
CWSEL = 2154.837 ft

Junction STMH73
CWSEL = 2152.526 ft

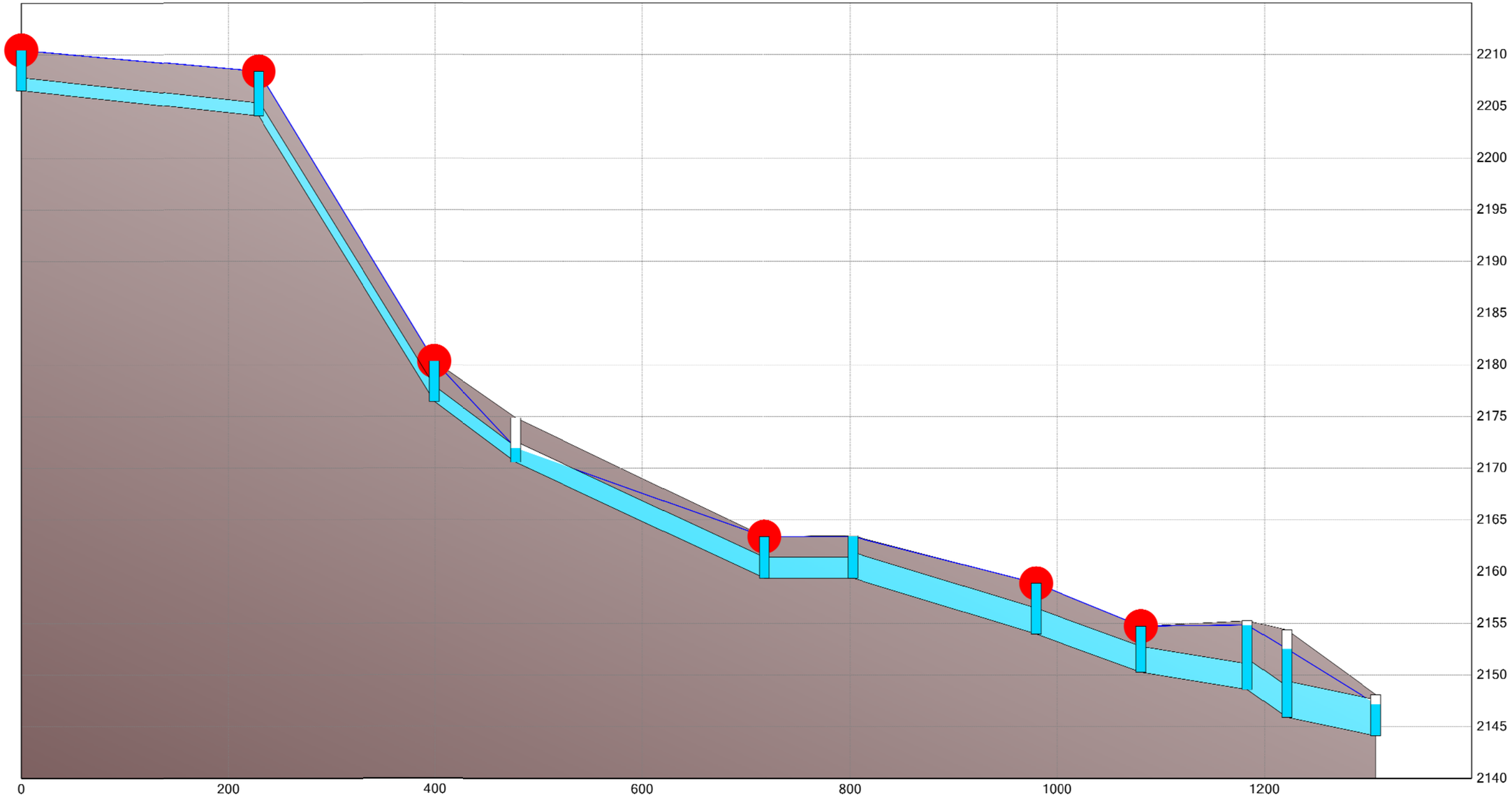
Junction STDP33
CWSEL = 2147.195 ft

HGL

Time: 4/5/2019 12:10:00 AM

**Links:**

| GRAV274 | GRAV277 | GRAV278 | GRAV280 | GRAV281 | GRAV283 | GRAV294 | GRAV295 | GRAV299 | GRAV300 |
|---|---|---|---|---|---|---|---|---|---|
| Q=6.163 cfs | Q=42.685 cfs | Q=34.159 cfs | Q=38.453 cfs | Q=-2.869 cfs | Q=65.577 cfs | Q=82.93 cfs | Q=-13.475 cfs | Q=10.727 cfs | Q=17.474 cfs |




**Nodes:**

| INLE401 | INLE400 | INLE404 | INLE405 | INLE408 | INLE409 | INLE410 | STMH49 | STMH72 | STMH73 | STDP33 |
|---|---|---|---|---|---|---|---|---|---|---|
| H=2210.455 ft | H=2208.366 ft | H=2180.349 ft | H=2171.952 ft | H=2163.382 ft | H=2163.396 ft | H=2158.872 ft | H=2154.726 ft | H=2154.837 ft | H=2152.526 ft | H=2147.195 ft |

Project Area 1A

Exisitng System

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" RCP | 730 |
| 18" RCP | 548 |
| 24" RCP | 917 |
| 30" RCP | 450 |
| 36" RCP | 381 |
| Manholes | 6 |
| Inlets | 27 |
| Headwalls | 1 |

Proposed System

| Structure | Quantity (pipes in lf) | Unit Price | Total |
|---|---|---|---|
| 24" RCP | 1278 | 115 | 146929 |
| 30" RCP | 917 | 125 | 114674 |
| 36" RCP | 450 | 150 | 67500 |
| Manholes | 6 | 3600 | 21600 |
| Inlets | 27 | 3600 | 97200 |
| Headwalls | 1 | 5000 | 5000 |
| | | Materials Subtotal | $452,903.89 |
| | | With Cost of Construction | $910,000.00 |
| | | With Engineering and Survey Costs | $1,100,000.00 |
| | | Additional Contingency | **$1,380,000.00** |

Assumptions

Does not include replacement of downstream culvert (GRAV299, STDP33)

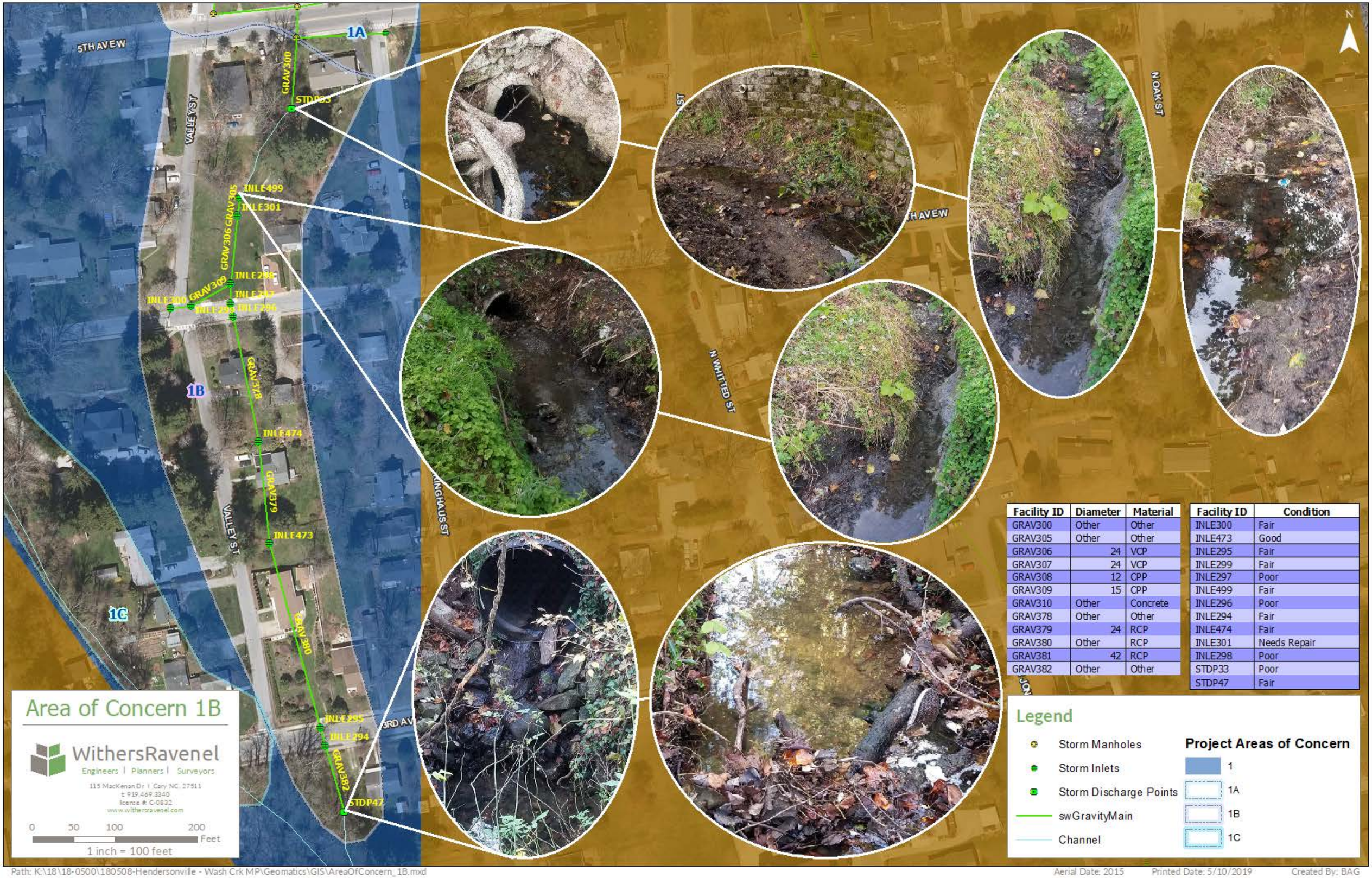
All structures assumed to have a 10' depth

All pipes replaced with Class III RCP (assumed depth 10') minimum pipe size is 15"

Construction costs assumed to be 2x materials

Engineering and Survey Costs assumed to be 20% of Construction Costs

25% additional contingency




# Area of Concern 1B

WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr | Cary, NC 27511
t 919.469.3340
license #: C-0832
www.withersravenel.com

0 50 100 200 Feet

1 inch = 100 feet

| Facility ID | Diameter | Material |
|---|---|---|
| GRAV300 | Other | Other |
| GRAV305 | Other | Other |
| GRAV306 | 24 | VCP |
| GRAV307 | 24 | VCP |
| GRAV308 | 12 | CPP |
| GRAV309 | 15 | CPP |
| GRAV310 | Other | Concrete |
| GRAV378 | Other | Other |
| GRAV379 | 24 | RCP |
| GRAV380 | Other | RCP |
| GRAV381 | 42 | RCP |
| GRAV382 | Other | Other |

| Facility ID | Condition |
|---|---|
| INLE300 | Fair |
| INLE473 | Good |
| INLE295 | Fair |
| INLE299 | Fair |
| INLE297 | Poor |
| INLE499 | Fair |
| INLE296 | Poor |
| INLE294 | Fair |
| INLE474 | Fair |
| INLE301 | Needs Repair |
| INLE298 | Poor |
| STDP33 | Poor |
| STDP47 | Fair |

## Legend

- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- swGravityMain
- Channel

**Project Areas of Concern**

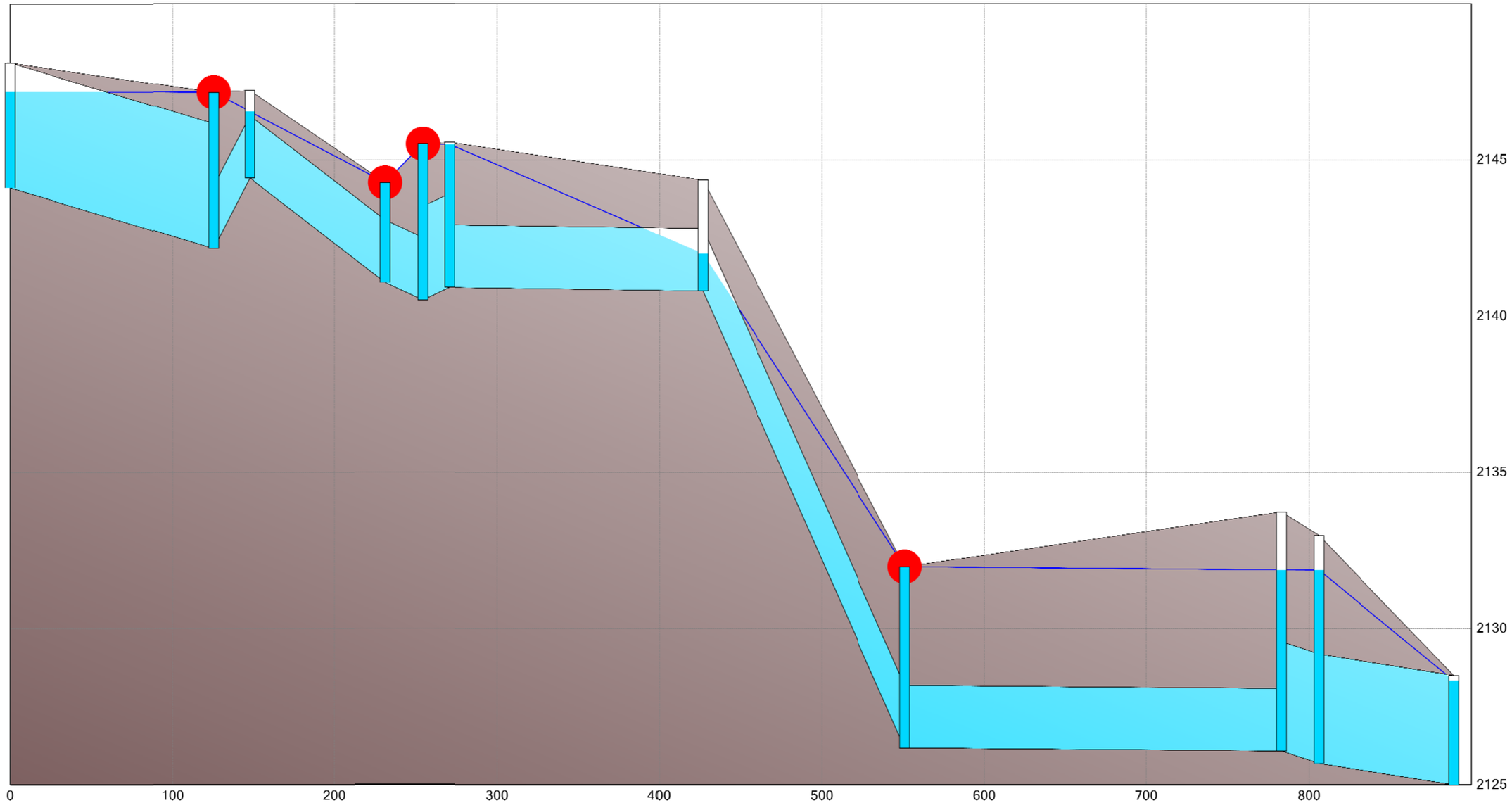
- 1
- 1A
- 1B
- 1C

HGL

Time: 4/5/2019 12:10:00 AM

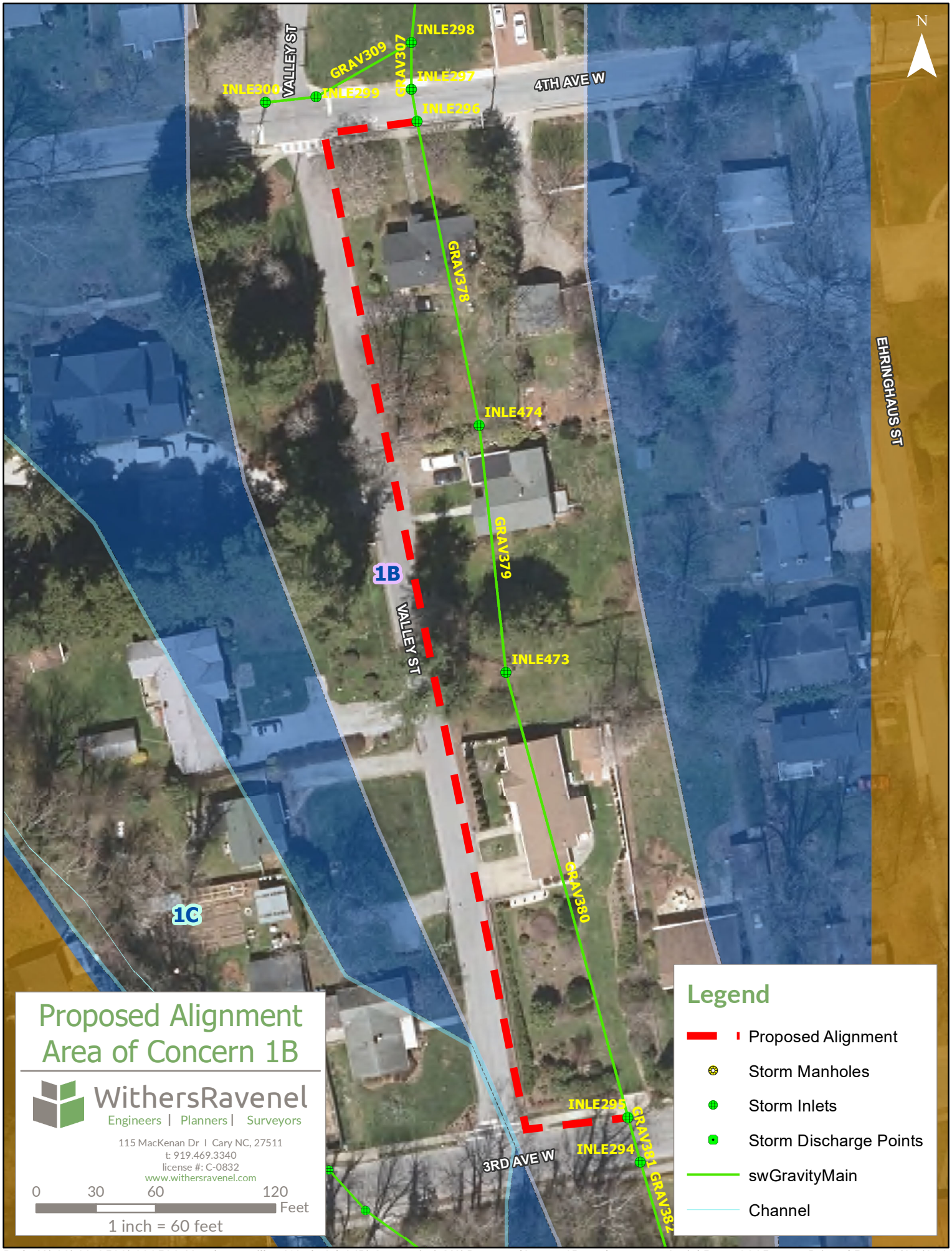
**Links:**

| C1 | GRAV305 | GRAV306 | GRAV307 | GRAV310 | GRAV378 | GRAV379 | GRAV380 | GRAV381 | GRAV382 |
|---|---|---|---|---|---|---|---|---|---|
| Q=17.456 cfs | Q=2.43 cfs | Q=2.43 cfs | Q=-3.395 cfs | Q=20.402 cfs | Q=20.402 cfs | Q=50.37 cfs | Q=4.796 cfs | Q=4.796 cfs | Q=136.589 cfs |




**Nodes:**

| STDP33 | INLE499 | INLE301 | INLE298 | INLE297 | INLE296 | INLE474 | INLE473 | INLE295 | INLE294 | STDP47 |
|---|---|---|---|---|---|---|---|---|---|---|
| H=2147.195 ft | H=2147.162 ft | H=2146.549 ft | H=2144.268 ft | H=2145.508 ft | H=2145.492 ft | H=2142 ft | H=2131.98 ft | H=2131.876 ft | H=2131.875 ft | H=2128.332 ft |




Path: K:\18\18-0500\180508-Hendersonville - Wash Crk MP\Geomatics\GIS\ProposedStorm_1B.mxd Aerial Date: 2015 Printed Date: 4/24/2019

Project Area 1B

Exisitng System

| Structure | Quantity (pipes in lf) |
|---|---|
| 24" RCP | 231 |
| 42" RCP | 23 |
| Small Box Culvert | 596 |
| Inlets | 11 |
| Headwalls | 2 |

Proposed System

| Structure | Quantity (pipes in lf) | Unit Price | Total |
|---|---|---|---|
| 42" RCP | 331 | 180 | 59670 |
| Small Box Culvert | 619 | 300 | 185636 |
| Inlets | 13 | 3600 | 46800 |
| Headwalls | 2 | 5000 | 10000 |
| | | Materials Subtotal | $302,105.75 |
| | | With Cost of Construction | $610,000.00 |
| | | With Engineering and Survey Costs | $740,000.00 |
| | | Additional Contingency | **$930,000.00** |

Assumptions

Includes additional 100 lf of pipe and 2 additional structures

All structures assumed to have a 10' depth

All pipes replaced with Class III RCP (assumed depth 10') minimum pipe size is 15"

Construction costs assumed to be 2x materials

Engineering and Survey Costs assumed to be 20% of Construction Costs

25% additional contingency

INLE515
GRAV522
INLE382
INLE381
GRAV605
STDP63
1C
1B
VALLEY ST
INGHAUS ST
INLE507
GRAV383
INLE383
INLE384
INLE436
PALATKA ST
STDP62
EWARTS POND
WLAKE AVE

| Facility ID | Diameter | Material |
|---|---|---|
| GRAV383 | 48" | RCP |
| GRAV384 | Other | Other |
| GRAV385 | 48" | RCP |
| GRAV386 | Other | Other |
| GRAV555 | Other | Concrete |
| GRAV604 | Other | Concrete |
| GRAV605 | Other | Other |

| Facility ID | Condition |
|---|---|
| INLE381 | Poor |
| INLE382 | Fair |
| INLE383 | Good |
| INLE384 | Good |
| INLE436 | Good |
| INLE507 | Good |
| INLE515 | Poor |
| STDP62 | Good |
| STDP63 | Poor |

## Legend

- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- Stormwater Gravity Main
- Channel

**Project Areas of Concern**

- 1
- 1B
- 1C
- 3

# Area of Concern 1C


WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr | Cary NC, 27511
t 919.469.3340
license #: C-0832
www.withersravenel.com


0 50 100 200 Feet
1 inch = 100 feet

HGL

Time: 4/5/2019 12:15:10 AM

Conduit GRAV555
Flow = 212.444 cfs

Conduit GRAV604
Flow = 111.415 cfs

Conduit GRAV605
Flow = 10.532 cfs

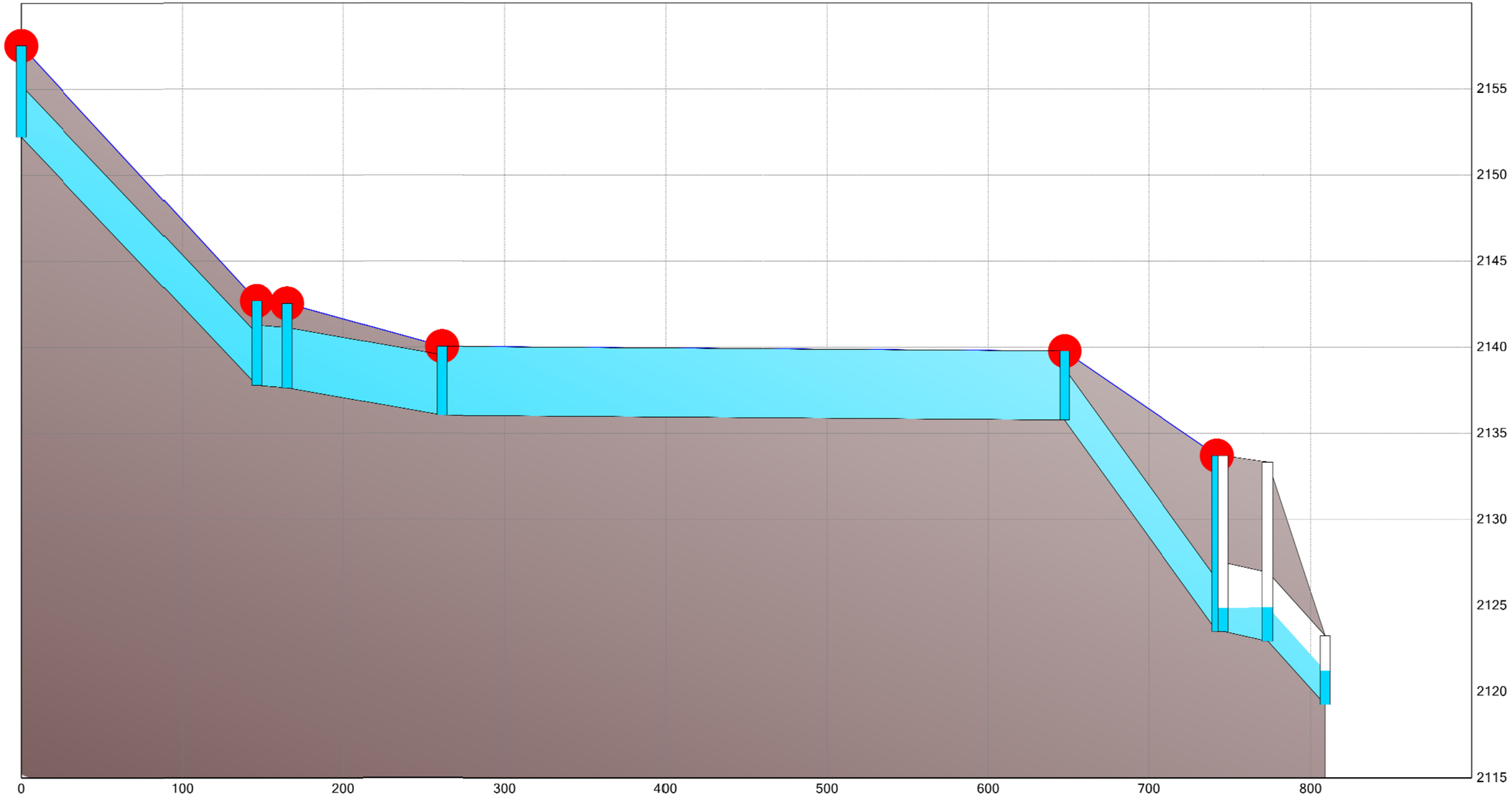
Conduit C2
Flow = 57.368 cfs

Conduit GRAV386
Flow = 10.982 cfs

Conduit GRAV384
Flow = -10.397 cfs

Conduit GRAV385
Flow = -10.397 cfs

Conduit GRAV383
Flow = 225.13 cfs




Junction INLE515
CWSEL = 2157.533 ft

Junction INLE382
CWSEL = 2142.694 ft

Junction INLE381
CWSEL = 2142.55 ft

Junction STDP63
CWSEL = 2140.055 ft

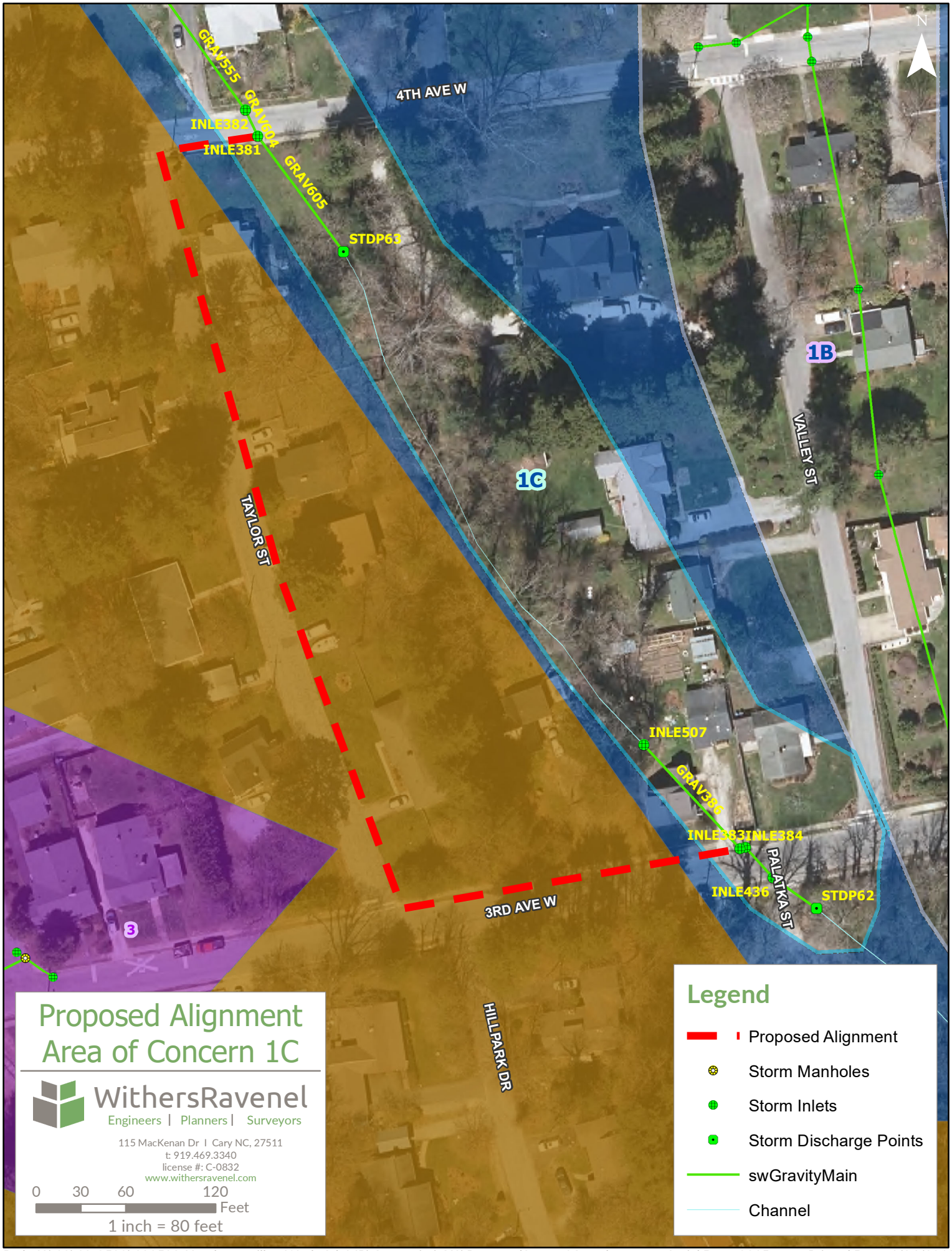
Junction INLE507
CWSEL = 2139.785 ft

Junction INLE384
CWSEL = 2133.717 ft

Junction INLE383
CWSEL = 2124.857 ft

Junction INLE436
CWSEL = 2124.916 ft

Outfall STDP62
CWSEL = 2121.227 ft




# Proposed Alignment
# Area of Concern 1C

WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr I Cary NC, 27511
t: 919.469.3340
license #: C-0832
www.withersravenel.com

0 30 60 120 Feet

1 inch = 80 feet

## Legend

- Proposed Alignment
- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- swGravityMain
- Channel

Project Area 1C

Exisitng System

| Structure | Quantity (pipes in lf) |
|---|---|
| 48" Pipe | 63 |
| Small Box Culvert | 360 |
| Inlets | 7 |
| Headwalls | 2 |

Proposed System

| Structure | Quantity (pipes in lf) | Unit Price | Total |
|---|---|---|---|
| 48" RCP | 800 | 200 | 160000 |
| Inlets | 11 | 3600 | 39600 |
| Headwalls | 2 | 5000 | 10000 |
| | | Materials Subtotal | $209,600.00 |
| | | With Cost of Construction | $420,000.00 |
| | | With Engineering and Survey Costs | $510,000.00 |
| | | Additional Contingency | **$640,000.00** |

Assumptions

Includes additional 800 lf of pipe of new pipe and 2 additional structures

Does not include stream improvements

All structures assumed to have a 10' depth

All pipes replaced with Class III RCP (assumed depth 10') minimum pipe size is 15"

Construction costs assumed to be 2x materials

Engineering and Survey Costs assumed to be 20% of Construction Costs

25% additional contingency

N JUSTICE ST

GENEVA ST

FLEMING ST

S JUSTICE ST

BUNCOMBE ST

RHODES ST

3RD AVE W

INLE485
INLE466
INLE79
INLE215
INLE216
INLE502
INLE194
INLE196
INLE67
INLE197
STDP28
STDP73
STDP74
STMH85

GRAV487
GRAV598
GRAV214
GRAV215
GRAV372
GRAV213
GRAV216
GRAV217

2A

| Facility ID | Diameter | Material |
|---|---|---|
| GRAV213 | 24 | VCP |
| GRAV214 | 30 | RCP |
| GRAV215 | 30 | RCP |
| GRAV216 | 30 | RCP |
| GRAV217 | 36 | RCP |
| GRAV218 | Other | Concrete |
| GRAV219 | Other | Concrete |
| GRAV220 | 18 | RCP |
| GRAV221 | 15 | RCP |
| GRAV367 | 36 | RCP |
| GRAV372 | 15 | RCP |
| GRAV487 | 36 | RCP |
| GRAV597 | Other | Concrete |
| GRAV598 | 36 | RCP |
| GRAV629 | 24 | RCP |

| Facility ID | Condition |
|---|---|
| INLE67 | Fair |
| INLE79 | Poor |
| INLE193 | Fair |
| INLE194 | Poor |
| INLE195 | Fair |
| INLE196 | Fair |
| INLE197 | Fair |
| INLE215 | Good |
| INLE216 | Poor |
| INLE466 | Fair |
| INLE485 | Fair |
| INLE502 | Poor |
| STDP28 | Poor |
| STDP73 | Fair |
| STDP74 | Fair |
| STMH85 | Good |
| STMH14 | Unknown |

# Area of Concern 2A


WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr | Cary NC, 27511
p 919.469.3340
licence #: C-0832
www.withersravenel.com


0 50 100 200 Feet

1 inch = 100 feet

## Legend

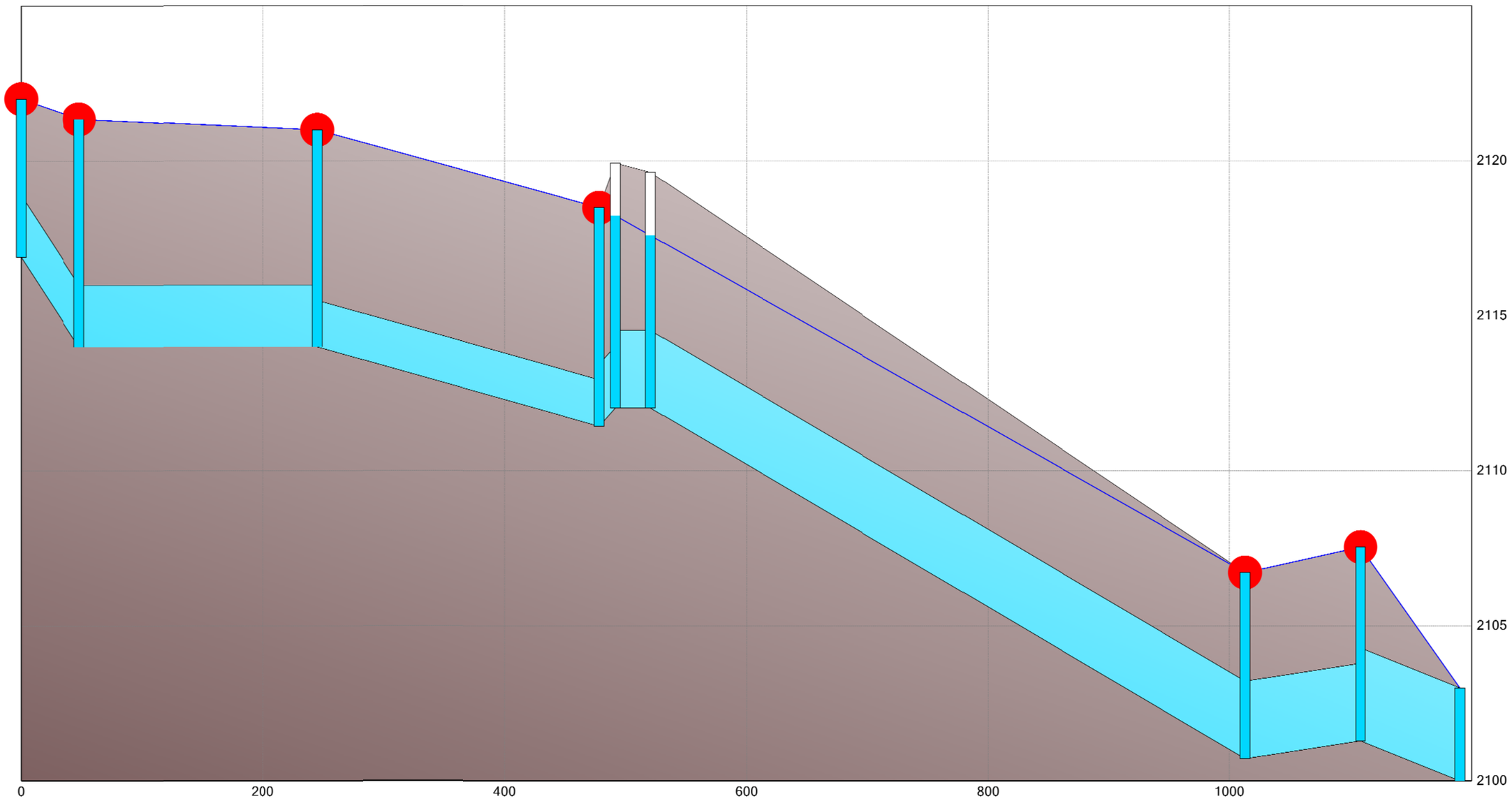
- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- Stormwater Gravity Main
- Channel

**Project Areas of Concern**

- 2
- 2A

HGL

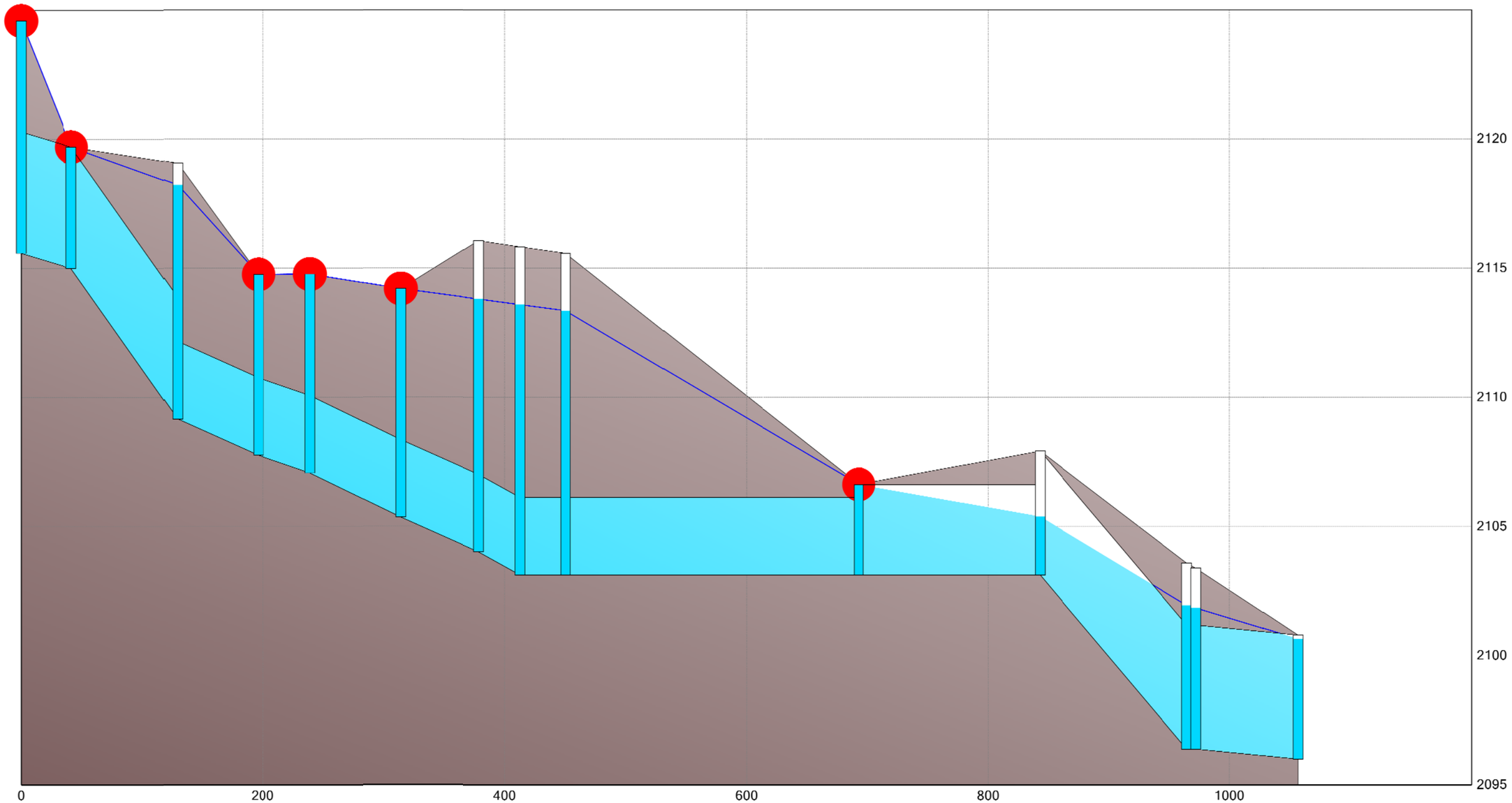
Time: 4/5/2019 12:20:40 AM



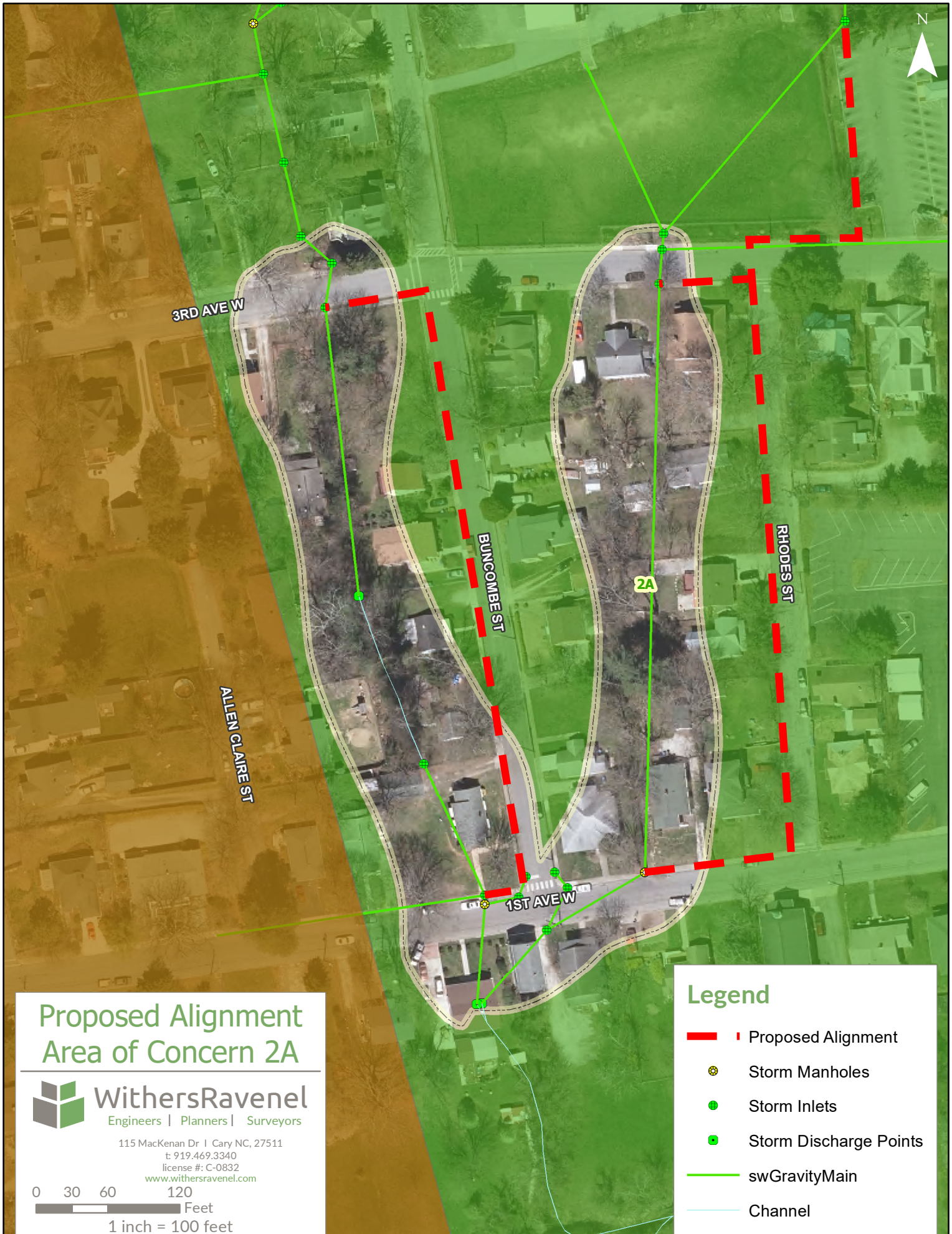
HGL

Time: 4/5/2019 12:20:40 AM

| Links: | GRAV612 | GRAV610 | GRAV374 | GRAV375 | GRAV376 | GRAV377 | GRAV486 | GRAV487 | GRAV598 | C3 | GRAV219 | GRAV597 | GRAV218 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q=519.903 cfs | Q=197.049 cfs | Q=197.049 cfs | Q=-15.707 cfs | Q=75.249 cfs | Q=68.676 cfs | Q=68.676 cfs | Q=68.676 cfs | Q=144.343 cfs | Q=79.817 cfs | Q=203.46 cfs | Q=243.462 cfs | Q=246.88 cfs |




| Nodes: | INLE520 | STMH108 | STMH18 | STMH17 | INLE470 | INLE471 | INLE472 | INLE485 | INLE466 | STDP28 | INLE502 | INLE193 | STMH14 | STDP74 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H=2124.589 ft | H=2119.7 ft | H=2118.225 ft | H=2114.759 ft | H=2114.773 ft | H=2114.205 ft | H=2113.805 ft | H=2113.59 ft | H=2113.352 ft | H=2106.628 ft | H=2105.389 ft | H=2101.948 ft | H=2101.845 ft | H=2100.656 ft |




# Proposed Alignment
# Area of Concern 2A

WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr I Cary NC, 27511
t: 919.469.3340
license #: C-0832
www.withersravenel.com

0 30 60 120
Feet
1 inch = 100 feet

Project Area 2a

Exisitng System

| Structure | Quantity (pipes in lf) |
|---|---|
| 15" Pipe | 339 |
| 18" Pipe | 17 |
| 24" Pipe | 53 |
| 30" Pipe | 616 |
| 36" Pipe | 392 |
| Small Box Culvert | 213 |
| Inlets | 8 |

Proposed System

| Structure | Quantity (pipes in lf) | Unit Price | Total |
|---|---|---|---|
| 24" RCP | 549 | 115 | 63144 |
| 30" RCP | 53 | 125 | 6609 |
| 36" RCP | 616 | 150 | 92428 |
| 42" RCP | 363 | 180 | 65282 |
| Small Box Culvert | 483 | 200 | 96615 |
| Inlets | 13 | 3600 | 46800 |
| | | Materials Subtotal | $370,876.15 |
| | | With Cost of Construction | $750,000.00 |
| | | With Engineering and Survey Costs | $900,000.00 |
| | | Additional Contingency | **$1,130,000.00** |

Assumptions

Includes realignment and upgrade of GRAV212 from 15" HDPE to 24" RCP (just outside of project area, upstream of INLE215)

Includes additional 195 lf of pipe and 4 additional structures on east and 270 lf of pipe and 1 additional structure on west

All structures assumed to have a 10' depth

All pipes replaced with Class III RCP (assumed depth 10') minimum pipe size is 15"

Construction costs assumed to be 2x materials

Engineering and Survey Costs assumed to be 20% of Construction Costs

25% additional contingency

STDP7

2B

INLE520

GRAV611

GRAV612

INLE41

GRAV610

STMH18

BUNCOMBE ST

| Facility ID | Diameter | Material |
|---|---|---|
| GRAV610 | Other | Concrete |
| GRAV611 | 12 | CPP |
| GRAV612 | Other | Concrete |

| Facility ID | Condition |
|---|---|
| INLE41 | Poor |
| INLE520 | Fair |
| STDP7 | Poor |
| STMH18 | Excellent |
| STMH108 | Unknown |

## Legend

- Storm Manholes
- Storm Inlets
- Storm Discharge Points
- Stormwater Gravity Main
- Channel

**Project Areas of Concern**

- 2
- 2B

# Area of Concern 2B


WithersRavenel
Engineers | Planners | Surveyors
115 MacKenan Dr | Cary NC, 27511
t 919.469.3340
licence #: C-0832
www.withersravenel.com

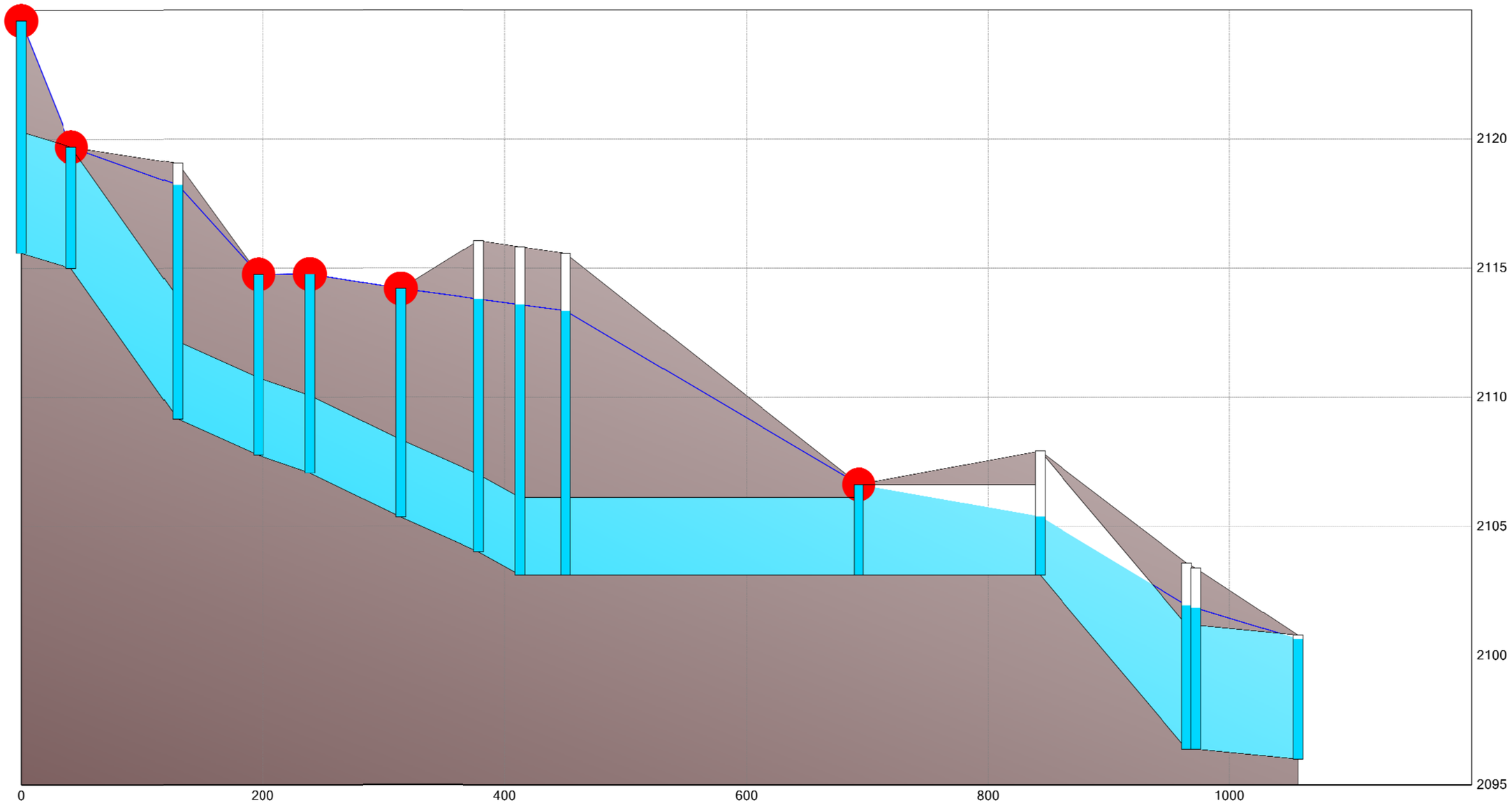

0 20 40 80 Feet

1 inch = 40 feet

HGL

Time: 4/5/2019 12:20:40 AM

| Links: | GRAV612 | GRAV610 | GRAV374 | GRAV375 | GRAV376 | GRAV377 | GRAV486 | GRAV487 | GRAV598 | C3 | GRAV219 | GRAV597 | GRAV218 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q=519.903 cfs | Q=197.049 cfs | Q=197.049 cfs | Q=-15.707 cfs | Q=75.249 cfs | Q=68.676 cfs | Q=68.676 cfs | Q=68.676 cfs | Q=144.343 cfs | Q=79.817 cfs | Q=203.46 cfs | Q=243.462 cfs | Q=246.88 cfs |




| Nodes: | INLE520 | STMH108 | STMH18 | STMH17 | INLE470 | INLE471 | INLE472 | INLE485 | INLE466 | STDP28 | INLE502 | INLE193 | STMH14 | STDP74 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H=2124.589 ft | H=2119.7 ft | H=2118.225 ft | H=2114.759 ft | H=2114.773 ft | H=2114.205 ft | H=2113.805 ft | H=2113.59 ft | H=2113.352 ft | H=2106.628 ft | H=2105.389 ft | H=2101.948 ft | H=2101.845 ft | H=2100.656 ft |

Project Area 2b

Exisitng System

| Structure | Quantity (pipes in lf) |
|---|---|
| Large Box Culvert | 129 |
| Inlets | 3 |
| Headwalls | 1 |

Proposed System

| Structure | Quantity (pipes in lf) | Unit Price | Total |
|---|---|---|---|
| Large Box Culvert | 129 | 500 | 64744 |
| Inlets | 3 | 3600 | 10800 |
| Headwalls | 1 | 5000 | 5000 |
| | | Materials Subtotal | $80,544.07 |
| | | With Cost of Construction | $170,000.00 |
| | | With Engineering and Survey Costs | $210,000.00 |
| | | Additional Contingency | **$270,000.00** |

Assumptions

All structures assumed to have a 10' depth

All pipes replaced with Class III RCP (assumed depth 10') minimum pipe size is 15"

Construction costs assumed to be 2x materials

Engineering and Survey Costs assumed to be 20% of Construction Costs

25% additional contingency