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ENGINEERING REPORT

Richmond Hills Subdivision
Drainage Improvements

PREPARED FOR:

City of Lebanon Engineering Department

PREPARED BY:

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Introduction

It has been reported that several homes on Barnes Drive suffered flood damages during the May 2010 flood. Storm water rose to a level that caused nuisance flooding in the area, but it is not believed that water inundated first floor living spaces. Damages were primarily incurred in garages, crawl spaces, and HVAC units.

The City of Lebanon commissioned Neel-Schaffer, Inc. to perform a comprehensive drainage analysis of this area in order to identify conceptual drainage improvements that will help reduce flooding. The following report describes methodology utilized and results obtained in the drainage analysis. In addition, both structural improvements and routine maintenance items were identified, and preliminary estimated project costs are included.

Field Review

The field review began just outside of the Churchhill Downs subdivision. A small creek runs along the outskirts of the subdivision to where it intersects with another ditch and continues north. Downstream along the creek, drainage flows from an 18-inch reinforced concrete pipe (RCP) cross drain north of Vicksburg Lane, which drains into a ditch flowing along the property line on Lexington Drive and finally empties into the creek. Further downstream, water is also collected from an 18-inch corrugated metal pipe (CMP) cross drain, which flows into a ditch running along the property lines of Lexington Drive. As the creek crosses Letcher Avenue, it flows through two (2) 8-foot by 3-foot box culverts. Between Letcher and Arlington Drive, water is collected from a 16" CMP cross drain flowing into a ditch along the property line. As the creek crosses Arlington, it again flows through two (2) 8-foot by 3-foot box culverts. A ditch empties into the creek, draining from pipes along Arlington Drive just before the creek flows through the box culverts. Water is also collected from a 36" CMP cross drain at the corner of Arlington Drive and Barnes Drive and flows into a ditch that drains into the main creek. Further downstream, water empties into the creek on either side from a 12" CMP cross drain (west) and a 36" CMP cross drain (east), both of which discharge to small ditches that drain into the main creek. The creek also receives discharge on the east bank from an 18" CMP further downstream. On the west bank, water is collected from a ditch receiving flow from another 18" CMP cross drain. Approximately three (3) lots downstream along Petersburg Court drain to a 24" CMP cross drain beneath Lexington Drive that discharges into a ditch that drains into the main creek. The next road crossing on the main creek is at South Fork Drive through a double 10-foot by 4-foot box culvert, and the last road crossing in the study area is at Palmer Road through a 10-foot by 7-foot box culvert with two elliptical CMP overflow pipes.

Watershed Description

The watershed covers an area of approximately 604 acres (0.94 square miles), and extends from Palmer Road to the southeast approximately two miles. The upper portions of the watershed extend beyond the City of Lebanon corporate limits. Three primary areas of interest were identified for this study:

- A potential location for regional detention between the end of Lexington Drive and Churchill Downs;
- The main creek channel behind the residential properties along Barnes Drive; and
- The main creek channel extending from the end of Barnes Drive to South Fork Drive.

Sub-basins for the watershed were delineated to provide an estimation of the storm water runoff at each of the areas of interest. The sub-basin boundaries were estimated based on the 5-foot interval topographic mapping provided by the City, and from information obtained during the field review.

The hydrologic model used in this analysis is HEC-HMS, developed by the U.S. Army Corps of Engineers. The Soil Conservation Service (SCS) method was used to compute storm water runoff for various frequency recurrence intervals. The SCS procedure is based on land use, soil data, and other topographic features which together are used to estimate the runoff potential (known as the Runoff Curve Number) at each area of interest.

Land use within the watershed was determined from aerial photography and is primarily residential, with large areas of undeveloped open spaces in the upper reaches of the watershed. Hydrologic Soil Group data was obtained from the Natural Resource Conservation Service (NRCS). Runoff Curve Numbers within the watershed range from 74 to 82, which reflects the varying degree of urbanization within the watershed. A summary of the hydrologic parameters is presented on Figure 1.

Analysis and Recommendations

Storm water runoff from approximately 415 acres (0.65 square miles) of residential and undeveloped area is collected in the main creek channel running parallel to Barnes Drive. The channel runs northwest, generally along the property boundaries between residential properties on Barnes Drive (to the west) and Lexington Drive (to the east). The runoff collected by the creek discharges to the previously mentioned double box culvert beneath South Fork Drive, which also collects runoff from an additional 115 acres of residential property.

During the technical analysis, it was determined that the main creek channel from Arlington Road to the end of Barnes Drive has insufficient capacity to carry the amount of storm water runoff draining to it. The channel depth varies from 2 feet to 3.5 feet, which is exceeded during the 2-year storm event, causing back yards of properties along Barnes Drive to experience nuisance flooding. During larger storm events, it is apparent that these homes experience damage to HVAC units and garages.

Structural Drainage Improvements

Two drainage improvement alternatives were considered for the mitigation of the flooding issues at Barnes Drive. Details of the items discussed below are shown on Figure 2.

Potential Regional Detention

During the initial phases of the project, a location for a potential detention area was identified between the end of Lexington Drive and Churchhill Downs (See Fig. 1). A 4.2 acre detention basin, with a depth of 17 feet, was modeled to intercept flow from the upper reaches of the watershed. Such a detention basin would provide a reduction of almost 27% in the existing discharges at Barnes Drive. However, the detention basin alone would not be sufficient enough to solve all flooding issues at Barnes Drive. This potential detention basin is located on portions of two large, undeveloped tracts of land, and is partially outside of the current Lebanon City Limits. However, it is possible that when the landowner develops the tract in the future, the City may annex this area and negotiate with the owner to build a regional detention basin.

A second potential detention area was identified on the south side of Arlington Road at Barnes Drive. A detention basin at this location would intercept storm water runoff from approximately 26 acres. Hydrologic analysis revealed that, due to the topography of the site, there would not be enough detention capacity to provide any significant reduction in the existing discharges along Barnes Drive.

Channel Improvement

No topographic survey was conducted as a part of this preliminary study. However, the approximate dimensions of the channel adjacent to Barnes Drive were obtained at three locations during the field reconnaissance. These were used to evaluate the potential for flood mitigation through channel improvement. The channel dimensions were input into a simplistic hydraulic model that uses a solution of the Manning's equation to estimate the normal depth of the channel section. Due to the long distance downstream to a culvert constriction at South Fork Drive, and due to the fairly steep slope of the channel beyond the cul-de-sac at Barnes Drive, it was determined that backwater effects are not the cause of flooding along Barnes Drive. Therefore, a normal depth solution was calculated for each channel section independently with no backwater effects from downstream areas considered. The three locations where channel measurements were taken are shown on Figure 2.

This technique shows that the existing 2-year flood elevation exceeds the elevation of the southern stream bank, and therefore flooding occurs along the properties on the south side of the creek in less than a 2-year storm. To evaluate the benefits of channel improvements, it was assumed that the improved channel would have a 10-foot bottom width, sides sloped of 2:1 (2 feet horizontal for every 1 foot vertical), and have a minimum depth of 3.5 feet. It was determined that the existing 2-year discharges would be contained within the improved channel (i.e. no flooding) by constructing this trapezoidal section for a length of 1,150 feet along the creek. The limits of proposed channel improvement are shown on Figure 2.

The next step was to evaluate the impacts of the improved channel with the decreased discharges resulting from the proposed detention basin described previously. This analysis shows that the improved channel would contain the 5-year discharges with the possible future detention basin in place.

It should be noted that the above hydraulic analysis of channel capacity was based on generalized assumptions. In the absence of exact survey data, channel dimensions were obtained with a tape measure and estimated elevations and channel slope were obtained from the 5-foot GIS topographic mapping, which has a relatively high degree of error. Therefore, the results of the channel capacity analysis should be regarded as conceptual until survey data is obtained and further analysis is undertaken.

Channel Clean-out

During the field reconnaissance it was noted that the channel from approximately the cul-de-sac of Barnes Drive northwestward to South Fork Drive was in need of maintenance. As shown on Figure 2, the channel contains numerous debris piles, sediment and rock deposits, and large diameter trees that are obstructing both normal and flood flows. As stated previously, backwater effects are not the sole cause of flooding along Barnes Drive. However, removing obstructions and cleaning sediment and debris from this reach of channel may yield a small improvement to the flooding depths upstream. In addition, many reaches of the channel banks are severely eroded between the end of Barnes Drive and South Fork Drive (see photographs on Figure 2). This is due in part to the large volumes of storm water runoff, but is also due to these obstructions causing turbulent conditions, which leads to stream bank erosion and scour.

In addition, an unauthorized wooden pedestrian bridge was found that causes a minor constriction during high flood flows (see photograph on Figure 2). This bridge should be removed at the expense of the property owner who installed it. While it is not a major contributor to flooding upstream, removing this manmade obstruction along with the other natural obstructions mentioned above may have small positive impacts to the upstream flooding situation along Barnes Drive.

Better reduction in flood levels are achieved with construction of the proposed detention basin, but this alternative causes significant additional expense. A description of the proposed structural alternatives and preliminary estimated project costs are shown below. The following costs include engineering/design fees and provision for 20% contingency:

Structural Alternatives (See Figure 2)	Preliminary Estimated Project Cost
Alternative 1: Grade 1,150 L.F. of main drainage channel to dimensions shown on Figure 2. Clear debris, sediment, trees and brush from approximately 1,900 L.F. of main drainage channel.	$ 40,700.00
Alternative 2: Alternative 1 plus construct 4.2-acre detention pond.	$ 240,400.00

<u>Routine Maintenance</u>

In addition to removing debris and obstructions described above, numerous routine maintenance issues were found throughout the study area during the field reconnaissance. Examples of required maintenance items include removing sediment buildup from culvert inlets, removing

excess vegetation and debris from culvert inlets, and regrading ditches to drain into the main creek behind Barnes Drive. While correcting these deficiencies will not solve flooding problems, it is critical to correct them sooner, rather than later, so that the drainage system can function as designed and conditions do not worsen, leading to possible flooding problems in the future. In addition, it is important to note that areas identified as requiring remediation should be regularly scheduled for maintenance by City crews to prevent future buildup of debris and sediment. A map showing locations identified as requiring maintenance is included as Figure 3. In addition, a document containing captioned photographs of each maintenance location is included as Appendix A, with locations and orientations of each photograph indicated with red arrows on Figure 3. A preliminary cost estimate for the proposed maintenance items are shown below:

Infrastructure Maintenance Items (See Figure 3)	**Preliminary Estimated Project Cost**
1. Ditch grading at four locations (Items 4, 5, 8, and 9) – 750 L.F.	$ 3,750.00
2. Debris/sediment removal from culvert ends at five locations (Items 1, 2, 3, 6, and 7)	$ 2,500.00
Total Maintenance Cost	**$ 6,250.00**

It should be noted that no field survey data was available for this study. Elevations used to make drainage improvement recommendations were estimated based on the 5-foot interval topographic mapping provided by the City, and from information obtained during the field reconnaissance. Therefore, evaluation of the proposed improvements included in this study should be regarded as conceptual.

The above costs do not include property acquisition, which will be necessary for Alternative 2 (future detention pond). It is estimated that the detention pond would require a drainage easement of approximately 5.0 acres. The proposed pond is situated on two large undeveloped tracts of land, owned by Bethlehem Road Farm Partners and Lynna Rhodes Jackman (see Figure 1). As stated previously, the detention basin location is partially outside of the current Lebanon City Limits. However, it is possible that when the landowner develops the tracts in the future, the City may annex this area and negotiate with the owner to build a regional detention basin.

Alternative 1 may require small tracts of additional drainage easement. It will be necessary to conduct a full topographic and property survey during the design phase to determine the extent of the required easement.

Although many steps will have to be taken prior to implementing structural drainage improvements in the study area, including survey and design; the infrastructure maintenance items discussed above and shown in Figure 3 can be performed by City crews immediately.

Richmond Hills Subdivision
Hydrologic Parameters

Subbasin	Area (ac)	Area (sq. miles)	Runoff Curve No.	Lag Time (min)
1	74.2	0.12	80	19.2
A	115.1	0.18	80	20.1
B	29.9	0.05	81	13.5
C	38.7	0.06	82	11.8
D	26.5	0.04	80	24.8
E	67.7	0.11	81	21.7
F	22.7	0.04	79	18.5
G	229.2	0.36	74	49.9
Watershed	603.8	0.94		

Detention Basin 1
25-year Design Level

Outlet Data	
Dia. & Type	24" RCP
Length (ft)	100
Slope	0.50%

Pond Data	
Pond IE	648
Top of Dam Elev.	665
Footprint Area (ac.)	4.23
Spillway Elev.	663.25
Spillway Type	Rip-Rap
Spillway Length (ft)	70

Hydrologic Data	25-year	100-year
Inflow (cfs)	346	488
Outflow (cfs)	52	252
Pool Elev	663	664.3
Storage (ac.ft.)	36.3	40.9
Freeboard (ft)	2	0.7

Point of Interest A
Proposed Detention Basin

Point of Interest B
Potential Channel
Improvement Location

See Figure 2 for
Channel Improvements
and Clean-out

Point of Interest C
South Fork Dr.

Point of Interest D
Palmer Rd.

Sub-basin A
Sub-basin B
Sub-basin C
Sub-basin D
Sub-basin E
Sub-basin F
Sub-basin G
Sub-basin 1

Bethlehem Rd.
Cliffbrake Pl.
Shenandoah Tr.
Hampton Dr.
Concord Rd.
Roanoke Dr.
Appomattox Dr.
Bella Jane Dr.
Bell Tower Blvd.
Jackson Retreat Dr.
Weston Way
Saratoga Dr.
Arlington Rd.
Vicksburg Ln.
Vine Yard Way
Antietam Dr.
Brunswick Dr.
Leal Cove
Lebanon Rd.
Hamilton Reserve
Barnes Dr.
New Market Ave.
Churchhill Downs
Ellis Park
Blue Ribbon Downs
Derby Downs
Stonewall Ct.
Lexington Dr.
Jarod Way
Ewing Dr.
Amarillo Dr.
Cartel Dr.
Charleston
Moore Haven Dr.
Valley View Cir.
Springdale Dr.
South Fork Dr.
South Fork Ct.
Ewing Ct.
Five Oaks Blvd.
Palmer Rd.

Richmond Hills Subdivision
Runoff Summary

Return Period	Point of Interest D Palmer Rd Watershed Outfall Drainage Area = 0.94 sq.mi.			Point of Interest C South Fork Dr. Drainage Area = 0.83 sq.mi.			Point of Interest B Potential Channel Improvement Location Drainage Area = 0.6 sq.mi.			Point of Interest A Proposed Detention Basin Drainage Area = 0.39 sq.mi.		
	Existing Discharge (cfs)	Discharge with Detention Basin 1 (cfs)	Reduction After Detention	Existing Discharge (cfs)	Discharge with Detention Basin 1 (cfs)	Reduction After Detention	Existing Discharge (cfs)	Discharge with Detention Basin 1 (cfs)	Reduction After Detention	Existing Discharge (cfs)	Discharge with Detention Basin 1 (cfs)	Reduction After Detention
2-year	554	521	6.0%	453	416	8.2%	249	197	20.9%	139	35	74.8%
5-year	771	722	6.4%	632	577	8.7%	352	273	22.4%	205	41	80.0%
10-year	959	893	6.9%	787	713	9.4%	441	337	23.6%	263	46	82.5%
25-year	1222	1131	7.4%	1003	903	10.0%	567	426	24.9%	346	52	85.0%
50-year	1438	1325	7.9%	1182	1057	10.6%	672	497	26.0%	415	142	65.8%
100-year	1665	1527	8.3%	1369	1218	11.0%	782	572	26.9%	488	252	48.4%

Legend

- Proposed Detention
- Sub-basin Boundaries
- Streams
- Parcels
- City Limits
- Existing Culverts
- Proposed Channel Improvements
- Proposed Channel Clean-out

City of Lebanon Drainage Analysis
Richmond Hills Subdivision
Drainage Improvements

N W E S

1 inch equals 800 feet

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Hydrology Results

Figure 1

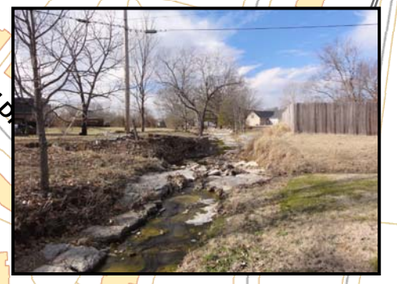
Clear debris, sediment, trees and brush from approx. 1,900 LF of channel.

Proposed Channel Improvement

Grade 1,150 LF of drainage channel to improve capacity and hydraulic efficiency.

Dimensions:
10 ft. bottom width, 2:1 side slopes, 3.5 ft. deep, channel grade 0.7%.

Property owner to remove unauthorized wooden pedestrian bridge.



Section 3

Section 2

Section 1

South Fork Dr.

Barnes Dr.

Cattel Dr.

Stonewall Ct.

Petersburg Ct.

Antietam Ct.

Brunswick Dr.

Saratoga Dr.

Shenandoah Tr.

SECTION 1

Return Period	With Existing Discharges			Discharges with Detention Basin 1			
	Existing Channel Water Depth (ft)	Improved Channel Water Depth (ft)	Depth Reduction from Existing (ft)	Existing Channel Water Depth (ft)	Depth Reduction From Existing (ft)	Improved Channel Water Depth (ft)	Depth Reduction From Existing (ft)
2yr	4.92	3.05	-1.87	4.51	-0.41	2.7	-2.22
5yr	6.46	3.69	-2.77	5.1	-1.36	3.2	-3.26
10yr	6.75	4.23	-2.52	6.4	-0.35	3.59	-3.16
25yr	7.06	4.9	-2.16	6.71	-0.35	4.15	-2.91
50yr	7.26	6.79	-0.47	6.9	-0.36	4.54	-2.72
100yr	7.45	7.03	-0.42	7.07	-0.38	4.92	-2.53

SECTION 2

Return Period	With Existing Discharges			Discharges with Detention Basin 1			
	Existing Channel Water Depth (ft)	Improved Channel Water Depth (ft)	Depth Reduction from Existing (ft)	Existing Channel Water Depth (ft)	Depth Reduction From Existing (ft)	Improved Channel Water Depth (ft)	Depth Reduction From Existing (ft)
2yr	4.74	3.05	-1.69	4.56	-0.18	2.7	-2.04
5yr	5.03	5.03	0	4.81	-0.22	3.2	-1.83
10yr	5.24	5.28	0	4.99	-0.25	4.98	-0.26
25yr	5.5	5.58	0	5.21	-0.29	5.24	-0.26
50yr	5.68	5.79	0	5.36	-0.32	5.42	-0.26
100yr	5.86	5.98	0	5.51	-0.35	5.59	-0.27

SECTION 3

Return Period	With Existing Discharges			Discharges with Detention Basin 1			
	Existing Channel Water Depth (ft)	Improved Channel Water Depth (ft)	Depth Reduction from Existing (ft)	Existing Channel Water Depth (ft)	Depth Reduction From Existing (ft)	Improved Channel Water Depth (ft)	Depth Reduction From Existing (ft)
2yr	3.21	3.14	-0.07	3.1	-0.11	3.03	-0.18
5yr	3.47	3.41	-0.06	3.34	-0.13	3.27	-0.2
10yr	3.67	3.6	-0.07	3.51	-0.16	3.44	-0.23
25yr	3.9	3.84	-0.06	3.71	-0.19	3.65	-0.25
50yr	4.07	4.01	-0.06	3.86	-0.21	3.81	-0.26
100yr	4.24	4.18	-0.06	4.01	-0.23	3.95	-0.29

Legend

- Existing Culverts
- Streams
- Parcels
- Buildings
- City Limits
- Proposed Channel Improvements
- Proposed Channel Clean-out
- Estimated Channel Sections

City of Lebanon Drainage Analysis
Richmond Hills Subdivision
Drainage Improvements

N W E S

1 inch equals 300 feet

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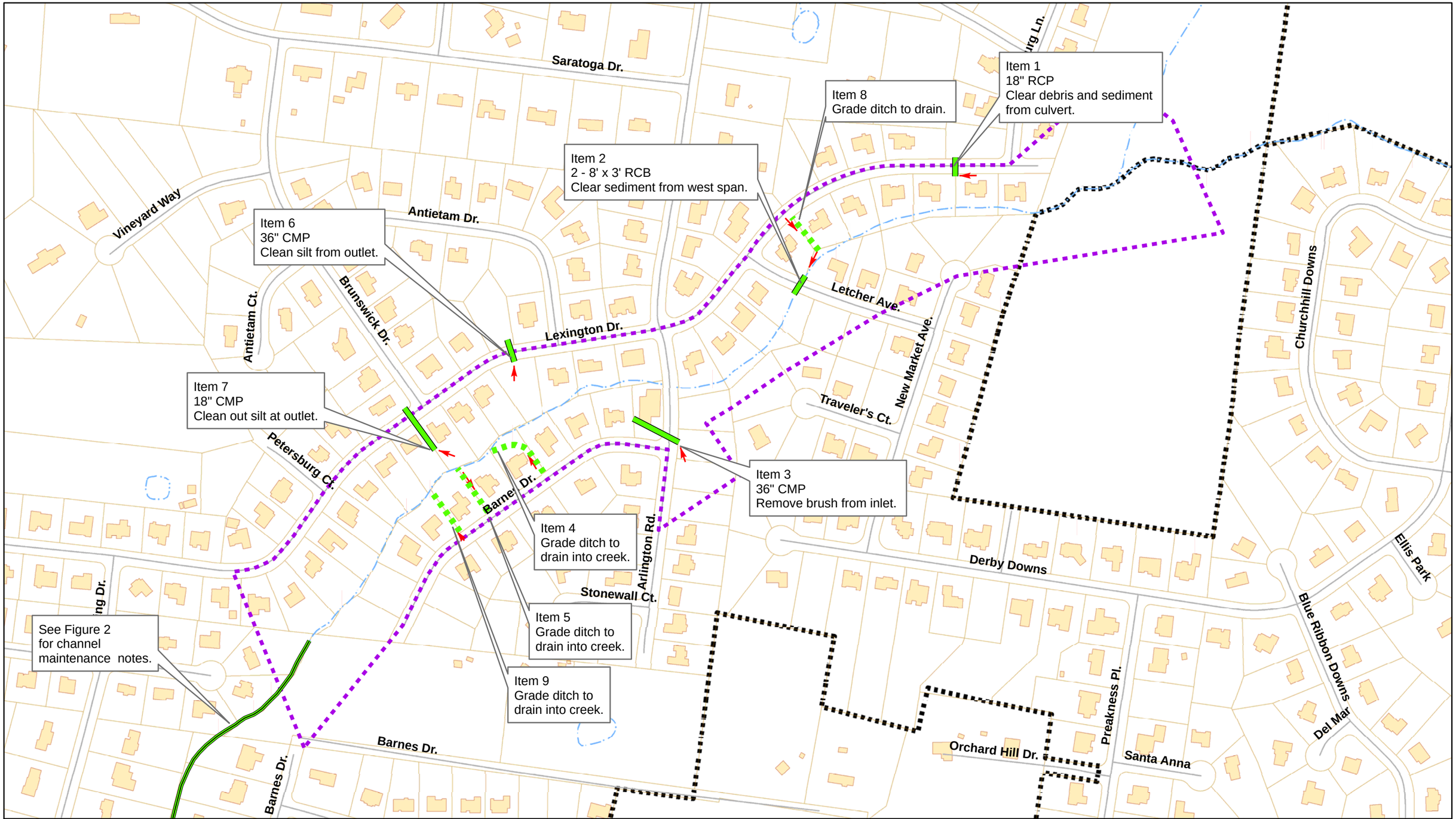
Conceptual Drainage Improvement Recommendations

Figure 2



Legend

- Streams
- Parcels
- Buildings
- City Limits
- Area of Field Reconnaissance
- Directional Photo Log
- Stream/Ditch Maintenance Locations
- Infrastructure Maintenance Locations
- Proposed Channel Clean-out

City of Lebanon Drainage Analysis
Richmond Hills Subdivision
Drainage Improvements

N W E S

1 inch equals 300 feet

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Infrastructure Maintenance Locations

Figure 3

APPENDIX A

Routine Maintenance Location Photographs

Item 1 - 18" RCP on Lexington Dr. north of Vicksburg Ln. Clear debris and sediment from 18" RCP culvert. Picture 2312.

Item 2 – Looking north at Letcher Ave. Clear sediment from west span of double 8' x 3' RCB. Picture 2318.

Item 3 - Arlington Rd. and Barnes Dr. Remove brush from inlet of 36" CMP. Picture 2333.

Item 4 - 413 Barnes Drive. Grade ditch to drain into creek. Note standing water. Looking downstream (east) from Barnes Dr. Picture 2350.

Item 5 – 409 Barnes Drive. Grade ditch to drain into creek. Looking upstream (west) toward Barnes Drive. Note standing water and debris. Picture 2352.

Item 6 - Lexington Dr. north of Antietam Dr. Clean silt from 36" CMP outlet. Picture 2368.

Item 7 - Lexington Dr. at Brunswick Dr. Clean out silt at outlet of 18" CMP. Picture 2370.

Item 8 – Looking west from Lexington Dr. cross drain (south of Letcher Ave). Grade ditch to drain into creek. Note standing water. Picture 2315.

Item 9 – 407/409 Barnes Dr.. Grade ditch to drain into creek. Picture 2356.