OAK ORCHARD
COASTAL DRAINAGE
ENGINEERING EVALUATION

Prepared for:

Delaware Department of Natural Resources and
Environmental Control
Division of Watershed Stewardship
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URS

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DelDOT	Delaware Department of Transportation
DGS	Delaware Geologic Survey
DNREC	Delaware Department of Natural Resources and Environmental Control
GIS	Geographic Information System
NAVD88	North American Vertical Datum of 1988
NED	National Elevation Dataset
NGVD29	National Geodetic Vertical Datum of 1929
NRCS	Natural Resources Conservation Service
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

This report summarizes URS Corporation's (URS') analysis of the drainage and flooding concerns in the Oak Orchard community in Delaware and identifies opportunities to address these concerns.

The coastal Oak Orchard community is located east of the town of Millsboro, south of John J Williams Highway (Delaware Route 24), and north of the Indian River Bay in Sussex County, Delaware. The study area encompasses approximately 2 square miles, including approximately 1 mile of Indian River Bay shoreline.

The Delaware Department of Natural Resources and Environmental Control (DNREC) contracted URS to evaluate the drainage problems in the community and to develop and prioritize potential solutions.

As a part of this study, URS reviewed information provided by DNREC, including responses to a questionnaire sent to property owners (created in coordination with URS), information from two public meetings hosted and facilitated by DNREC, and geographic information system (GIS) data.

URS reviewed 76 questionnaires provided by DNREC and performed a site investigation at the location of each drainage concern. URS proposed 31 solutions and prioritized them based on:

- The questionnaires
- Field observations
- GIS data
- Community input from the public meetings

The solutions were prioritized using a variation of the DNREC prioritization matrix modified for the scope of coastal drainage projects. The prioritization matrix was used to help DNREC select high priority projects under DNREC jurisdiction for further analyses. For the high priority projects, URS developed conceptual designs that include a preliminary description of the recommended improvements, design considerations, feasibility, and planning level cost estimates. Prior to receiving the selection of high priority projects, a hydrologic analysis was performed for the Oak Orchard study area to estimate the runoff for the upland areas of the community. The results of this analysis were used to develop the conceptual designs.

Solutions that are under the jurisdiction of agencies other than DNREC are also identified (i.e., Delaware Department of Transportation [DelDOT] and homeowner associations). DNREC intends to forward information for these potential improvements to the respective agencies for implementation. Lastly, a summary of recommendations that can be implemented by homeowners on individual properties is provided that DNREC can use to assist to homeowners.

SECTION ONE: INTRODUCTION

1.1 Authorization

The Delaware Department of Natural Resources and Environmental Control (DNREC) retained URS Corporation (URS) to develop a detailed drainage and flooding report for Oak Orchard, an unincorporated community is Sussex County, Delaware. The project was funded by DNREC.

1.2 Background and Purpose

The coastal Oak Orchard community is located between John J Williams Highway (Delaware Route 24) and the Indian River Bay in Sussex County, Delaware. Residents of this community consist of both year-round and seasonal residents.

The Indian River Bay is coastally influenced and impacts several marsh areas within the community. The community is susceptible to frequent flooding due to coastal effects from the Indian River Bay and localized stormwater runoff.

Changes in development and the natural environment have intensified flooding issues for the community. In particular, residential and commercial areas have been built in the community over several decades, resulting in an increase in impervious area and therefore an increase in flooding frequency from localized runoff for several of the areas. Residential properties and roads also flood frequently from local runoff because of stormwater, drainage, and transportation infrastructure that is undersized or in disrepair. This flooding can range from nuisance flooding of yards and residential roads to severe flooding of access roads, which affects access to homes and businesses. Drainage and flooding mitigation in Oak Orchard was identified as a priority of the Delaware Governor and Legislature due to the frequency and severity of flooding.

The purpose of this study is to evaluate existing drainage problems and provide recommendations to DNREC for drainage improvements in the Oak Orchard community. The focus of this study is on developing small- to medium-scale drainage solutions to reduce the frequency and duration of flooding.

1.3 Related DNREC Studies

URS provided a Coastal Drainage Engineering Evaluation for the Delaware Bay Beach communities to DNREC in December 2014. The Bay Beach communities include three beaches in Kent County (Pickering Beach, Kitts Hummock, and South Bowers Beach) and four communities in Sussex County (Slaughter Beach, Prime Hook Beach, Broadkill Beach, and Lewes Beach). This Oak Orchard Coastal Drainage Engineering Evaluation report structure and study methodology closely follow that of the Bay Beach Study. These similarities include:

- Questionnaire numbering scheme
- Solution identification numbering
- Ranking criteria for proposed solutions
- Recommendations for homeowner implementations

SECTION TWO: STUDY AREA CHARACTERISTICS

2.1 Study Area Location

The coastal Oak Orchard community is located east of the town of Millsboro, south of the John J Williams Highway (Delaware Route 24), and north of the Indian River Bay in Sussex County, Delaware. The study area encompasses approximately 2 square miles, including approximately 1 mile of Indian River Bay shoreline (Figure 2.1).

River Road runs parallel to the Indian River Bay shoreline, with several marsh areas to the north. Oak Orchard Road and the John J Williams Highway are major collectors; all other roads in the community are local roads.

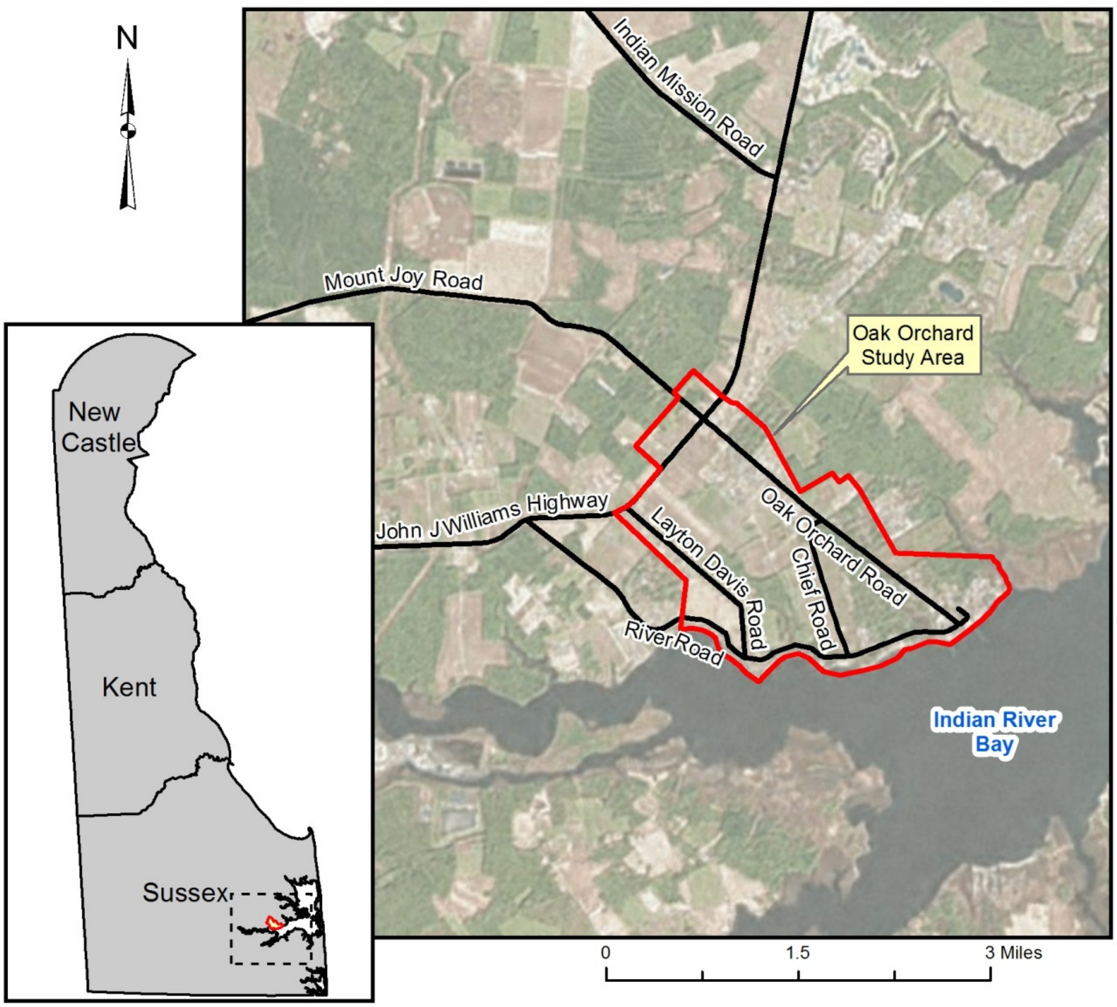

Figure 2.1: Oak Orchard Drainage Study Vicinity Map

2.2 Topography and Terrain

Contour data were provided by the Delaware Geological Survey (DGS), and the National Elevation Dataset (NED) 1/9-arc second (3-meter) raster was acquired from the U.S. Geological Survey (USGS). The vertical datum for both data sets is the North American Vertical Datum of 1988 (NAVD88).

The Oak Orchard community contains flat coastal lowland areas to the south, and steeper upland areas to the north. The lowland area extends from the Indian River Bay, north past River Road, with several marsh areas north of River Road connected to the bay via culverts. The maximum elevations north of the Indian River Bay in this lowland area typically range from 3 to 6 feet NAVD88, while the marsh elevations range from -1 to 2 feet NAVD88. The elevations of the upland areas generally range from 6 to 24 feet NAVD88.

2.3 Land Use

Land use data were provided by the Delaware Office of Management and Budget (2007) and aerial imagery (2011 and 2012). The Oak Orchard community is composed primarily of single-family homes, mobile home parks, and crop lands. The community is bounded to the south by the Indian River Bay, and there are both tidal and non-tidal wetlands adjacent to forested or residential areas north of River Road. The northeastern extent of the study area (at the intersection of Oak Orchard Road and John J Williams Highway) is a commercial area.

2.4 Soil and Groundwater

Soil data were obtained from the 2009 Soil Survey Geographic database of the Natural Resources Conservation Service (NRCS). The Oak Orchard study area is composed primarily of Fort Mott loamy sand and Downer loamy sand, which are hydrologic group A and B soils, respectively, that drain rapidly. The marsh areas on the landward side of River Road are primarily made up of Purnell peat. These soils are flooded frequently by tidal water and are hydrologic group D soils with poor infiltration and high clay content.

Digital water-table data were obtained from DGS. The normal water table is approximately 2 to 5 feet below the land surface elevation in the southern portion of the Oak Orchard community adjacent to the Indian River Bay and areas adjacent to the wetland areas. The normal water table depth is approximately 5 to 9 feet below the land surface for the upland areas.

2.5 Indian River Bay Water Surface Elevation

The USGS Indian River stream gage at Rosedale Beach (Gage 01484540) is less than one mile from the Oak Orchard community, and was used to estimate average low tide, average high tide, and overall average water surface elevations for the Indian River Bay (USGS, 2015). The data from the gage are in National Geodetic Vertical Datum of 1929 (NGVD29), and were converted to NAVD88 by applying a -0.78 foot correction to the NGVD29 elevation. According to daily data from 2006 to 2015, the average low tide elevation is -0.83 foot, the average high tide elevation is 1.83 feet, and the average water surface elevation is approximately 0.5 foot.

SECTION THREE: MAJOR DRAINAGE AND FLOODING CAUSES

3.1 Local Drainage and Flooding

In general, localized drainage issues and flooding result from both the hydrology and hydraulics of a drainage area. The hydrology of a drainage area is dependent on topography, existing land use, impervious area, soil types of the area, and the amount of precipitation. Runoff increases when changes in land use reduce pervious area or when precipitation rates increase (as has been the case throughout the United States in recent years).

Hydraulic systems include stormwater conveyance structures (e.g., pipes, ditches) that collect and transport stormwater runoff to receiving streams and other bodies of water. Where there are no stormwater conveyance systems, or where they are inadequate, runoff travels via concentrated flow, or it ponds prior to infiltrating into the soil. Catch basins, stormwater inlets, ditches, pipes, gates, culverts, and other stormwater conveyance structures must be cleaned on a regular basis to maintain hydraulic function. Materials that can hinder hydraulic function include accumulated sediments, debris, vegetation, log jams, trash, and fallen trees.

Coastal areas are also heavily influenced by coastal water bodies. The Oak Orchard community is bounded by the Indian River Bay to the south, with occasional coastally influenced marsh areas that extend north of River Road. The coastal water bodies can cause flooding directly by overflowing onto land surfaces, or indirectly by preventing runoff from draining through the conveyance systems. Significant coastal events such as nor'easters and hurricanes often overwhelm existing conveyance systems. The marsh areas, which are coastally influenced, can provide storage for runoff draining through conveyance systems; however, if the water surface elevations in the marsh are high due to high tides or previous rainfall events, the storage capacities may be compromised.

3.2 Sea Level Rise

The global mean sea level increased throughout the twentieth century, and this trend is expected to continue in the near future based on climate-related phenomena (IPCC, 2007). The two primary causes of global mean sea level rise are the thermal expansion of saltwater as it warms and melt-water from ice on land (e.g., glaciers). The published rates of sea level rise at Lewes Beach, Delaware and Ocean City, Maryland are approximately 3 millimeters/year (0.1 inch/year) and 5.5 millimeters/year (0.2 inch/year), respectively, although the rate is expected to increase throughout this century (DNREC, 2013). The DNREC Sea Level Rise Technical Work Group suggests planning scenarios for sea level increases ranging from 1.6 feet to 5 feet by 2100.

The Delaware coast is a vital ecologic resource and is a key component of the state's economy because it provides jobs and recreation (DNREC, 2013). Sea level rise can increase the rate of shoreline erosion, damaging dunes and other environmental features that protect the inland areas from coastal flooding. Overall, sea level rise is anticipated to exacerbate local drainage issues and flooding.

SECTION FOUR: STUDY METHODOLOGY

The purpose of this study was to evaluate existing drainage problems and provide recommendations to DNREC for future drainage improvements in the Oak Orchard community (including prioritization) while meeting the goals and expectations of DNREC and community residents. The focus of this study was on developing the most appropriate small- to medium-scale drainage solutions to reduce the frequency and duration of flooding that would also complement expected future projects (e.g., a DelDOT storm drain upgrade at the intersection of Oak Orchard Road and River Road). Structure-based flood mitigation measures (e.g., raising houses and flood proofing) were not considered in this study.

URS performed the following tasks as a part of this project:

1. Evaluate Public Input: This task included analyzing questionnaires from residents and notes from two public meetings between Oak Orchard residents and DNREC (Section 5).
2. Review Existing Data: This task involved a desktop analysis using GIS (Section 2).
3. Field Reconnaissance: This task involved investigating the location of drainage concerns identified by the public (Section 6).
4. Identify Drainage Concerns: This task involved consolidating information from the data review, public meetings, and field reconnaissance (Section 6).
5. Develop Initial Recommendations for Improvements: This task included developing recommendations for each of the drainage concerns, as well as identifying design considerations (Section 6).
6. Prioritize Drainage Solution: This task involved ranking each proposed recommendation using the criteria established in coordination with DNREC (Section 6).
7. Conduct Hydrologic Analysis: This task involved performing a hydrologic analysis of the Oak Orchard study area used for concept design hydraulic calculations (Section 6).
8. Develop Concept Design Plans: This task involved developing schematic concept plans for five recommended improvements selected by DNREC for additional analyses (Section 7).

The remaining sections of this report describe the analyses performed for this project.

SECTION FIVE: COMMUNITY INPUT

5.1 Questionnaires

As part of this study, URS and DNREC created a questionnaire to solicit information on drainage and flooding observations from residents of the Oak Orchard community. The questionnaire requested that residents provide:

- Resident contact information (i.e., name, address, and ownership information);
- Description of flooding and drainage concerns;
- The location of drainage and flooding concerns;
- The probable cause of drainage and flooding concerns (e.g., poor drainage system or low-lying area);
- When the drainage and flooding problems typically occur (e.g., during high tides, after every rain event, after large rain events, or during hurricanes); and
- Frequency of drainage and flooding issues.

DNREC distributed the questionnaire to the property owners in the study area in 2014. A blank questionnaire is provided in Appendix A. The completed questionnaires received by DNREC are available on the CD provided with this report. A total of 76 questionnaires were received in March 2014 and were reviewed for this study.

5.2 Public Meetings

DNREC and Delaware House of Representative Ruth Briggs-King hosted and facilitated two public meetings with members of the Oak Orchard community on July 16, 2013 and October 9, 2013. These meetings were held prior to the initiation of this study because the mitigation in Oak Orchard was identified as a priority of the Delaware Governor and Legislature. The intent of these meetings was to discuss drainage problems in the area. Information gathered from these meetings was used to supplement the questionnaires received and to identify additional drainage problems. Detailed notes from these meetings were provided by DNREC to URS on August 20, 2014.

SECTION SIX: IDENTIFICATION OF DRAINAGE DEFICIENCIES AND SOLUTIONS

6.1 Desktop Analysis

GIS data were compiled from DNREC and other state agencies. Data compiled included topography, land use, transportation, parcel, and groundwater data (as discussed in Section 2).

6.2 Identification of Drainage Deficiencies

The information from the questionnaires was input into a GIS database to spatially represent the data. For each questionnaire received, a unique 3-digit identification number was assigned and a point in the GIS database denotes the respondent's local address. When a resident had a drainage concern at a location other than his or her home address, a point was placed at the location of the identified concern (in addition to the point at the home address) and a decimal added to the identification number. Appendix B contains maps of the community showing the location of drainage concerns, as well as the location of homeowner addresses where there are no drainage concerns (over 150 total data points). A key for the identification numbers for each questionnaire is also provided in Appendix B. Figure 6.1 shows the spatial distribution of the drainage concerns received.

The drainage concerns were grouped based on apparent cause of the problem (e.g., undersized culvert west of the intersection of Chief Road and River Road). This was completed with the understanding that some of the groupings would change following field reconnaissance verification. These groupings were used to organize the potential drainage solutions described in Appendix C.

Drainage deficiencies include undersized or non-existent storm drain systems, storm drain systems that require maintenance, and low ground surface elevations. These deficiencies result in problems such as localized flooding, backwater flooding from inland marsh, or coastal inundation directly from the Indian River Bay.

Several of the drainage deficiencies are triggered or intensified by the flooding causes described in Section 3. For example, sea level rise can reduce storage for runoff by causing marsh levels to rise. Sea level rise also reduces the flow through culverts due to higher water surface elevations at the outlet.

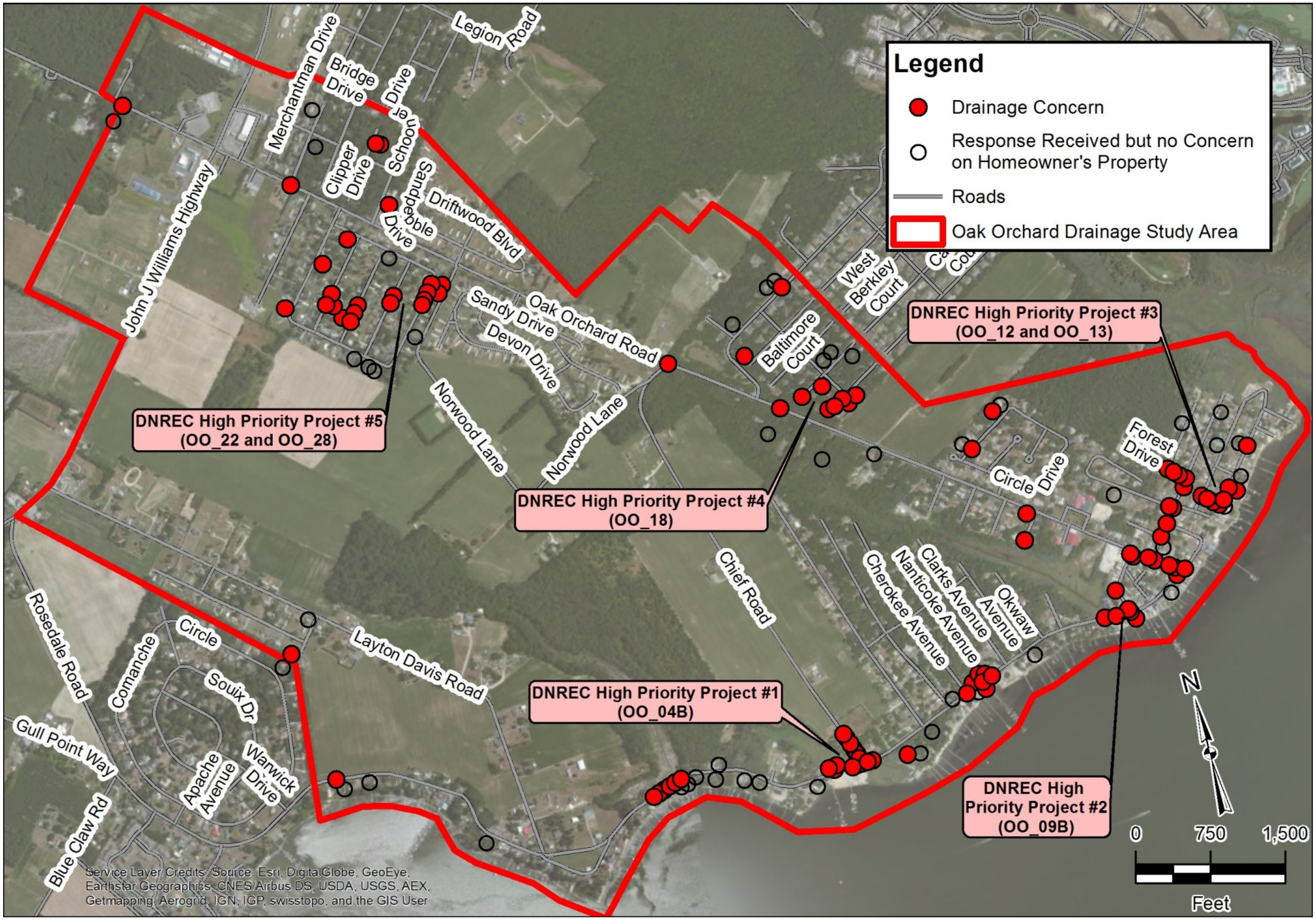

Figure 6.1: Oak Orchard Locations of Drainage Concerns and Approximate Locations of DNREC High Priority Projects

6.3 Field Reconnaissance

URS performed the initial field reconnaissance in September 2014. Field maps displayed contours, the locations of drainage concerns from the questionnaires, and infrastructure that could affect drainage. The team of engineers used these maps in tandem with the questionnaires to investigate each drainage concern described in the questionnaires and public meetings. Photographs from the field investigation are provided in Appendix D.

URS completed a field data form for each drainage concern group to capture the existing site conditions and potential drainage improvements including:

- Type of flooding (e.g., road, yard, coastal);
- Apparent cause of the problem (e.g., elevation, debris, ponding, ditch);
- Site ownership (e.g., state, private); and
- Design constraints (e.g., utility and environmental impacts).

Based on this information, URS identified at least one solution (e.g., re-grade road, ditch maintenance, upgrade culvert, install storm drain pipes, install bulkhead) for each site. Sketches of existing and proposed conditions at each drainage concern were developed and photographs were taken. A blank field data form is available in Appendix E. The completed field data forms are on the CD provided with this report.

6.4 Development of Drainage Solutions

The potential solutions identified in the field for each drainage concern were further developed following the field investigation. A total of 31 potential solutions were identified.

The solutions were labeled using the two-letter identifier “OO” (Oak Orchard) followed by a two-digit number. The two-letter identifier is used for consistency with the Bay Beach Drainage Study nomenclature. For each solution, the proposed project location, source of flooding, existing site conditions, recommendations, constraints, effectiveness, and property ownership were analyzed. Where two solutions were recommended at the same location, an “A” or “B” was added to the solution label. The solutions are discussed in Section 7.

Appendix C provides a summary of each identified drainage problem, potential solution, possible constraints, and expected effectiveness, cross referenced to questionnaire number. Existing drainage deficiencies are organized by proposed solution. Each proposed solution is also cross referenced to the drainage concerns from the questionnaires. Appendix B provides maps of each community showing the location of drainage concerns and approximate locations of the proposed solutions.

6.5 Hydrologic Analysis

To accurately assess the potential drainage improvements, hydrologic analyses are necessary to estimate runoff volume present in or conveyed by natural and engineered water systems such as channels, ditches, and culverts. A hydrologic analysis was performed for the contributing drainage areas in the Oak Orchard Study area using HEC-HMS (USACE, 2010) to develop hydrographs for the 2-, 10-, 25-, 50-, and 100-year storm events for existing land use conditions. Figure 6.2 displays the 8 watersheds and 31 sub-basins included in the hydrologic analysis. Figure 6.3 displays the sub-basins, 24 junctions, 8 outfalls, and the routing reaches modeled using HEC-HMS.

The peak flows were calibrated using a nearby stream gage outside the watershed, and were validated using the USGS Scientific Investigations Report 2006-5146 (Ries, 2006) regression equations. Table 6.1 presents the results of the hydrologic analysis. Appendix F is the hydrologic report summarizing the methods and results of the hydrologic analysis.

The results of the hydrologic analysis were used to develop solutions for the recommendations selected for concept design. In addition, the results of this study can be used by DNREC for future stormwater management improvements.

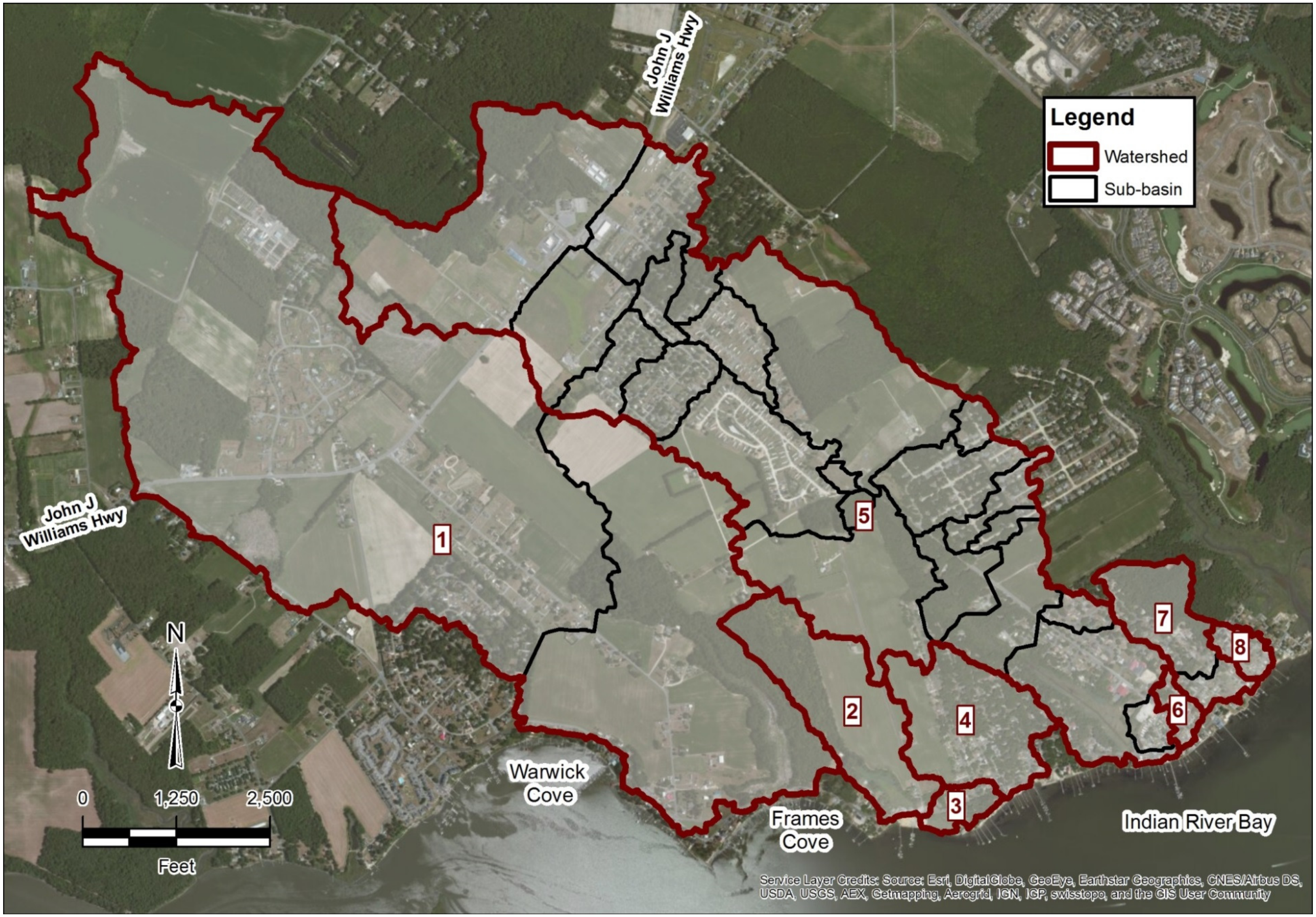

Figure 6.2: Oak Orchard Drainage Divide Map

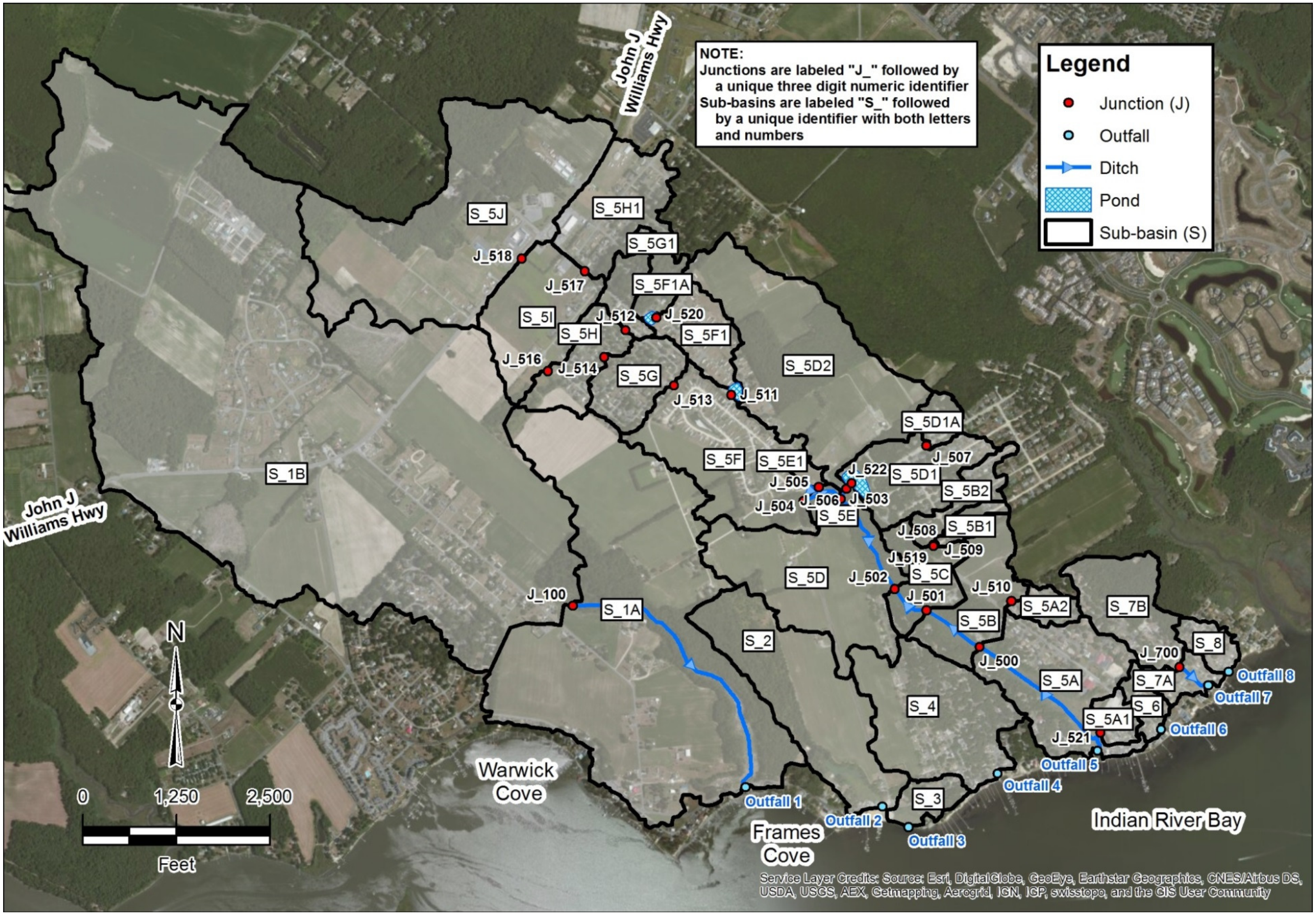

Figure 6.3: Oak Orchard Hydrologic Analysis Map

Table 6.1: Summary of Hydrologic Analysis

Name	Drainage Area, mi^2	Storm Event Flows (cubic feet per second)				
		2-year	10-year	25-year	50-year	100-year
J_100	1.10	56	122	178	230	289
J_500	1.14	64	156	246	334	436
J_501	1.07	71	168	259	345	445
J_502	1.04	71	174	268	356	457
J_503	0.89	65	150	233	307	389
J_504	0.64	48	109	160	207	261
J_505	0.01	3	5	8	10	13
J_506	0.24	23	52	77	100	127
J_507	0.01	2	5	8	10	13
J_508	0.02	4	10	15	20	26
J_509	0.01	3	6	9	12	16
J_510	0.01	4	8	12	16	21
J_511	0.05	3	15	25	34	43
J_512	0.02	4	9	13	17	21
J_513	0.48	42	91	134	174	220
J_514	0.44	39	87	128	167	211
J_516	0.39	35	77	114	149	190
J_517	0.07	10	23	34	44	56
J_518	0.25	18	40	61	80	103
J_519	0.03	7	16	24	31	40
J_520	0.02	1	5	8	11	14
J_521	0.01	4	9	13	17	22
J_522	0.01	6	26	41	54	70
J_700	0.05	4	10	16	22	28
Outfall 1	1.53	77	169	253	328	413
Outfall 2	0.12	10	22	33	44	57
Outfall 3	0.02	4	10	14	19	24
Outfall 4	0.11	15	33	49	64	81
Outfall 5	1.25	57	146	224	297	381
Outfall 6	0.01	3	6	9	12	15
Outfall 7	0.07	6	13	21	28	36
Outfall 8	0.01	2	5	8	10	13

6.6 Prioritization

The Bay Beach Workgroup developed an extensive drainage project prioritization ranking criteria in 2011. This worksheet included 38 prioritization categories in eight groups (public safety impacts, economic impacts, technical criteria, environmental/ecological impacts, agricultural impacts, public health impacts, societal impacts, and miscellaneous impacts). The Workgroup criteria were tailored for coastal drainage projects as part of the Bay Beach Coastal Drainage Study.

In an August 20, 2014 meeting, DNREC recommended that the prioritization matrix created for the Bay Beach Drainage Study be used for the Oak Orchard Coastal Drainage Study. Table 6.2 lists the ranking criteria URS used to score the proposed solutions. The criteria include 12 prioritization categories in six groups (the economic and societal impacts are incorporated into the ingress-egress prioritization category).

URS ranked the proposed engineering solutions using the DNREC approved ranking criteria. Solutions that did not require an engineering solution (i.e., maintenance or homeowner solutions) or solutions that would be solved by ongoing projects (e.g., ongoing DelDOT project at the intersection of Oak Orchard Road and River Road) were not ranked at this time. Appendix C shows the prioritization of the proposed solutions.

Table 6.2: Ranking Criteria for Proposed Solutions

Prioritization Category	Description	Score
PUBLIC SAFETY IMPACTS		
Number of Questionnaires with Observations	0 to 3	0
	4 to 9	6
	10 or more	12
Ingress and Egress	Does not affect	0
	Small vehicles may not be able to pass (6 inches or less of water) [1,2]	6
	Road impassible (6 inches or greater) [1,2]	12
TECHNICAL CRITERIA		
Frequency of Drainage/Flooding (as reported in questionnaires)	Occurs less frequently than every 10 years	2
	Every 2-10 years	4
	Yearly	6
	Several times per year	8
	Monthly	10
Flooding Severity	Yard/driveway flooding	4
	Nuisance road flooding	8
	Structural flooding/road closure	12
Complexity of Solution	Significant impact to utilities, roads (closure), business (closure or interruption), or drainage	0
	Minor impact to utilities, roads (partial closure), or drainage	4
	No impact to utilities, roads, or drainage	8
Easement/Right of Way Requirement	Solution entirely on private property, or requiring more than four easements through private property	0
	Solution primarily on public property, with one to three easements through private property	4
	Solution entirely public property (e.g., DelDOT, DNREC, U.S. Department of Interior)	8
ENVIRONMENTAL/ECOLOGICAL IMPACTS		
Environmental Impact of Proposed Solution	Construction in wetlands or streams, or involves removal of more than 10 trees	0
	Construction on edge of wetlands or streams, or involves removal of 1-9 trees	3
	No impact	6
Environmental Permitting	Required	0
	Not required	6
AGRICULTURAL IMPACTS		
Agricultural Impact	Long term	0
	Short term	4
	None	8
PUBLIC HEALTH IMPACTS		
Septic System Impact	Long term	0
	Short term	4
	None	8
MISCELLANEOUS IMPACTS		
Project Cost	High	0
	Medium	4
	Low	8
Maintenance Cost	High	0
	Medium	4
	Low	8

[1] If there are two or more access roads, multiply score by 0.5
[2] If there is one access road, multiply score by 1

6.7 DNREC Selection of High Priority Drainage Solutions

URS submitted the identified drainage deficiencies and initial solutions along with the ranking of the solutions to DNREC on October 17, 2014. URS discussed the potential solutions with DNREC at a meeting held on November 12, 2014, and comments were incorporated into the recommendations by URS.

DNREC selected five high priority projects to proceed to the concept design phase. DNREC based its selection on the prioritization matrix, responsible agency, and engineering judgment. Additional factors DNREC considered in the selection process included:

- Agency with jurisdiction over the project area;
- Ongoing or planned DNREC projects in the vicinity of the proposed projects;
- The complexity of the project;
- Whether a concept design for a similar project could be adapted for multiple sites; and
- The interdependence of proposed projects (e.g., improving the conveyance at Oak Meadows [OO_12] would likely worsen flooding at River Road [OO_09] if the existing culvert were not upgraded).

The development of the concept designs is discussed in Section 7.

SECTION SEVEN: POTENTIAL SOLUTIONS

The goal for this study is to identify, evaluate, and recommend potential solutions for drainage deficiencies in the Oak Orchard community. To facilitate implementation, the projects have been organized by the agency having jurisdiction of the project area (Table 7.1). The complete potential drainage solution table organized by community is available in Appendix C.

Table 7.1: Summary of Proposed Drainage Solutions by Agency

Agency	Number of Solutions
DNREC	19
Delaware Department of Transportation (DelDOT)	3
Homeowner Solution (DNREC Technical Assistance)	7
Homeowner Association (DNREC Technical Assistance)	2

7.1 DNREC Projects

The majority of the recommended drainage solutions are within DNREC jurisdiction. The DNREC projects are further subdivided into high priority projects, for which a concept design was developed, and lower priority drainage solutions.

7.1.1 High Priority Drainage Solutions

Concept designs were developed for the five high priority recommendations selected by DNREC. The approximate location of each high priority drainage solution site is shown in Figure 6.1. Appendix G contains concept design packages for each of the sites that were analyzed in detail. The package for each high priority site includes:

- A description of the existing problem;
- A description of potential solutions;
- Existing and proposed site condition graphics;
- Typical cross sections;

Collapsed headwall at River Road culvert during high tide, approximately 2,000 feet west of Chief Road (OO_04).

- Pertinent computations;
- Analysis of proposed improvements and benefits;
- Analysis of the feasibility of the solutions;
- A description of required plans and permits; and
- Cost estimates.

An additional field investigation was performed in February 2015 for the five high priority projects selected by DNREC. The purpose of this investigation was to acquire additional data on each site to establish a more detailed solution based on the preliminary recommendations provided in Appendix C.

The concept design packages include preliminary hydraulic calculations using the hydrologic data from the Oak Orchard hydrology report (Appendix F). Hydraulic calculations were performed using HY-8, Manning's equation, or Bentley Pond Pack software. The water surface elevation data for Indian River Bay, discussed in Section 2.5, were considered for culverts crossing River Road (OO_04B, OO_09B, and OO_12).

The feasibility of each proposed solution was assessed by considering:

- **Soil and Groundwater:** Most of the proposed solutions are in areas with hydrologic group A soils (sand) and groundwater depths of 5 feet or less. The effects of these soil and groundwater conditions were considered.
- **Construction Access**: Construction access to the proposed improvement site was identified. The proximity to roads, private property, and potential heavy equipment parking are noted.
- **Maintenance Considerations:** Activities required to maintain the function of the proposed improvements are described.
- **Utility Conflicts:** Potential utility conflicts, such as water, sewer, electric, cable, and power lines, were identified based on field observations, and data from the Sussex County Engineering Department.
- **Effectiveness:** The ability of the proposed solution to solve the existing problem is evaluated.
- **Environmental Issues:** Potential impacts to trees and wetlands are noted.
- **Easements:** Potential easements necessary for project construction are noted.
- **Plans and Permitting:** Anticipated construction documentation and plans are listed.

The conceptual costs were developed based on engineering judgment. The cost estimates include engineering, permitting, and construction costs. Typical unit costs are based on contractors' estimates and on unit price data for Anne Arundel County, Maryland and other areas. Costs reflect current rates and geographic conditions. A qualitative cost-benefit analysis was performed by comparing the cost of each project with the expected benefits. The concept design data for each solution is provided in Appendix G, and a summary of each solution is presented in Table 7.2.

Table 7.2: Summary of Proposed High Priority Solutions Selected for Concept Design

Solution ID	Proposed Project Location	Recommendation	Cost
OO_04B	River Road, approximately 2,000 feet west of Chief Road	Install 1,000 feet of bulkhead north of River Road, and install three 30-inch culverts crossing River Road. Install backwater control check valves for each pipe. Repair the upstream and downstream face of the existing culvert, and slip line the pipe if needed. Install a headwall and tide gate at the downstream face of the existing culvert to allow saltwater flow to the marsh during low and average tides (promoting the biologic function of the marsh) while preventing inundation during high tide. Install three at-grade drainage inlets with one-way check valves to drain the roadway.	$945,000
OO_09B	The intersection of Cerise Avenue and River Road, and Roberta Lane	Install 700 feet of bulkhead north of River Road, and install three 36-inch culverts crossing River Road. Install backwater control check valves for each pipe. Slip line the existing culvert if needed. Install a headwall and tide gate at the downstream face of the existing culvert to allow saltwater flow to the marsh during low and average tides (promoting the biologic function of marsh) while preventing inundation during high tide. Install three at-grade drainage inlets with one-way check valves to drain the roadway.	$951,000
OO_12 and OO_13	Mercer Avenue and Forest Drive	Clean 650 feet of existing grass ditch along Mercer Avenue and Delaware Street and replace 400 feet of existing damaged storm drain system. Extend pipe into the Bay and install backflow prevention. Install two catch basins by the intersection of Forest Avenue with Delaware Street, and install 150 feet of storm drain pipe to the existing Mercer Avenue ditch.	$218,000

Solution ID	Proposed Project Location	Recommendation	Cost
OO_18	West Fairfax Court and West James Court (southwest corner of Captains Grant), and Oak Orchard Road west of Captains Grant	Regrade 600 feet of grass ditch northeast of Oak Orchard Road from Fairfax Court to the 24-inch corrugated metal pipe culvert crossing Captains Way that flows to the existing wet pond. Install 400 feet of grass ditch northeast of Oak Orchard Road from West James Court to the existing ditch. Replace the existing culvert crossing Oak Orchard Road, and implement sediment reduction practice at existing catch basin.	$76,000
OO_22 and OO_28	Oak Meadow Drive	Resize and replace 2,500 feet of existing storm drain pipes, and replace with a storm drain system. Pipes should be replaced from Briar Lane to the outlet into the Amber Drive wet pond. Install/upgrade ditches as needed, including from the driveway of 27706 Oak Meadows Drive to the existing catch basin. Install a ditch north of Briar Lane from the intersection of Oak Meadow Drive and Briar Lane to the existing catch basin. Install storm drain pipes under driveways as needed.	$918,000

7.1.2 Additional DNREC Drainage Solutions

In addition to the high priority drainage solutions described in Section 7.1.1, there are lower priority engineering drainage solutions that are recommended for implementation. The most frequently recommended engineering solutions in this study involve improving existing stormwater conveyance systems. These stormwater conveyance systems include drainage ditches, storm drain pipes, and valley gutters. The improvements recommended in this study include:

- **Installing Storm Drain Systems that Drain to Non-Tidal Area:** At-grade inlets and storm drain pipes are common in flat and urban areas. It is recommended that the inlets and pipes be placed in low-lying areas adjacent to roadways and connected to existing stormwater management facilities, or non-tidal marshes. Examples of recommendations to install or upgrade existing at-grade inlets and storm drain pipes that drain to non-tidal outfalls include OO_10, OO_16, and OO_21.

Catch Basin at River View Avenue

- **Installing Storm Drain Systems That Drain to Tidal Area:** Installing at-grade inlets and storm drain pipes that drain to tidal areas requires additional components to prevent inlet surcharging during abnormally high tides. Backwater prevention equipment is recommended in areas where storm drain pipes drain to the Indian River Bay or a tidally influenced marsh. Backwater prevention will allow localized runoff to drain lower tides and will deter flooding from the marsh during higher tides. Examples of recommendations to install or upgrade existing at-grade inlets and storm drain pipes that drain to tidal outfalls include OO_08 and OO_38.

Existing Grass Ditch at the Corner of Oak Orchard Road and Caravel

- **Installing or Upgrading Existing Ditches:** Drainage ditches are shallow channels that allow water to drain to storm drain pipes, culverts, stormwater management ponds, or backwater marsh areas. Ditch drainage is limited by the water surface elevation of downstream water bodies. Examples of recommendations to install new ditches or improve existing ditches include OO_21 and OO_32.

The intersection of Myrtle Avenue and Delaware Street with standing water

- **Installing Valley Gutters:** Valley gutters are "v" shaped channels in the roadway that convey flow over a road or driveway without affecting traffic. Valley gutters are applicable when conveyance is required from a low point in the roadway to a ditch, catch basin, or sloped segment of roadway. This study recommends two valley gutters (OO_36 and OO_37) to convey ponded water.

- **Constructing a Stormwater Management Facility**: Stormwater management facilities such as wet ponds and dry ponds reduce the peak flow of a watershed by temporarily storing runoff. One stormwater management facility is recommended for this study (OO_34) to reduce the flow downstream. Stormwater management facilities are often costly, and typically have a relatively large footprint.

7.2 DelDOT Projects

Three of the recommended drainage solutions in this study involve modifications to DelDOT roads. URS recommends raising River Road at several locations

River Road near the intersection with Chief Road

(OO_04A, OO_06, and OO_09A) where the road is frequently flooded from Indian River Bay to the south or from marshland to the north. In these situations, the existing hydraulic conveyance capacity needs to be maintained or improved by adding culverts or other means to convey water. Both OO_04A, and OO_09A overlap with high priority DNREC projects and may require coordination between DelDOT and DNREC. The projects under DelDOT jurisdiction are summarized in Table 7.3 and will be shared with DelDOT to assist in their capital planning efforts.

Table 7.3: Summary of Proposed Solutions under DelDOT Jurisdiction

Solution ID	Proposed Project Location	Recommendation
OO_04A[1]	River Road, approximately 2,000 feet west of Chief Road	Raise approximately 400 linear feet of River Road from elevation 2 feet NAVD88 to a finished elevation of 3 to 4 feet NAVD88 (an increase of 1 to 2 feet) from 32026 River Road to 31362 River Road. Install ditch north of River Road if needed to connect to existing ditch system. Replace existing pipe, and install backflow prevention on the bay side of the pipe. If the marsh north of River Road is a salt water marsh, a tide gate may be required to allow saltwater flow to maintain environmental functions.
OO_06	Intersection of Chief Road. and River Road	Raise approximately 500 linear feet of River Road from an elevation of approximately 2 feet NAVD88 to a finished elevation of 4 feet NAVD88 (an increase of 1 to 2 feet) from 400 feet west of the intersection of River Road and Chief Road to 100 feet east of the intersection. Install approximately 300 feet of bulkhead to tie existing bulkhead south of existing parking lot to elevation of 4 feet NAVD88. Regrade boat ramp to keep tidewater from flooding the parking lot. Possibly replace existing storm drain pipe with a larger pipe with a backflow prevention valve on the bay side of pipe. If the marsh north of River Road is a saltwater marsh, a tide gate may be required to allow saltwater flow to maintain environmental functions.
OO_09A[1]	Intersection of Cerise Avenue, River Road, and Roberta Lane	Raise approximately 600 linear feet of River Road from an elevation of approximately 2 feet NAVD88 to a finished elevation of 3 feet NAVD88 (an increase of 0.5 to 1 foot). Resize the existing 30-inch storm drain pipe and install backflow prevention on the bayside of the pipe. If the marsh north of River Road is a saltwater marsh, a tide gate may be required to allow saltwater flow to maintain environmental functions.

[1] This solution is at the same location as a DNREC high priority project, and any future improvements may require coordination between DelDOT and DNREC

7.3 Recommendations for Homeowner Implementation

During the field investigation, URS identified drainage solutions that homeowners or homeowner associations could implement. Structure-based mitigation options (e.g., flood proofing) are not discussed in this report. Solutions that are recommended for homeowner implementation fall into several general categories that are consistent with the homeowner solutions recommended for the Bay Beach Coastal Drainage Engineering Evaluation. Table 7.4 lists potential solutions for each type of problem that were developed for the Bay Beach Coastal Drainage Engineering Evaluation that are also applicable for residents of Oak Orchard. The

DNREC Homeowners Handbook (2011) and Prince George's County Department of Environment Resources Homeowner's Guide to Drainage Problems and Solutions (1998) were used to help generalize proposed solutions. In addition to the general solutions listed below, specific recommendations for the homeowner sites are included in Appendix C.

Table 7.4: Potential Solutions for Homeowner Implementation

Solution Type	Problem	Potential Solution	Applicability / Comments
Yard grading	Ponding areas in yards, swampy yards, backyard that remain wet long after rainfall events	• Grade yard to eliminate ponding areas and ensure water is directed away from home (e.g., fill low areas) • Direct sump pump discharge and gutter discharge away from home using a pipe and/or ditch	• Backfill with non-organic and root-free soil that is more pervious, for best results • Eliminating ponding areas may reduce mosquito population • The proposed practices would be expected to reduce nuisance flooding from storm events, particularly when the yards are raised above the marsh elevation
Driveway grading	Ponding areas in driveway, water entering garage from driveway	• Raise driveway to provide positive drainage to road • Regrade driveway to eliminate low points or sags that collect water • For driveways sloped toward the house, install a lip / speed-bump to prevent water from entering garage/house and direct drainage away from house via sheet flow, ditch, or pipe	• The proposed practices would be expected to reduce nuisance flooding from storm events
Removal of debris/obstacles	Restricted conveyance of stormwater, ponding upstream of conveyance system	• Clear debris, trash, sediment, etc. from culverts, channels, and ditches to ensure adequate conveyance • Remove structures or other objects, such as landscape materials, sheds, and man-made obstacles that inhibit the flow of water	• The effectiveness of conveyance systems are reduced substantially when clogged

Solution Type	Problem	Potential Solution	Applicability / Comments
Gutter improvements	Ponding of water near house	• Direct gutter downspouts away from house (ideally to pervious areas via splash block) • Add plastic pipe to downspout outfalls or create ditch to divert water away from house • Maintain gutters and downspouts by cleaning them out twice a year or as needed • Inspect gutters to make sure that they are securely attached to the house and that the joints are not leaking • Direct gutter runoff to rain garden or rain barrel	• Infiltration is limited when there is a high water table
Rain garden	Ponding of water near house	• Provide a vegetated area adjacent to house or driveway to capture runoff • Rain gardens require excavation, planting soil, and a thin mulch layer, and should be 2 feet above the seasonal high water table elevation	• This is an infiltration option and should be considered only if the water table is at least 2 feet below the ground surface or if it is impossible to create positive drainage by another option (e.g., if garage is at a lower area than surrounding driveway/yard) • Rain gardens provide storage within the engineered soil bed
Waterproofing	Basement flooding	• Caulk gaps and cracks and seal joints and connections in basement walls and floors • Repaint interior of basement with a waterproofing agent • Professionally waterproof basement	• These practices should be considered in tandem with surface drainage improvements
Sump pump improvements	Basement flooding	• Inspect/maintain sump pumps regularly per manufacturers' recommendations • Install a generator, back-up battery, or redundant pump that is powered by water pressure that turns on when the power goes out • Evaluate the size of the sump pump for adequacy and upgrade if needed • Verify that the sump pump discharges to an adequate outfall that provides positive drainage away from the house and that it will not result in erosion	• These practices should be considered in tandem with surface drainage improvements

Solution Type	Problem	Potential Solution	Applicability / Comments
Perimeter French drain	Basement flooding	• Install perimeter French drain (e.g., gravel trench with permeable pipe) around house • Install sump pump (see "sump pump improvement" recommendations above) to pump water away from the property • The French drain can drain to a dry well where the water table is low	• Applicable when a residential flooding is due to a raised groundwater table • These practices should be considered in tandem with surface drainage improvements
Yard Erosion Control	Eroding yards, lack of topsoil, small channels forming in yard	• Plant vegetation (e.g., grass) to stabilize soil • Send a soil sample to the University of Delaware Soiling Testing Program for soil testing and follow recommendations on the type of vegetation to plant and/or required soil improvements • Provide erosion protection (e.g., straw mulch, jute matting, or straw bales) while the vegetation is growing • Where severe erosion is occurring construct timber or rock erosion check dams to trap soil before it leaves the property	• The proposed practices would be expected to reduce erosion from storm events and prevent impedance of downstream drainage
Ditch Erosion Control	Eroding ditch, meandering ditch	• Place riprap (Class I or larger) over filter fabric on eroded face of ditch with a minimum slope of 2 to 1 (horizontal to vertical) and extend at least 1 foot into the base of the ditch • Install retaining wall on eroding face of ditch using timber, pre-packaged concrete, or other suitable material	• Retaining walls greater than 3 feet in height require structural design
General practices	As appropriate	• Consider the effect of all improvements on adjacent properties and discuss alternatives with other homeowners • Avoid encroachment of public land, especially wetland areas	• Improvements installed in coordination with neighbors can be more effective than improvements installed individually

SECTION EIGHT: IMPLEMENTATION PLAN AND CONCLUSIONS

This report presents an analysis of the existing drainage issues for the Oak Orchard community. The evaluation of the drainage deficiencies and solutions is based on community input (i.e., questionnaires and public meetings), field reconnaissance, and GIS data. Potential solutions for the sites investigated in this study are described in Appendix C. A list of solutions that homeowners can implement is presented in Table 7.4, and detailed conceptual level designs for the five DNREC high priority projects are provided in Appendix G. Additional technical analyses, such as detailed design, geotechnical analyses, and field survey are required to confirm that solutions are feasible and constructible.

This report is intended to help the Oak Orchard community identify, prioritize, and implement solutions to drainage problems. The implementation plans for projects under the jurisdiction of each agency identified in this study are as follows:

- **DNREC:** The high priority projects will be considered for capital improvement projects in the 2015 fiscal year, and the low priority projects will be considered for future years.
- **DelDOT:** DNREC will provide DelDOT with recommended solutions under their jurisdiction to assist in capital planning.
- **Homeowners and Homeowner Associations:** DNREC will share potential solutions for homeowner implementation with residents of the Oak Orchard community and provide technical assistance as needed.

Implementing the solutions recommended can reduce the frequency of flooding in the Oak Orchard Community.

SECTION NINE: REFERENCES

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