

Potential Impact of New Urban Development on Flooding on James Island, Charleston, South Carolina

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LIGHTNING SUMMARY

The plans for the proposed Central Park and Riverland Oaks developments on James Island within the city of Charleston, South Carolina, are inconsistent with Charleston stormwater manuals that require that new developments will not increase the probability of flooding during a 100-year, 24-hour storm event. Such calculations cannot be carried out because the current stormwater infrastructure is insufficiently documented and is in poor condition where it is documented. Moreover, based on 22 flooding events that have occurred on James Island over the past five years, the probability of flooding is already 100% for 24-hour storms with a return period greater than only 4.9 years.

ABSTRACT

The proposed Central Park development on James Island within the city of Charleston, South Carolina, would involve the conversion of 10.35 acres of woods and wetlands into 38 single-family lots, while the nearby proposed Riverland Oaks development would convert 28.6 acres of woods with grassed areas and pockets of dense vegetation into 146 single-family lots. The 2013 and 2020 Charleston stormwater manuals both require that a new development will not “increase the likelihood of dwelling flooding and property damage above current conditions” for a 24-hour storm with a 100-year return period and that, for the special protection areas (which include both proposed developments), the post-development, peak discharge rates not be greater than the downstream system capacity. Such calculations require that the current stormwater infrastructure be documented, be in good condition, and be relied upon to prevent substantial flooding during a 100-year, 24-hour storm. However, James Island residents have documented, within the immediate neighborhoods of the proposed development sites, numerous examples of partially or fully blocked stormwater ditches and pipes, as well as infrastructure alterations for which the City has no records. Media articles, social media posts, and photos from residents were used to reconstruct 22 flooding events on James Island between May 1, 2015 – June 25, 2020. These flooding events were compared with daily precipitation records to show that the probability of flooding is 10%, 50% and 100% for 24-hour precipitations equal to or exceeding 0.53 inches, 2.50 inches and 5.53 inches, respectively. A comparison with local precipitation-frequency statistics showed that the probability of flooding is 59% and 100% for 24-hour precipitations with return periods equal to or exceeding 1 year and 4.9 years, respectively. On the above basis, it should be assumed that massive flooding would already be inevitable on James Island during a 100-year storm. Since 2019, the City and County of Charleston have been carrying out a drainage study in the area of the proposed developments with a completion deadline of 2020-21. No new developments in the area should be considered prior to implementation and evaluation of the recommendations of the ongoing drainage study.

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OVERVIEW

The City of Charleston, South Carolina, is currently considering approval of two proposed urban developments on James Island (see Figs. 1-3). The proposed Central Park development would involve the conversion of 10.35 acres of woods and wetlands, including grand oak trees and dense undergrowth, into 38 single-family lots (Seamon Whiteside, 2020; see Figs. 4a-b). The proposed Riverland Oaks development would involve the conversion of 28.6 acres of woods with grassed areas and pockets of dense vegetation into 146 single-family townhomes (see Figs. 5a-b; Hussey Gay Bell, 2020a-b). Due to the timing of submission of the stormwater management plans for the two developments, the Central Park development is being evaluated under the older Stormwater Design Standards Manual (City of Charleston, 2013), while the Riverland Oaks Development is being evaluated under the newer Stormwater Design Standards Manual (AECOM, 2020), which became effective on July 1, 2020. The objective of this report is to address the following question: Are the stormwater management plans for the proposed Central Park and Riverland Oaks developments consist with the respective stormwater manuals under which they are being evaluated? Before discussing the methodology for addressing this question, I will first review the two stormwater manuals and then the two proposed stormwater management plans.

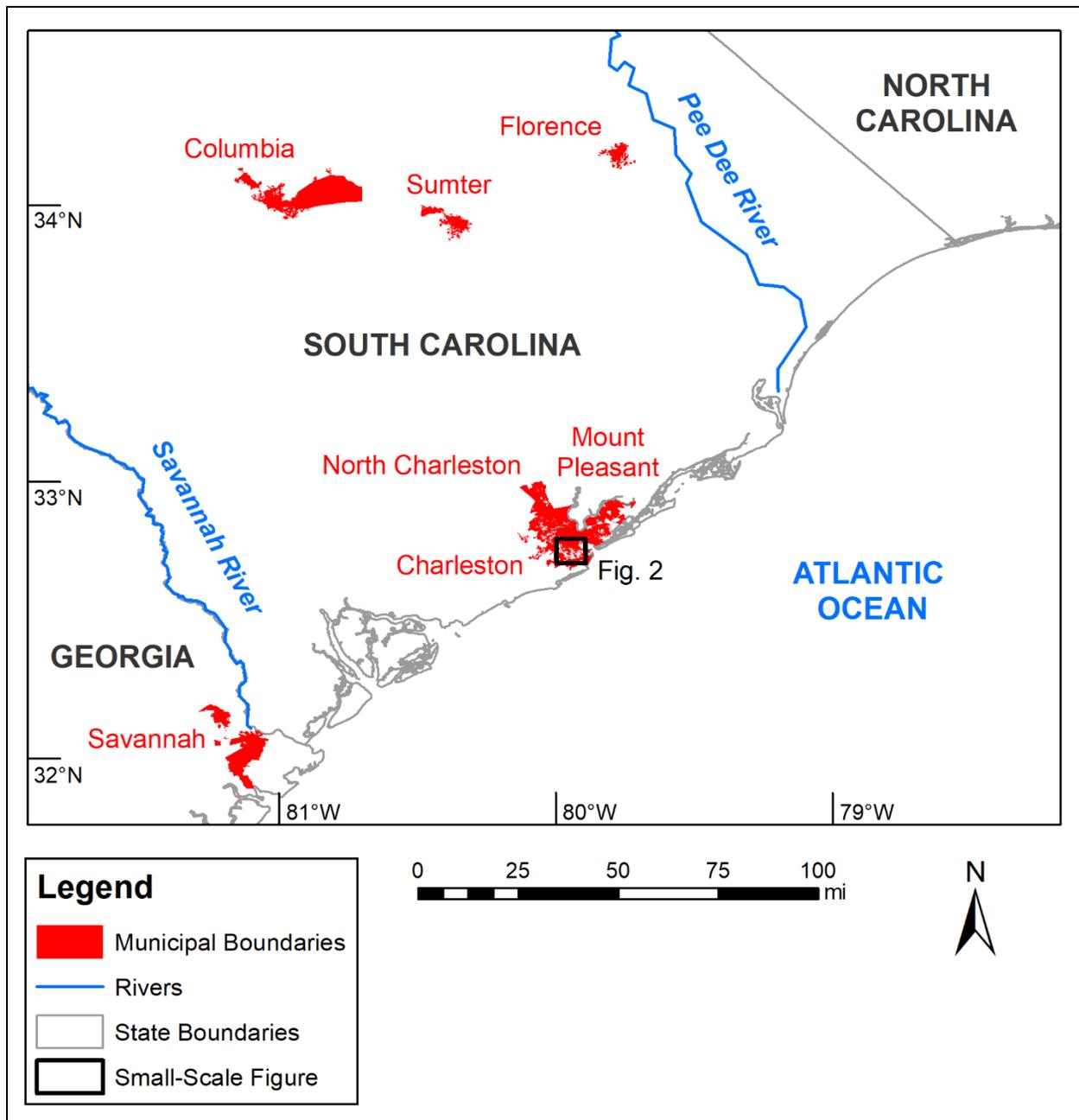


Figure 1. The Central Park and Riverland Oak developments (see Figs. 2-3) have been proposed on James Island within the city of Charleston, South Carolina.

CITY OF CHARLESTON STORMWATER MANUALS

2013 Stormwater Manual

The 2013 Stormwater Design Standards Manual (City of Charleston, 2013) rests on five principles. The first three principles relate to the purpose of the stormwater manual and are stated as follows (City of Charleston, 2013):

- 1) “This manual is not intended to restrain or inhibit engineering creativity, freedom of design, or the need for engineering judgment”
- 2) “The Stormwater Design Standards Manual is not intended as a textbook or a comprehensive engineering design reference. It was developed under the assumption that the user possesses a thorough understanding of stormwater control design, construction, and land development.”
- 3) “The natural or historic condition will be the standard by which the stormwater plan for a construction, development and re-development activity is evaluated.”

The next two principles relate to the required design response of an urban development to a storm with a 24-hour duration and a given return period. The return period refers to the probability of exceedance of a given precipitation amount within any given year. For example, storms with return periods of 2, 10, 25, and 100 years have annual exceedance probabilities of 50%, 10%, 4% and 1%, respectively. The design precipitations for 24-hour storms with return periods of 1, 2, 5, 10, 25, 50 and 100 years are stated in the manual (City of Charleston, 2013) and are identical (rounded to the nearest 0.1 inch) to the current NOAA (2020a) estimates for 24-hour storms with the same return periods at NOAA weather station Charleston WSO City (see Table 1 and Fig. 2). The required design responses are stated as follows (City of Charleston, 2013):

- 4) “Post-development discharge rates shall not exceed pre-development discharge rates for the 2, 10, and 25-year frequency 24-hour duration storm events.”
- 5) “All construction, development and redevelopment activities which disturb one acre or more shall perform an hydraulic analysis to determine the impacts of the proposed development during a 100-year 24-hour storm event (precipitation only). The project shall not (i) increase the likelihood of dwelling flooding and property damage above current conditions; (ii) increase water surface elevations or reduce system capacity in stormwater system and facilities upstream or downstream of the project. An increase or reduction shall be based on a comparison with pre-development conditions.”

(Although the above principles are quotes from the stormwater manual (City of Charleston, 2013), the manual does not explicitly state that there are “five principles.”)

The 2013 stormwater manual (City of Charleston, 2013) recognizes the existence of special protection areas within the city for which the above required design responses are not sufficiently conservative (not sufficiently protective of property and human life). According to the manual, “Flooding exists in many locations around the city where development densities have increased to the point that stormwater controls have become overwhelmed” (City of Charleston, 2013). Within these areas, a new development should not reproduce the natural or historic stormwater runoff, but should reduce it so that the above Principle #4 is revised to read “The post-development, peak discharge rates [are] restricted to one-half the pre-development rates for the 2 and 10-year 24-hour storm event or to the downstream system capacity, whichever is less” (City of Charleston, 2013) In other words, the present capacity of the downstream stormwater infrastructure sets an upper bound on the allowable peak discharge rate from a new development. These special protection areas also require design responses in terms of runoff volumes so that “The post-development runoff volumes for the 2-year frequency 24-hour duration storm events above the pre-development level shall be stored for a period of 24 hours on average before release” (City of Charleston, 2013) with the implied requirement of the construction of water storage or detention ponds in new developments. The above list of design responses for special protection areas is not exhaustive because “additional criteria may be established by the Department of Public Service” (City of Charleston, 2013).

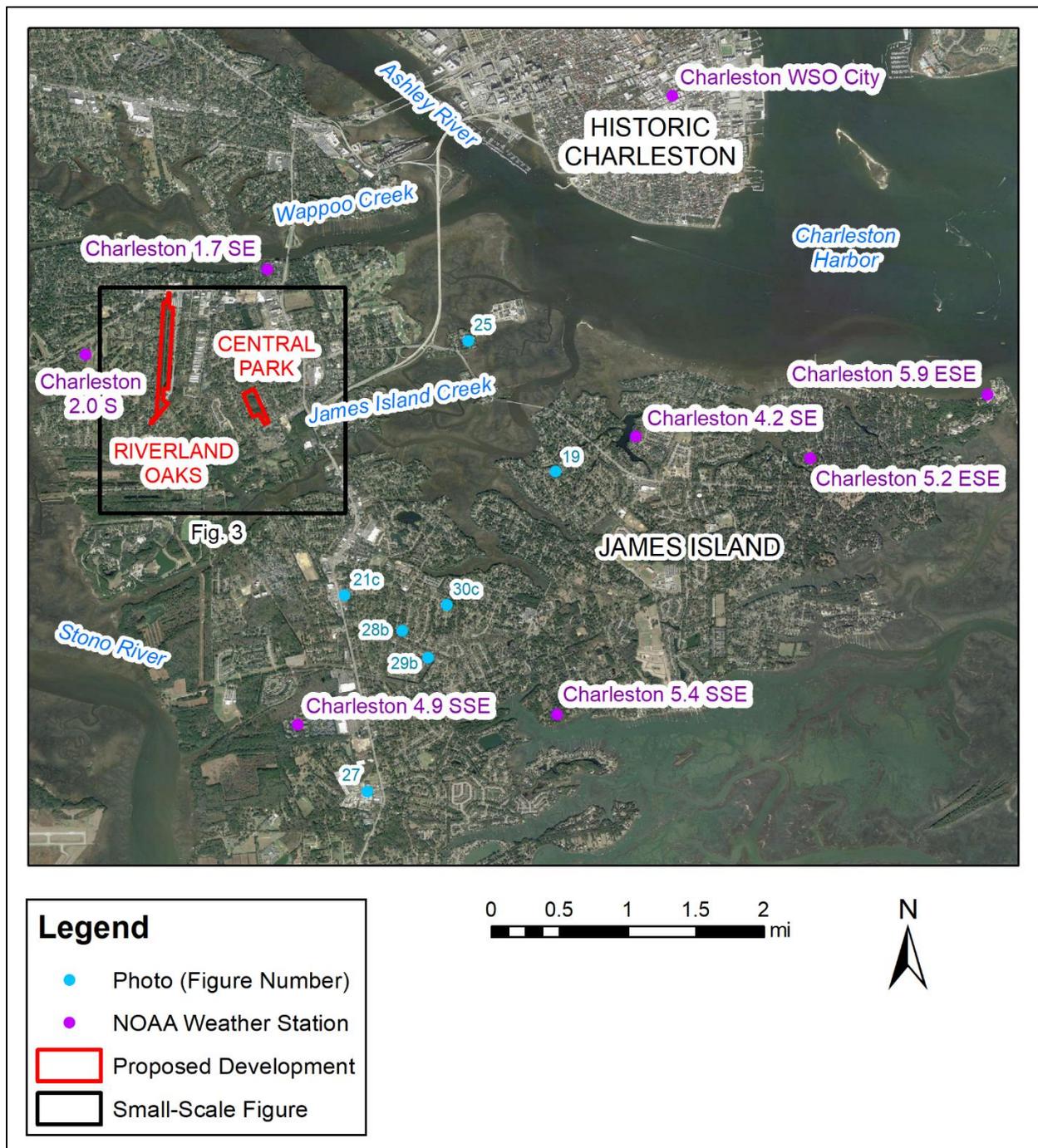


Figure 2. Flooding events on James Island were compared with daily precipitation records at NOAA weather station Charleston 2.0 S, which has 99% coverage. Although Charleston 1.7 SE is closer to the neighborhoods that would be affected by the Central Park and Riverland Oaks developments, it has only 83% coverage (NOAA, 2020b). Return periods corresponding to 24-hour precipitation events were obtained from long-term records at NOAA weather station Charleston WSO City (NOAA, 2020a). Perimeters of proposed Central Park and Riverland Oaks developments traced from Seamon Whiteside (2020) and Hussey Gay Bell (2020b), respectively. Background is Google Earth image from January 10, 2019.

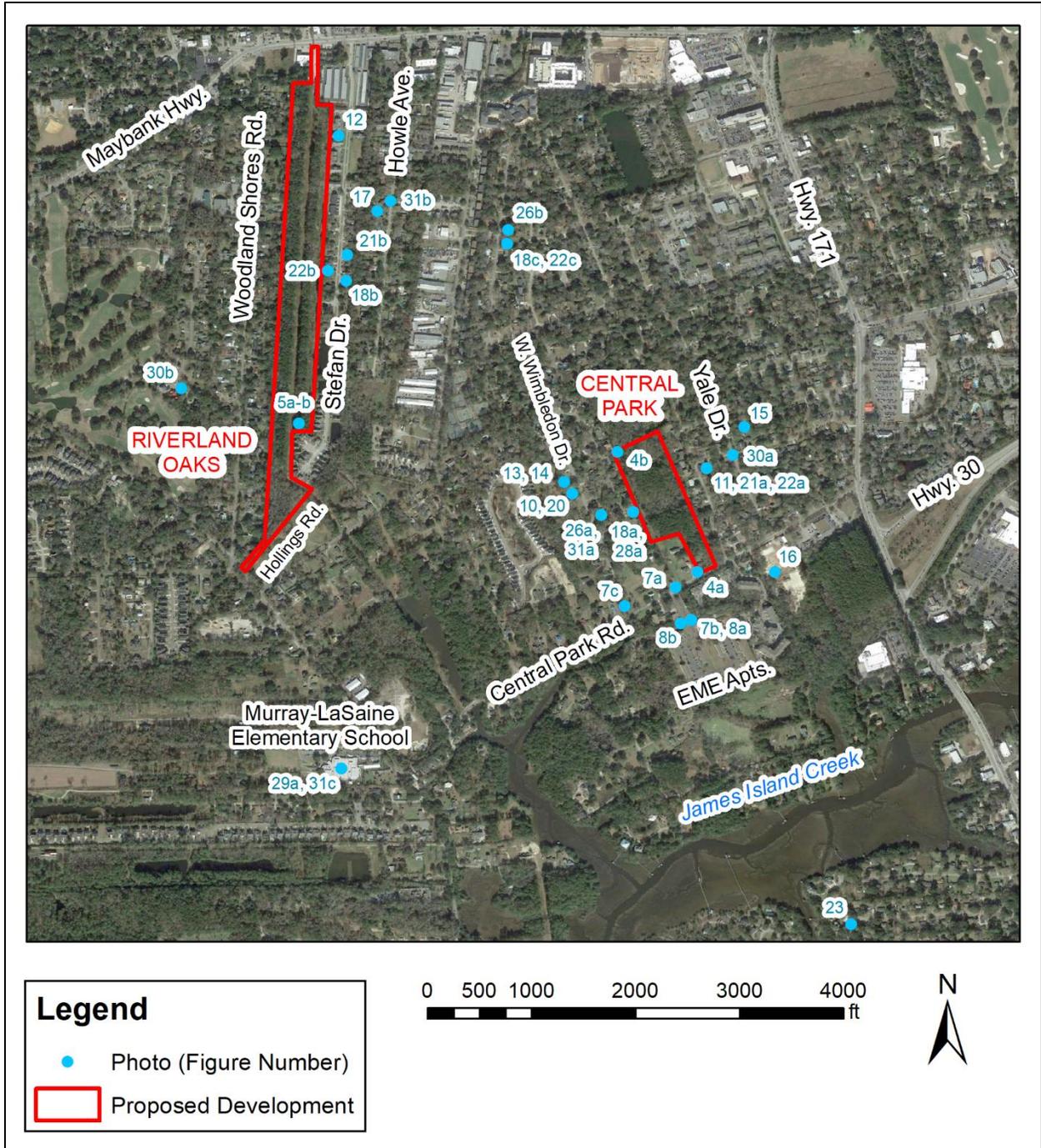


Figure 3. Based on media articles, social media posts, and photos and videos from local residents, 22 flooding events were documented on James Island during the period May 1, 2015 – June 25, 2020 (see Table 3). Photos were chosen that emphasized the impact of flooding on the neighborhoods surrounding the sites of the proposed Central Park and Riverland Oaks developments. Perimeters of proposed Central Park and Riverland Oaks developments traced from Seamon Whiteside (2020) and Hussey Gay Bell (2020b), respectively. Background is Google Earth image from January 10, 2019.



Figure 4a. The proposed Central Park development (see Figs. 2-3) would involve the conversion of 10.35 acres of woods and wetlands into 38 single-family lots. Photo is still at 0:42 of video at Henty (2019). See Fig. 3 for photo location.



Figure 4b. The site of the proposed Central Park development includes grand oak trees and dense undergrowth. Photo taken by Theodosia Wade on July 1, 2020. See Fig. 3 for photo location.



Figure 5a. The proposed Riverland Oaks development (see Figs. 2-3) would involve the conversion of 28.6 acres of woods with grassed areas and pockets of dense vegetation into 146 single-family townhomes. Photo taken by Amy-Marie Tamblyn (see Fig. 3 for location).



Figure 5b. According to Hussey Gay Bell (2020b), although the site of the proposed Riverland Oaks development is “seasonally wet in some areas, this property does not experience any on-site flooding.” There was no explanation as to how “seasonally wet” and “on-site flooding” were different concepts. Photo taken by Amy-Marie Tamblyn (see Fig. 3 for location).

Table 1. Comparison of Design Precipitations (inches) for 24-Hour Storms

Return Period (yrs)	2013 Manual¹	2020 Manual²	NOAA (2020a)³
1	3.5	3.8	3.48 (3.14-3.81)
2	4.2	4.6	4.23 (3.83-4.63)
5	5.5	6.1	5.47 (4.95-5.98)
10	6.5	7.2	6.47 (5.84-7.08)
25	7.9	8.7	7.89 (7.08-8.63)
50	9.0	9.9	9.04 (8.10-9.88)
100	10.3	11.3	10.3 (9.14-11.2)

¹Stormwater Design Standards Manual (City of Charleston, 2013)

²Stormwater Design Standards Manual (AECOM, 2020)

³Mean followed by 90% confidence interval in parentheses for NOAA weather station Charleston WSO City (see Fig. 2)

Much of the 2013 stormwater manual (City of Charleston, 2013) concerns detailed guidelines related to how the five principles stated above might typically be achieved. For example, the manual states “The minimum size storm drainage pipe allowable in the right-of-way shall be 15 inches in diameter. The minimum size pipe allowable outside the right-of-way shall be 10 inches in diameter; The minimum slope for storm drainage pipe shall be 0.003 ft/ft where possible. The minimum flow velocity shall be 3 feet per second for pipes flowing full or half full...Maximum allowable flow velocity shall be 10 feet per second under any flow condition” (City of Charleston, 2013). However, nothing in the manual suggests that a strict adherence to details, such as pipe diameters and slopes, would override the five fundamental principles stated above.

2020 Stormwater Manual

The 2020 Stormwater Design Standards Manual (AECOM, 2020) follows the same framework as the 2013 manual, although it is even more conservative. The first three principles stated above are repeated verbatim from the 2013 manual (City of Charleston, 2013). The new manual refers to storms as having a given AEP (Annual Exceedance Probability) as opposed to a given return period, so that a 100-year storm in the 2013 manual is referred to as a 1 percent AEP storm in the 2020 manual. According to AECOM (2020), “AEP is used as opposed to recurrence intervals [return periods] to avoid the public incorrectly interpreting that an X-year storm event only happens once in every X-years.” (The phrase “return period” is continued in this report since its usage is so common.) The 2020 manual also increases the design precipitations for 24-hour storms by “a 10 percent safety factor to account for uncertainties in the design process and the increasing intensities of storms” (AECOM, 2020). This 10% safety factor makes the design precipitations approximately equal to the upper bound of the 90% confidence intervals for the current NOAA (2020a) estimates for 24-hour storms with the same return periods at NOAA weather station Charleston WSO City (see Table 1 and Fig. 2). With the replacement of return period (or recurrence interval) with percentage AEP, the fourth and fifth principles are also repeated in the 2020 manual (AECOM, 2020) nearly verbatim from the 2013 manual (City of Charleston, 2013).

The 2020 stormwater manual continues the concept of special protection areas from the 2013 manual. According to the 2020 manual, “Any development or redevelopment...within or discharging to these special protection areas must comply with a more stringent set of design

criteria in addition to the minimum standards and LOS [Level of Service] determined by the City...The City can designate any area as a special protection area...The Director of Stormwater Management shall make the determination on whether a site is within a special protection area.” For the special protection areas, Principle #4 is strengthened as in the 2013 manual to read, “For non-SFR [Single-Family Residence] sites of 0.5 acres or more, the post-development, peak discharge rates are restricted to one-half the pre-development rates for the 50 percent and 10 percent AEP [2-year and 10-year], 24-hour storm events or to the downstream system capacity, whichever is less” (AECOM, 2020). Thus, it is still the case that the present capacity of the downstream stormwater infrastructure sets an upper bound on the allowable peak discharge rate from a new development. The special protection areas include the additional design requirement that “for non-SFR sites of 0.5 acres or more, the post-development runoff volumes for the 50 percent, 10 percent, and 4 percent AEP [2-year, 10-year and 25-year], 24-hour duration storm events above the pre-development level shall be stored for 24 hours before release. The runoff volume excess between pre-development and post-development must be released steadily over a period of 48 hours after the initial 24 hours of storage.” Thus, the 2020 manual requires stormwater storage for a greater range of return periods (as opposed to storage for only the 2-year storm in the 2013 manual) with an additional requirement on the time period for release of the stored stormwater (none stated in the 2013 manual). Again, the 2020 stormwater manual emphasizes that the preceding list of design criteria for special protection areas are not exhaustive because “additional stormwater design criteria may be determined and required by the Department of Stormwater Management during the permitting process” (AECOM, 2020).

In summary, the 2020 stormwater manual (AECOM, 2020) is very similar to the 2013 stormwater manual (City of Charleston, 2013), except with more conservative choices for design precipitation (see Table 1) and with more conservative criteria on maximum discharge rates and minimum stormwater storage volumes (with the addition of a specified time period for release of stored stormwater) for the special protection areas. In some cases, the 2020 manual is more conservative in terms of the detailed guidelines by which the fundamental principles might be achieved. For example, the previous passage regarding storm drainage pipes in the 2013 manual is re-written in the 2020 manual as “The minimum size storm drainage pipe allowable in the right-of-way shall be 15 inches in nominal inner diameter. The minimum size pipe allowable outside the right-of-way shall be 12 inches in diameter. The minimum slope for storm drainage pipe shall be 0.003 ft/ft where possible. The minimum flow velocity shall be 2 fps [feet per second] for pipes flowing full or half full...Maximum allowable flow velocity shall be 10 fps under any flow condition” (AECOM, 2020). Thus, the 2020 manual requires larger pipes outside of the right-of-way and lower minimum flow velocities. Of course, nothing in the 2020 manual suggests that a strict adherence to details would override the five fundamental principles stated above, either inside or outside of the special protection areas.

STORMWATER ASPECTS OF PROPOSED DEVELOPMENTS

Central Park Development

Typically, the conversion of woods and wetlands into residential lots would increase both the peak stormwater discharge rate and the stormwater runoff volume. In conventional stormwater management, this result is avoided by the construction of stormwater detention ponds. At the present site of the proposed Central Park development, stormwater flows to the

southeast, where it enters an existing drainage ditch at the edge of the site, after which it is eventually conveyed to James Island Creek and Charleston Harbor (Seamon Whiteside, 2020; see Figs. 2-3). According to the Comprehensive Storm Water Pollution Prevention Plan (C-SWPPP), construction of the Central Park development will include the construction of a stormwater drainage system that will flow into a new wet pond (typically partially full of water) and two interconnected dry ponds (typically dry, except during and shortly after storms), after which it will be released to an existing drainage ditch on the western boundary of the site (Seamon Whiteside, 2020; see Fig. 3). A separate bypass system will convey stormwater from upstream of the site through the site to the same drainage ditch on the western boundary.

The C-SWPPP acknowledges that “this site is located in an area to which the local City of Charleston, Charleston County, and SCDOT [South Carolina Department of Transportation] maintained stormwater infrastructure is overwhelmed” and that “there is known flooding in the area” (Seamon-Whiteside, 2020). On that basis, “the City of Charleston Stormwater Department is placing this site into a Special Protection Area and restricting this site to the requirements set forth by section 3.9.1 [Areas Associated with Flooding] of the City of Charleston Stormwater Design Standards Manual” (Seamon-Whiteside, 2020). The City of Charleston also required all stormwater modeling to include the entire contributing watershed upstream from the site and the entire downstream area until the entry of the stormwater into James Island Creek. In other words, the stormwater calculations involved the integration of the proposed stormwater infrastructure with the existing stormwater infrastructure both upstream and downstream of the site. In fact, the site of the proposed development is only 5.1% of the watershed area for which stormwater calculations were carried out (Seamon-Whiteside, 2020).

The Streamflow Technologies Interconnected Channel and Pond Routing Model (ICPR) was used to claim that the requirements for a special protection area, as stated in the 2013 stormwater manual (City of Charleston, 2013), would be fulfilled by the proposed stormwater infrastructure as integrated with the existing stormwater infrastructure. According to the C-SWPPP, “The multiple post-development models show that not only will this site, at just over 5% of the total watershed, reduce the staging in the adjacent drainage canal but will also reduce to the overall flows to the James Island Creek. The results also show that this site is providing an increase of flood storage area in the post development condition as well as reducing the post-development flows from the built upon area by over 80% in the 2-year and 10-year 24-hour storm event. This study...show[s] that this site, although privately developed, will be a benefit to the local publicly maintained infrastructure in the surrounding watershed” (Seamon-Whiteside, 2020).

Riverland Oaks Development

The present site of the proposed Riverland Oaks development slopes down to the east, so that stormwater runoff flows into an existing drainage ditch and then into an existing detention pond within the Stefan Acres development (Hussey Gay Bell, 2020a; see Fig. 3). From the detention pond, stormwater flows through a network of pipes and ponds that also receive stormwater from other sources. This combined stormwater passes under Hollings Road (see Fig. 3) to “a small impaired ditch” (Hussey Gay Bell, 2020a) from which it discharges into James Island Creek and flows into Charleston Harbor (see Figs. 2-3). The proposed stormwater plan includes the construction of 12 detention ponds within the development and one downstream of the development. Two of the detention ponds within the development would be created by dredging existing wetland areas. Ten of the 12 constructed on-site ponds would store and

gradually release stormwater to the existing drainage ditch on the Stefan Acres development, from where it would, as before, flow into the Stefan Acres detention pond. Some of the stormwater from the Stefan acres pond would be routed back onto the Riverland Oaks development into the other two on-site detention ponds that would be collecting additional stormwater from the development site. This combined stormwater would flow into the single off-site detention pond before it reaches Hollings Road, from where it would be conveyed to a recently constructed Charleston County drainage ditch (Hussey Gay Bell, 2020b).

According to Hussey Gay Bell (2020b), “Although low and seasonally wet in some areas [see Fig. 5b], this property [the site of the proposed Riverland Oaks development] does not experience any on-site flooding.” The document did not include any explanation as to how “seasonally wet” and “on-site flooding” were different concepts (see Fig. 5b). Hussey Gay Bell (2020b) continued, “However, this site does fall within a larger common drainage basin with adjacent developments and properties which have experience flooding in recent years. The majority of these flood prone properties are downstream where existing drainage infrastructure has been undermaintained and neglected.” In an earlier communication with the consultants for the Riverland Oaks development, the City of Charleston (2015) indicated that “the drainage basin that is the location of this proposed development is an area that experiences frequent flooding during moderate to heavy rains. Currently the flooding effects areas both upstream and downstream of this property.” The City of Charleston (2015) objected to “the current mapping we have reviewed [that] appears to be limited to on-site areas only.” The City of Charleston (2015) insisted that “there is off-site drainage that must be considered. In order to assure us that these areas were considered, we need a comprehensive pre and post drainage basin map that incorporates the entirety of the offsite areas draining into the Riverland Oaks site.” In other words, just as with the proposed Central Park development, the City of Charleston is requiring that stormwater calculations take into account the integration of the proposed stormwater infrastructure with the existing upstream and downstream stormwater infrastructure. The most recent report from Hussey Gay Bell (2020b) has also acknowledged “downstream infrastructures and improvements [that] must be completed in order for this proposed development to meet the requirements and requests of the City’s Stormwater Department.” As of the date of this report, the consultants for the developers have not submitted a C-SWPPP that would show compliance with the general requirements of the 2020 stormwater manual (AECOM, 2020) and the stricter requirements for a special protection area.

METHODOLOGY

The question as to whether the stormwater management plans for the proposed Central Park and Riverland Oaks developments are consistent with their corresponding stormwater manuals includes, but is not limited to the following questions:

- 1) Can it be demonstrated that the post-development, peak discharge rates will not exceed the downstream stormwater capacity for the 2-year and 10-year 24-hour storm events?
- 2) Can it be demonstrated that the developments will not increase the probability of dwelling flooding and property damage during a 100-year 24-hour storm?

Note that the questions are the same regardless of which stormwater manual is being considered, except that the 2020 manual (AECOM, 2020) uses higher design precipitations for a storm with a given return period (see Table 1).

The proper approval of the stormwater plans would require not simply asking the questions, but answering the questions in a positive manner. A positive answer to the first question would require that the existing downstream stormwater infrastructure be known and be known to be in a good condition. In other words, it would be impossible to give a positive answer to the first question if any of the following conditions were met:

- 1) There were insufficient design plans for the stormwater infrastructure.
- 2) There were insufficient records as to whether the stormwater infrastructure had been built as designed.
- 3) There were insufficient records regarding any alterations to the stormwater infrastructure.
- 4) There were insufficient records regarding the maintenance of the stormwater infrastructure.
- 5) An insufficient portion of the stormwater infrastructure could be observed to be in good condition.

For both the Central Park and Riverland Oaks developments, the City of Charleston has already emphasized the need to include both the existing upstream and downstream stormwater infrastructure in all stormwater calculations (City of Charleston, 2015; Seamon-Whiteside, 2020), which, of course, requires the correct knowledge of the existing infrastructure.

The second question can be answered in a positive manner only if it could be reasonably assumed that, at the present time, a 24-hour storm with a 100-year return period would not result in massive dwelling flooding with total losses of homes or other properties. If massive dwelling flooding with total losses is already assured, then it is meaningless to ask whether an additional development would increase the probability of flooding. On that basis, the fifth principle of the stormwater manuals rests on the underlying assumption that a reasonably robust stormwater system (with the capacity to prevent massive destruction from a 100-year storm) is already in existence. The assumption can be questioned on James Island if only due to the communication from Charleston County Public Works (2020) that “subdivisions built before 1990 were not designed for a specific rain event, which is why Laurel Park [the subdivision downstream from the proposed Central Park development site] has no detention ponds.”

In light of the above discussion, the objective of this report can be re-stated as the following two questions:

- 1) Based upon its appearance and upon records, is the stormwater infrastructure in the vicinity of the proposed Central Park and Riverland Oaks developments known and known to be in good condition?
- 2) Based upon the response of the stormwater infrastructure to recent storms, is it likely that the current stormwater infrastructure could prevent massive flooding with total losses of homes in response to a 24-hour storm with a 100-year return period?

The first question was addressed by the visual inspection of stormwater ditches and pipes by local residents, largely in the neighborhood of EME Apartments, which is downstream from the proposed Central Park development site (see Fig. 3). Any apparent alterations to the stormwater infrastructure were compared with records available with the Department of Stormwater Management of the City of Charleston. No resources were available for a systematic survey of a significant portion of the stormwater infrastructure. In particular, the author was not able to carry out any fieldwork due to the ongoing COVID-19 pandemic.

The second question was addressed by using published media articles, social media posts (mostly the Save James Island Facebook Group) and photos and videos provided by local residents to document flooding events on James Island during the time period May 1, 2015 – June 25, 2020. For each flooding event, the earliest documented date was regarded as the date of

onset of flooding. That date was compared with the maximum daily precipitation that occurred the day before, the day of, and the day after the onset of flooding, which provided an upper bound on the 24-hour precipitation required to initiate flooding. Out of the seven NOAA weather stations on James Island (NOAA, 2020b), the Charleston 2.0 S and Charleston 1.7 SE stations are closest to the Central Park and Riverland Oaks development sites (see Table 2 and Fig. 2). Although the Charleston 1.7 SE weather station is most centrally located to both proposed developments, precipitation records from the Charleston 2.0 S station were used due to the 99% coverage (over time) of the station, as opposed to the incomplete coverage (83%) at the Charleston 1.7 SE station (see Table 2).

Table 2. NOAA Weather Stations on James Island¹

Name	Latitude (°N)	Longitude (°W)	Duration	Coverage
Charleston 2.0 S, SC US	32.755856	79.995506	12/1/2013 - present	99%
Charleston 1.7 SE, SC US	32.764938	79.976242	12/9/2013 - present	83%
Charleston 4.2 SE, SC US	32.747219	79.937171	2/27/2008 - 3/13/2018	6%
Charleston 5.2 ESE, SC US	32.744873	79.918617	8/3/2014 - present	91%
Charleston 5.9 ESE, SC US	32.751632	79.899845	4/27/2017 - present	38%
Charleston 5.4 SSE, SC US	32.717687	79.945517	11/27/2011 - present	93%
Charleston 4.9 SSE, SC US	32.716641	79.973019	4/1/2019 - present	96%

¹NOAA (2020b)

Daily precipitations corresponding to flooding events were converted to return periods using precipitation-frequency statistics for NOAA weather station Charleston WSO City, which is the weather station closest to James Island with a sufficiently long precipitation record (NOAA, 2020a; see Fig. 2). Estimates for precipitation amounts corresponding to 24-hour storms with return periods of 1, 2, 5, 10, 25, 50, 100, 200, 500 and 1000 years were used to calculate the best-fit exponential curve that predicted return period from daily precipitation (see Fig. 6). The minimum and maximum precipitation amounts (based on a 90% confidence interval) for a given return period were also used to calculate the best-fit exponential curve that predicted the minimum and maximum return period from daily precipitation (see Table 1 and Fig. 6). The use of the best-fit exponential curve resulted in some fairly low 24-hour precipitation amounts that corresponded to flooding events with return periods less than one year. These return periods were included for completeness (see Table 3), but they are essentially meaningless because a storm with a 1-year return period already has a 100% probability of exceedance with a given year. The daily precipitations corresponding to flooding events were then compared with the daily precipitations that did not correspond to flooding events to determine the probability of flooding on James Island as a function of daily precipitation and the 24-hour storm return period.

RESULTS

Current Condition of Stormwater Infrastructure: Appearance and Records

The stormwater infrastructure in the vicinity of EME Apartments (see Fig. 3) was documented to be in very poor condition. Numerous stormwater drainage ditches were found to be almost non-functional because they were nearly completely filled with mud, vegetation,

woody debris, and trash, such as abandoned shopping carts (see Fig. 3, 7a-c). At one site, two parallel subsurface stormwater pipes were located with diameters of 42 and 48 inches (see Fig. 8a). The 42-inch pipe was completely blocked and was about half-full of standing water (see left-hand side of Fig. 8a). The blocked pipe was immediately below a manhole cover, which could have facilitated inspection and maintenance (see right-hand side of Fig. 8a). At the downstream end where the stormwater pipes emerged at the surface and flowed to James Island Creek, the 48-inch pipe was observed to be open at both ends (see Fig. 3 and right-hand side of Fig. 8b). However, the 42-inch pipe was completely blocked with large rocks on the downstream side (see left-hand side of Fig. 8b).

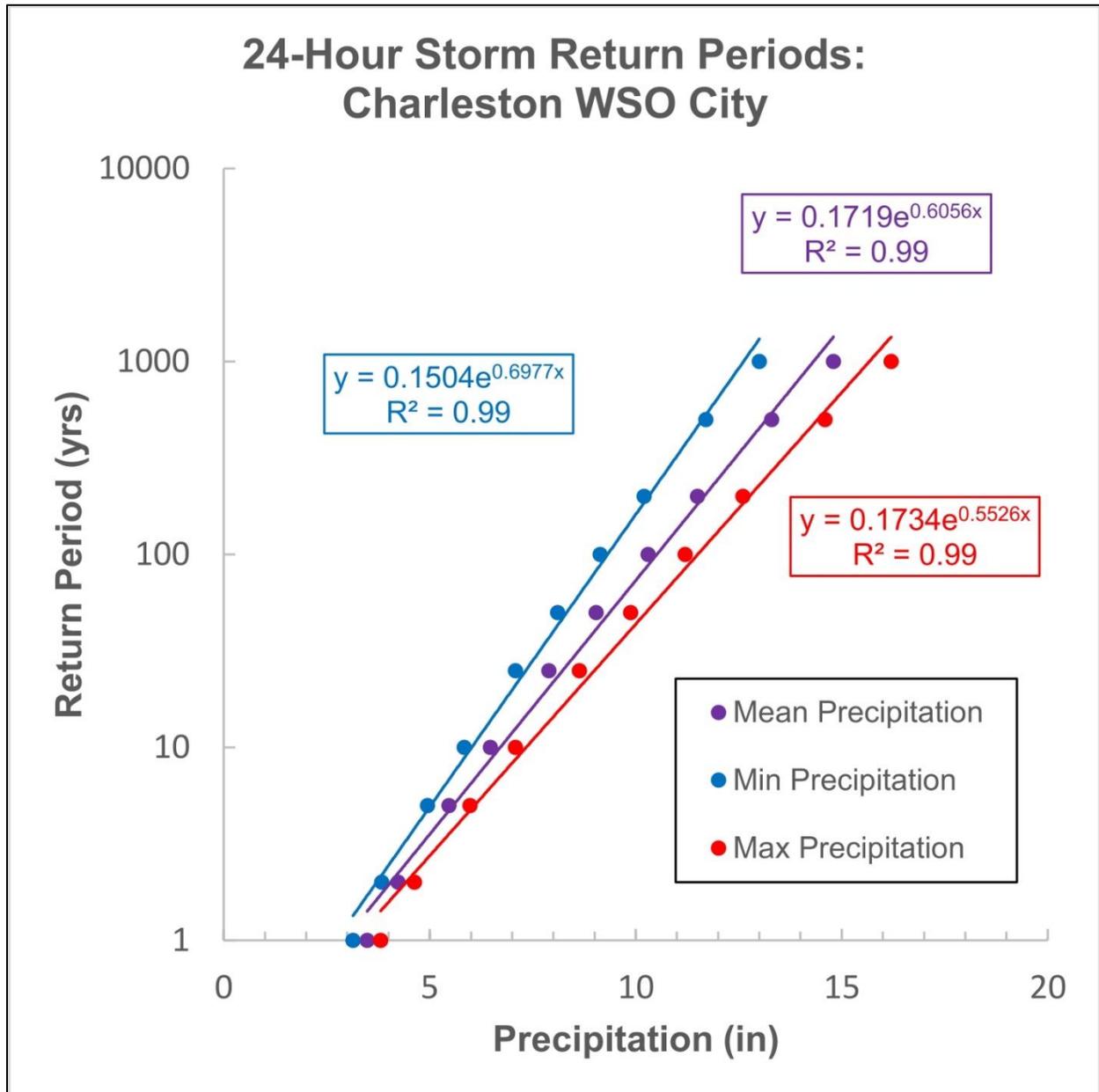


Figure 6. An exponential curve is an excellent fit to return periods for 24-hour precipitation events at NOAA weather station Charleston WSO City (see Fig. 2; NOAA, 2020a). The minimum and maximum precipitations indicate 90% confidence intervals for 24-hour precipitations corresponding to a given return period.

According to the Department of Stormwater Management, the blocked pipe (see Figs. 8a-b) was an intentional alteration of the stormwater infrastructure, not a lack of maintenance. The City of Charleston (2020a) responded to local residents, “It does look like the 42” pipe was actually sealed shut a number of years ago rather than it being clogged.” However, the Department of Stormwater Management had no records of such an alteration. In a follow-up message, City of Charleston (2020b) wrote, “From the records of the work we did to rehabilitate this system in 2016 it looks like the pipe must have been closed off before that. As a result, it would have been done before most of us working in stormwater engineering at the City and County were here. We are looking into if we have any records of what might have happened on this system or if any of the longer tenured maintenance employees have any knowledge on this and will let you know if we find anything out.” There was no follow-up on the preceding message, so that, presumably, neither written nor mental records were located.



Figure 7a. A drainage ditch that should convey stormwater into a 36-inch and a 42-inch pipe that pass under Central Park Road toward EME Apartments is almost completely filled with mud. Photo taken by James Mazyck on January 4, 2020 (see Fig. 3 for location).

Within the same communications to local residents, the Department of Stormwater Management said that it was irrelevant for stormwater modeling whether that particular 42-inch stormwater pipe was or was not blocked. According to City of Charleston (2020a), “We did have AECOM evaluate upsizing or reconstructing this pipe [the blocked 42-inch pipe] in our current

model to determine if it has any benefit on reducing flooding. The drainage model shows that there are a number of upstream constrictions that also need to be improved before upsizing this pipe would reduce flooding in the area. For example, the pipes under Central Park Road are a 42” pipe and a 36” pipe [see clogged stormwater ditches leading to the 36-inch and 42-inch pipes in Fig. 7a], and between Central Park and this drainage box are another pair of 42” pipes, all of which already have less capacity than this downstream 48” pipe.” The Department of Stormwater Management considered the impact on stormwater modeling of altering only a single downstream component of the stormwater infrastructure. However, that single altered component was found through a fairly cursory survey of the visible infrastructure over a small area. This raises the possibility that there could be numerous alterations of the stormwater infrastructure for which the Department of Stormwater Management has no records, and there is no way to assess the impact on stormwater modeling of these unknown alterations.



Figure 7b. A drainage ditch at EME Apartments is almost completely filled with mud and debris. Photo taken by James Mazzyck on January 4, 2020 (see Fig. 3 for location).

Current Condition of Stormwater Infrastructure: Performance

A total of 22 flooding events were documented on James Island during the time period May 1, 2015 – June 25, 2020 (see Table 3). Three of the flooding events (September 11, 2017; July 7, 2018; December 23, 2019) were documented in media articles (Coyle; 2017; Phillips,

2018; Phillips and Streicher, 2018; Streicher, 2018a-b; Arruda, 2019), while the remainder were documented from resident photos and videos and from social media posts. Some flooding dates were mentioned in media articles about flooding in Charleston, but which did not specifically mention James Island. Of the 22 flooding events, all but four (July 30, 2018; September 10, 2018; November 24, 2018; June 12, 2019) could be documented in the vicinity of the Central Park and Riverland Oaks development sites (see Table 3). The largest daily precipitations over the study period were 9.02 inches on October 4, 2015 (Hurricane Joaquin), 8.48 inches on October 8, 2016 (Hurricane Matthew), and 6.78 inches on September 12, 2017 (Hurricane Irma), corresponding to return periods of 40.5 years, 29.2 years, and 10.4 years, respectively (see Table 3). Only seven other flooding events corresponded to daily precipitations with equivalent return periods longer than one year (see Table 3), leaving 12 flooding events corresponding to fairly minor daily precipitations (calculated return periods shorter than one year). In fact, flooding has occurred with daily precipitations as low as 0.20 inches (January 30, 2016), 0.30 inches (September 10, 2018), 0.60 inches (November 24, 2018), and 0.65 inches (December 22, 2015) (see Table 3).



Figure 7c. A drainage ditch at 1836 Central Park Road is almost completely filled with mud, vegetation, woody debris and trash, including abandoned shopping carts. Photo taken by James Mazyck on January 4, 2020 (see Fig. 3 for location).

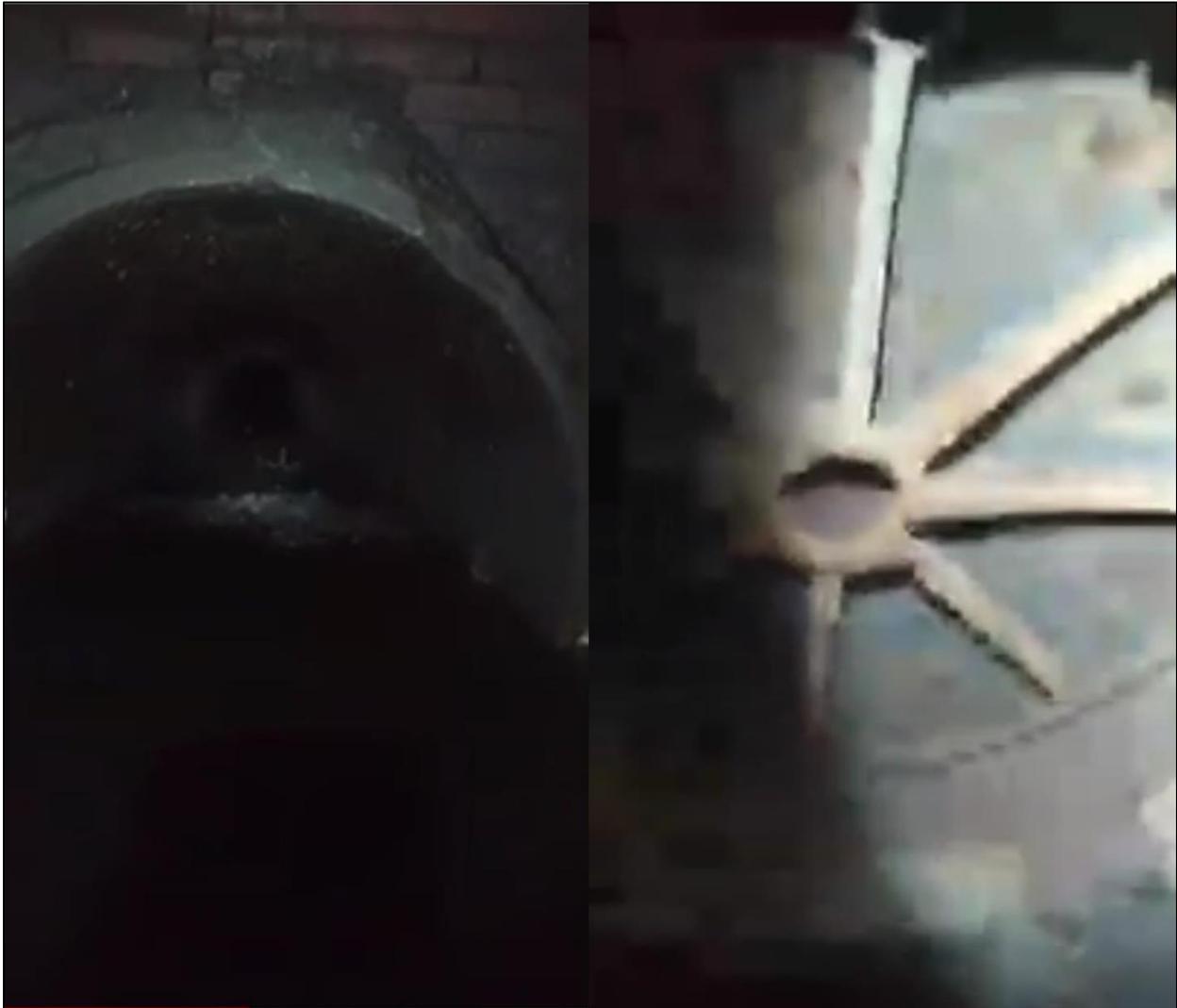


Figure 8a. A 42-inch subsurface stormwater pipe at EME Apartments is completely blocked (left-hand side). The observation and maintenance of the blocked pipe should be facilitated by the presence of the manhole cover immediately above the pipe (right-hand side). Left-hand and right-hand photos are stills at 0:35 and 1:09, respectively, from a video at Henty (2020a). See Fig. 3 for video location.

It should be noted that the most-likely storm return periods in Table 3 (the middle of the range given in parentheses) result from the use of the most-likely NOAA (2020a) estimates for the daily precipitation corresponding to a given return period (see Table 1). In turn, these most-likely storm return periods are consistent with the design precipitations that are stated in the 2013 stormwater manual (City of Charleston, 2013; see Table 1). On the other hand, as mentioned previously, the more conservative design precipitations in the 2020 stormwater manual (AECOM, 2020) are similar to the maximum daily precipitation amounts (upper bound of the 90% confidence interval) in the NOAA (2020a) estimates for a given return period (see Table 1). The use of these maximum daily precipitation amounts results in the calculated minimum storm return period corresponding to a given flooding event. For example, the flooding event on October 3, 2015 (Hurricane Joaquin) resulted from a 40.5-year storm, based on the design precipitations of the 2013 stormwater manual (City of Charleston, 2013) and the most-likely

NOAA (2020a) estimates. However, the same flooding event resulted from a 25.3-year storm, based on the design precipitations of the 2020 stormwater manual (AECOM, 2020) and the maximum daily precipitation corresponding to a given return period as estimated by NOAA (2020a). Throughout the rest of this report, return periods corresponding to particular flooding events on James Island will refer to the most-likely return periods consist with NOAA (2020a) and the earlier stormwater manual (City of Charleston, 2013).



Figure 8b. Two stormwater pipes are buried side-by-side under a road at EME Apartments. The 48-inch pipe on the right-hand photo is open at both ends and carries stormwater to James Island Creek. The 42-inch pipe on the left-hand photo is open on the eastern side, but is completely blocked with rocks on the western side, which prevents any flow toward James Island Creek. According to City of Charleston (2020a-b), there are no records indicating when or why the 42-inch pipe was blocked off. Left-hand and right-hand photos are stills at 0:03 and 0:38, respectively, from a video at Henty (2020b). See Fig. 3 for video location.

The probability of flooding on James Island was 10%, 50% and 100%, if the daily precipitation equaled or exceeded 0.53 inches, 2.50 inches and 5.53 inches, respectively (see Fig. 9a). In other words, flooding was inevitable if daily precipitation equaled or exceeded 5.53 inches and was expected if daily precipitation equaled or exceeded 2.50 inches. Moreover,

stormwater infrastructure could not be relied upon to prevent flooding if the daily precipitation equaled or exceeded only 0.53 inches. In terms of the storm return period, the probability of flooding on James Island was 59% and 100% if the daily precipitation equaled or exceeded 1.0 and 4.9 years, respectively (see Fig. 9b). In other words, flooding is inevitable for a 5-year storm and is expected for a 1-year storm. In summary, the current stormwater infrastructure does not even have the capacity to accommodate a 1-year storm (which has a 100% probability of exceedance in any given year).

Table 3. Flooding Events on James Island, May 1, 2015 – June 25, 2020

Onset of Flooding	Maximum Rainfall¹	Figures	24-Hour Rainfall¹ (in)	Return Period² (yrs)
5/1/2015	4/30/2015	10	1.13	0.3 (0.3-0.3)
10/3/2015	10/4/2015	11	9.02	40.5 (25.3-81.4)
12/22/2015	12/23/2015	12	0.65	0.3 (0.2-0.3)
1/15/2016	1/16/2016	13	1.39	0.4 (0.4-0.4)
1/30/2016	1/29/2016	14	0.20	0.2 (0.2-0.2)
10/8/2016	10/8/2016	15	8.48	29.2 (18.8-55.8)
12/6/2016	12/6/2016	16	1.74	0.5 (0.5-0.5)
5/23/2017	5/24/2017	17	3.12	1.1 (1.0-1.3)
9/11/2017	9/12/2017	18a-c	6.78	10.4 (7.3-17.0)
10/23/2017	10/23/2017	19	2.50	0.8 (0.7-0.9)
6/30/2018	7/1/2018	20	1.66	0.5 (0.4-0.5)
7/7/2018	7/8/2018	21a-c	3.15	1.2 (1.0-1.4)
7/20/2018	7/20/2018	22a-c	4.10	2.1 (1.7-2.6)
7/30/2018	7/30/2018	23	2.64	0.9 (0.7-0.9)
9/10/2018	9/10/2018	24	0.30	0.2 (0.2-0.2)
11/24/2018	11/24/2018	25	0.60	0.2 (0.2-0.2)
12/14/2018	12/15/2018	26a-b	3.05	1.1 (0.9-1.3)
6/12/2019	6/13/2019	27	1.73	0.5 (0.5-0.5)
12/23/2019	12/24/2019	28a-b	3.77	1.7 (1.4-2.1)
3/5/2020	3/6/2020	29a-b	1.99	0.6 (0.5-0.6)
4/23/2020	4/24/2020	30a-c	5.53	4.9 (3.7-7.1)
5/20/2020	5/21/2020	31a-c	4.43	2.5 (2.0-3.3)

¹Measured at NOAA weather station Charleston 2.0 S (see Fig. 2; NOAA, 2020b).

²Mean followed by 90% confidence interval in parentheses. Return period calculated for NOAA weather station Charleston WSO City (see Fig.2; NOAA, 2020a). Return periods shorter than one year are not meaningful, since a precipitation amount corresponding to a 1-year return period indicates 100% probability of exceedance in a given year.

The next 35 figures are photos that document the 12 flooding events (see Figs. 10-17, 18a-c, 19, 20, 21a-c, 22a-c, 23-25, 26a-b, 27, 28a-b, 29a-b, 30a-c, 31a-c). For each flooding event, the first photo documents flooding near the Central Park development site (if available), the second photo documents flooding near the Riverland Oaks development site (if available), while the third photo documents flooding elsewhere on James Island (if available). See Fig. 3 for locations of photos near the proposed developments and Fig. 2 for other photo locations.

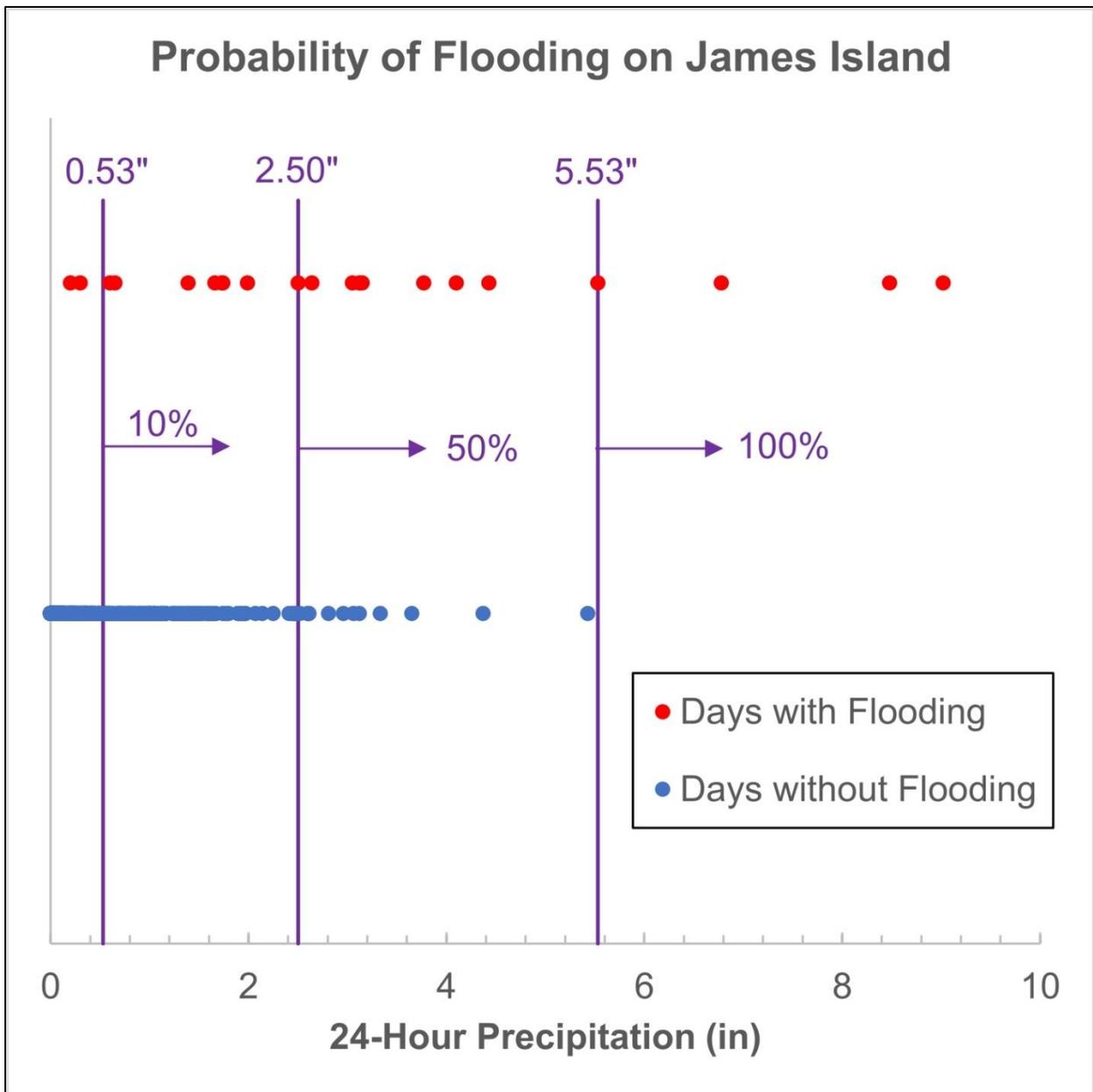


Figure 9a. A comparison of 22 flooding events on James Island between May 1, 2015 – June 25, 2020 with daily precipitation records at NOAA weather station Charleston 2.0 S (see Table 3; NOAA, 2020b) indicates that the probability of flooding is 10%, 50% and 100% for 24-hour precipitations equal to or exceeding 0.53 inches, 2.50 inches and 5.53 inches, respectively.

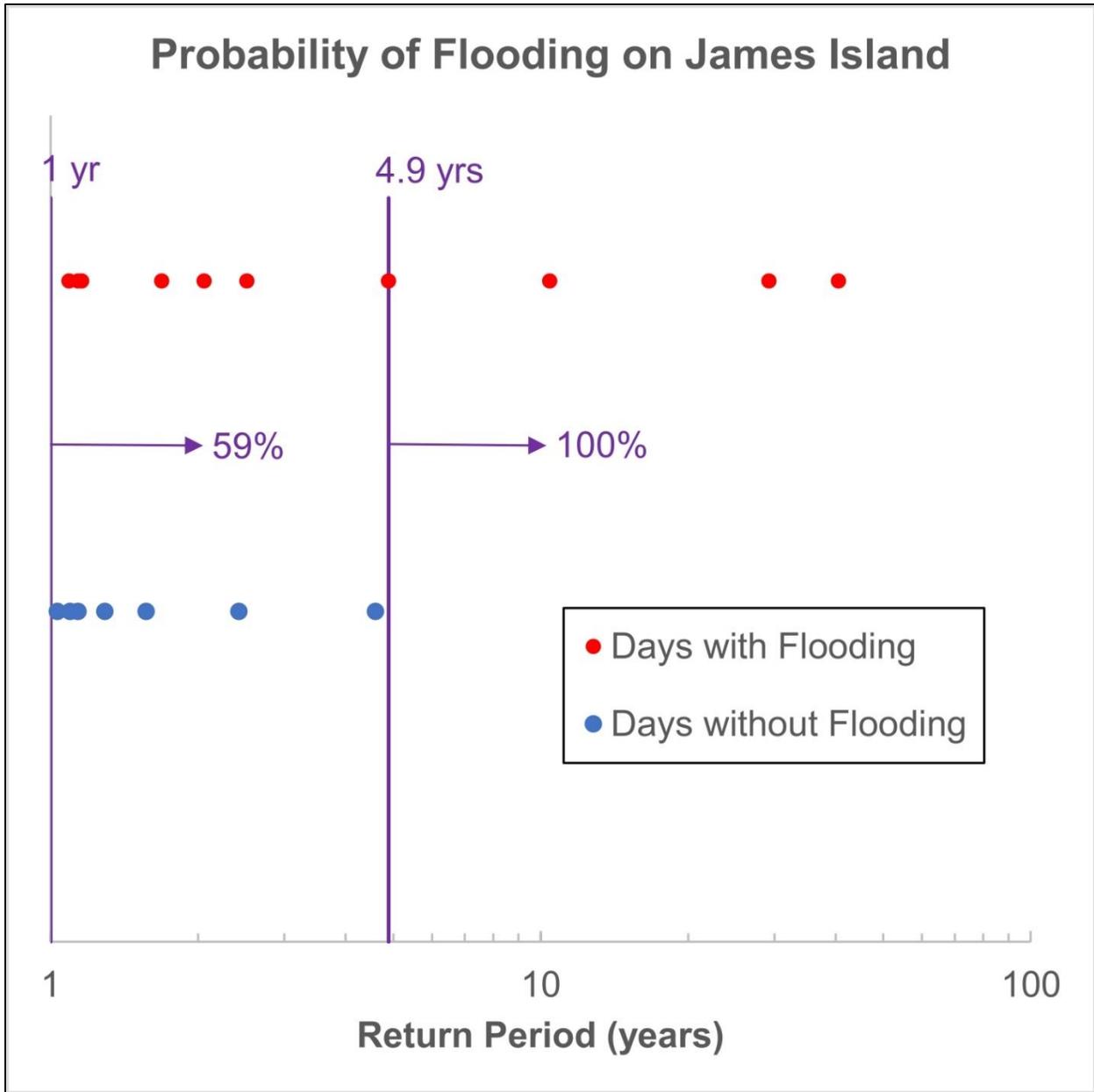


Figure 9b. A comparison of 22 flooding events on James Island between May 1, 2015 – June 25, 2020 with daily precipitation records at NOAA weather station Charleston 2.0 S (see Table 3; NOAA, 2020b) and their corresponding return periods (see Fig. 8; NOAA, 2020a) indicates that the probability of flooding is 59% and 100% for 24-hour precipitations with return periods equal to or exceeding 1 year and 4.9 years, respectively.



Figure 10. Flooding began on May 1, 2015, in response to a 24-hour precipitation event of 1.13 inches, as measured at the NOAA weather station Charleston 2.0 S on April 30, 2015 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Harriet Reavis at 509 West Wimbledon Drive (see Fig. 3) on May 1, 2015.



Figure 11. Flooding began on October 3, 2015, in response to a 24-hour precipitation event of 9.02 inches, as measured at the NOAA weather station Charleston 2.0 S on October 4, 2015 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by George Morrison at 1765 Mohawk (see Fig. 3) on October 3, 2015.

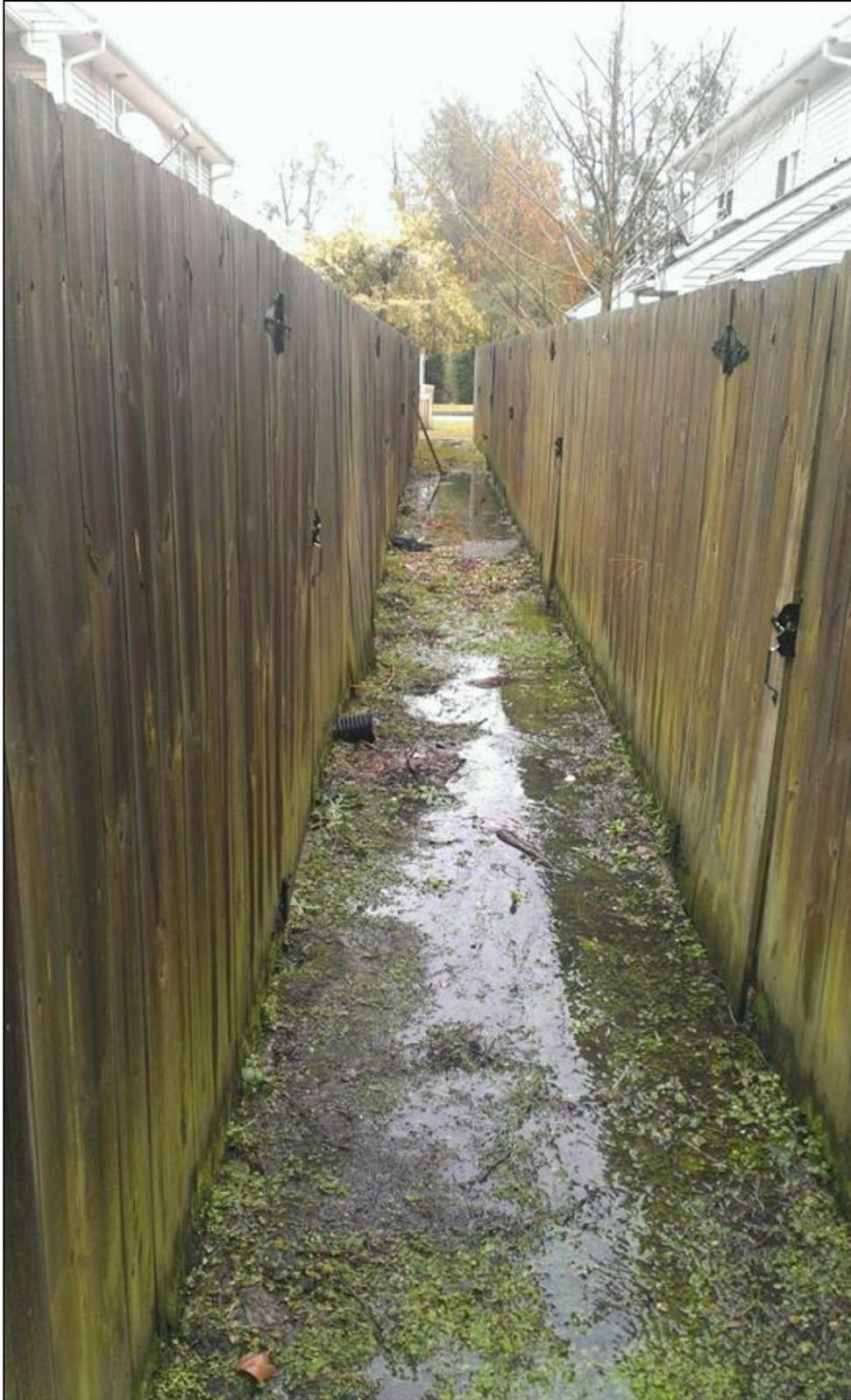


Figure 12. Flooding began on December 22, 2015, in response to a 24-hour precipitation event of 0.65 inches, as measured at the NOAA weather station Charleston 2.0 S on December 23, 2015 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 246A Stefan Drive (see Fig. 3) on December 22, 2015 (Save James Island, 2015).



Figure 13. Flooding began on January 15, 2016, in response to a 24-hour precipitation event of 1.39 inches, as measured at the NOAA weather station Charleston 2.0 S on January 16, 2016 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Harriet Reavis at 505 West Wimbledon Drive (see Fig. 3) on January 15, 2016. Note overflow of West Wimbledon drainage ditch in near background.



Figure 14. Flooding began on January 30, 2016, in response to a 24-hour precipitation event of 0.20 inches, as measured at the NOAA weather station Charleston 2.0 S on January 29, 2016 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Harriet Reavis at 505 West Wimbledon Drive (see Fig. 3) on January 30, 2016. Note overflow of West Wimbledon drainage ditch in mid-ground.



Figure 15. Flooding began on October 8, 2016, in response to a 24-hour precipitation event of 8.48 inches, as measured at the NOAA weather station Charleston 2.0 S on October 8, 2016 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by James Mazyck (see Fig. 3) at 1747 Wambaw Avenue on October 8, 2016.



Figure 16. Flooding began on December 6, 2016, in response to a 24-hour precipitation event of 1.74 inches, as measured at the NOAA weather station Charleston 2.0 S on December 6, 2016 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 1743 Central Park Road (see Fig. 3) on December 6, 2016 (Save James Island, 2016).



Figure 17. Flooding began on May 23, 2017, in response to a 24-hour precipitation event of 3.12 inches, as measured at the NOAA weather station Charleston 2.0 S on May 24, 2017 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 331 Howle Avenue (see Fig. 3) on May 23, 2017 (Save James Island, 2017a).



Figure 18a. Flooding began on September 11, 2017, in response to a 24-hour precipitation event of 6.78 inches, as measured at the NOAA weather station Charleston 2.0 S on September 12, 2017 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 518 East Wimbledon Drive (see Fig. 3) on September 11, 2017 by Carol and Steve Green.



Figure 18b. Flooding began on September 11, 2017, in response to a 24-hour precipitation event of 6.78 inches, as measured at the NOAA weather station Charleston 2.0 S on September 12, 2017 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 313 Stefan Drive (see Fig. 3) on September 12, 2017 (Save James Island, 2017b).



Figure 18c. Flooding began on September 11, 2017, in response to a 24-hour precipitation event of 6.78 inches, as measured at the NOAA weather station Charleston 2.0 S on September 12, 2017 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 18 Paddlecreek Avenue (see Fig. 3) on September 12, 2017 (Save James Island, 2017c).



Figure 19. Flooding began on October 23, 2017, in response to a 24-hour precipitation event of 2.50 inches, as measured at the NOAA weather station Charleston 2.0 S on October 23, 2017 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 1160 Montgomery Road (see Fig. 3) on October 23, 2017 (Save James Island, 2017d).



Figure 20. Flooding began on June 30, 2018, in response to a 24-hour precipitation event of 1.66 inches, as measured at the NOAA weather station Charleston 2.0 S on July 1, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Harriet Reavis at 509 West Wimbledon Drive (see Fig. 3) on June 30, 2018. Note West Wimbledon drainage ditch in foreground and slumping of property into drainage ditch.



Figure 21a. Flooding began on July 7, 2018, in response to a 24-hour precipitation event of 3.15 inches, as measured at the NOAA weather station Charleston 2.0 S on July 8, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by George Morrison at 1765 Mohawk (see Fig. 3) on July 7, 2018.



Figure 21b. Flooding began on July 7, 2018, in response to a 24-hour precipitation event of 3.15 inches, as measured at the NOAA weather station Charleston 2.0 S on July 8, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 301 Stefan Drive (see Fig. 3) on July 7, 2018 (Save James Island, 2018a).



Figure 21c. Flooding began on July 7, 2018, in response to a 24-hour precipitation event of 3.15 inches, as measured at the NOAA weather station Charleston 2.0 S on July 8, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken in Stag Erin parking lot at 1006 Folly Road (see Fig. 2) on July 7, 2018 (Save James Island, 2018b).



Figure 22a. Flooding began on July 20, 2018, in response to a 24-hour precipitation event of 4.10 inches, as measured at the NOAA weather station Charleston 2.0 S on July 20, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by George Morrison at 1765 Mohawk (see Fig. 3) on July 20, 2018.



Figure 22b. Flooding began on July 20, 2018, in response to a 24-hour precipitation event of 4.10 inches, as measured at the NOAA weather station Charleston 2.0 S on July 20, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 310 Stefan Drive (see Fig. 3) on July 20, 2018 (Save James Island, 2018c).



Figure 22c. Flooding began on July 20, 2018, in response to a 24-hour precipitation event of 4.10 inches, as measured at the NOAA weather station Charleston 2.0 S on July 20, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 18 Paddlecreek Avenue (see Fig. 3) on July 20, 2018 (Save James Island, 2018d).



Figure 23. Flooding began on July 30, 2018, in response to a 24-hour precipitation event of 2.64 inches, as measured at the NOAA weather station Charleston 2.0 S on July 30, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Santee Street (see Fig. 3) on July 30, 2018 (Save James Island, 2018e).



Figure 24. Flooding began on September 10, 2018, in response to a 24-hour precipitation event of 0.30 inches, as measured at the NOAA weather station Charleston 2.0 S on September 10, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo is still at 0:15 of video at Streicher (2018b).



Figure 25. Flooding began on November 24, 2018, in response to a 24-hour precipitation event of 0.60 inches, as measured at the NOAA weather station Charleston 2.0 S on November 24, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Harborview Circle (see Fig. 2) on July 30, 2018 (Save James Island, 2018f).



Figure 26a. Flooding began on December 14, 2018, in response to a 24-hour precipitation event of 3.05 inches, as measured at the NOAA weather station Charleston 2.0 S on December 15, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Amber Knight at 518 West Wimbledon Drive (see Fig. 3) on December 15, 2018.



Figure 26b. Flooding began on December 14, 2018, in response to a 24-hour precipitation event of 3.05 inches, as measured at the NOAA weather station Charleston 2.0 S on December 15, 2018 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 20 Paddlecreek Avenue (see Fig. 3) on December 14, 2018 (Save James Island, 2018g).



Figure 27. Flooding began on June 12, 2019, in response to a 24-hour precipitation event of 1.73 inches, as measured at the NOAA weather station Charleston 2.0 S on June 13, 2019 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Signal Point Road (see Fig. 2) on June 12, 2019 (Save James Island, 2019a).



Figure 28a. Flooding began on December 23, 2019, in response to a 24-hour precipitation event of 3.77 inches, as measured at the NOAA weather station Charleston 2.0 S on December 24, 2019 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 518 East Wimbledon Drive (see Fig. 3) on December 24, 2019, by Carol and Steve Green. Note the overflowing East Wimbledon drainage ditch on the left.



Figure 28b. Flooding began on December 23, 2019, in response to a 24-hour precipitation event of 3.77 inches, as measured at the NOAA weather station Charleston 2.0 S on December 24, 2019 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken in Lynwood subdivision (see Fig. 2) on December 24, 2019 (Save James Island, 2019b).



Figure 29a. Flooding began on March 5, 2020, in response to a 24-hour precipitation event of 1.99 inches, as measured at the NOAA weather station Charleston 2.0 S on March 6, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at Murray-LaSaine Elementary School (see Fig. 2) on March 5, 2020 (Save James Island, 2020a).



Figure 29b. Flooding began on March 5, 2020, in response to a 24-hour precipitation event of 1.99 inches, as measured at the NOAA weather station Charleston 2.0 S on March 6, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at the corner of Shoreham Road and Oakcrest Drive (see Fig. 2) on March 5, 2020 (Save James Island, 2020b).



Figure 30a. Flooding began on April 23, 2020, in response to a 24-hour precipitation event of 5.53 inches, as measured at the NOAA weather station Charleston 2.0 S on April 24, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Yale Drive (see Fig. 3) on April 23, 2020 (Save James Island, 2020c).



Figure 30b. Flooding began on April 23, 2020, in response to a 24-hour precipitation event of 5.53 inches, as measured at the NOAA weather station Charleston 2.0 S on April 24, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Carol Street (see Fig. 3) on April 23, 2020 (Save James Island, 2020d).



Figure 30c. Flooding began on April 23, 2020, in response to a 24-hour precipitation event of 5.53 inches, as measured at the NOAA weather station Charleston 2.0 S on April 24, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at 569 Kentwood Circle (see Fig. 2) on April 23, 2020 (Save James Island, 2020e).



Figure 31a. Flooding began on May 20, 2020, in response to a 24-hour precipitation event of 4.43 inches, as measured at the NOAA weather station Charleston 2.0 S on May 21, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken by Amber Knight at 518 West Wimbledon Drive (see Fig. 3) on May 20, 2020.



Figure 31b. Flooding began on May 20, 2020, in response to a 24-hour precipitation event of 4.43 inches, as measured at the NOAA weather station Charleston 2.0 S on May 21, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken on Howle Avenue (see Fig. 3) on May 21, 2020 (Save James Island, 2020f).



Figure 31c. Flooding began on May 20, 2020, in response to a 24-hour precipitation event of 4.43 inches, as measured at the NOAA weather station Charleston 2.0 S on May 21, 2020 (see Fig. 2 and Table 3; NOAA, 2020b). Photo taken at Murray-LaSaine Elementary School (see Fig. 3) on May 21, 2020 (Save James Island, 2020g).

DISCUSSION

Since flooding is already expected for storms with a 1-year return period and is inevitable for storms with a 5-year return period, it should be assumed that devastating flooding with considerable total losses of homes and businesses would result from a true 100-year storm. On that basis, it is not possible to demonstrate that an additional development would not increase the probability of dwelling flooding and property damage, as required by the 2013 and 2020 stormwater manuals (City of Charleston, 2013; AECOM, 2020). It is also not possible to demonstrate that the peak discharge rate from a new development would not exceed the downstream capacity for 2-year and 10-year storms, as also required by the stormwater manuals, because the current stormwater system lacks the capacity to convey the stormwater from even a 1-year storm. A documented inability to accommodate even a 1-year storm is essentially equivalent to a non-functional stormwater system, especially in light of the poor condition of much of the stormwater system (see Figs. 7a-c, 8a-b). Finally, the lack of records regarding alterations to the stormwater infrastructure means that it is not possible to carry out any stormwater calculations at all.

An equivalent approach would be to consider the literal meaning of the requirement in the 2013 stormwater manual: “The post-development, peak discharge rates [are] restricted to one-half the pre-development rates for the 2 and 10-year 24-hour storm event or to the downstream system capacity, whichever is less (City of Charleston, 2013). The equivalent in the 2020 stormwater is repeated nearly verbatim: “For non-SFR [Single-Family Residence] sites of

0.5 acres or more, the post-development, peak discharge rates are restricted to one-half the pre-development rates for the 50 percent and 10 percent AEP [2-year and 10-year], 24-hour storm events or to the downstream system capacity, whichever is less” (AECOM, 2020). If the current stormwater infrastructure cannot be relied upon to prevent flooding if the daily precipitation exceeds 0.53 inches (see Fig. 9a), then the downstream system capacity is no more than the peak discharge rate that should result from daily precipitation of 0.53 inches. According to the above requirements, the peak discharge rate from the proposed Central Park development should be no greater, even for a daily precipitation of 6.5 inches, which is the design precipitation for a 10-year storm, according to the 2013 stormwater manual (see Table 1). For the proposed Riverland Oaks development, even for a daily precipitation of 7.2 inches, which is the design precipitation for a 10-year storm, according to the 2020 stormwater manual (see Table 1), the peak discharge rate should be no greater than the downstream peak discharge rate that would result from daily precipitation of 0.53 inches. There is no indication in either of the stormwater plans (Hussey Gay Bell, 2020a-b; Seamon-Whiteside, 2020) that such low peak discharge rates can be achieved. It cannot be overemphasized that stormwater calculations should be based upon the actual performance of the stormwater infrastructure, not simply upon its design performance.

The lack of knowledge regarding the current stormwater system means that even questions asked by local residents cannot be answered at the present time. Some residents have asked whether development of either the Central Park or Riverland Oaks sites could be feasible if the proposed housing were less dense. An example could be two-acre lots (only five lots on the Central Park site) with preservation of much of the original forest and wetlands. Other residents have asked about particular aspects of the stormwater plans for the proposed developments. A sample question concerned the possible erosion of neighboring property due to the addition of stormwater to the existing East Wimbledon drainage ditch on the western boundary of the Central Park development site (see Figs. 3 and 28a). None of those questions can be answered because, as the City of Charleston has emphasized, all stormwater calculations require the computational integration of a proposed stormwater infrastructure with the existing (and unknown) upstream and downstream stormwater infrastructure (City of Charleston, 2015; Seamon and Whiteside, 2020).

It is now appropriate to consider the consistency of the stormwater plans for the proposed developments with the first fundamental principle of both stormwater manuals: “This manual is not intended to restrain or inhibit...the need for engineering judgment” (City of Charleston, 2013; AECOM, 2020). The most fundamental aspect of engineering judgement is that problems are solved and decisions are made on the basis of knowledge. There are many frameworks for formal decision-making and problem-solving and they all begin with the acquisition of knowledge. For example, the Toyota version of the PDCA (Plan-Do-Check-Act) cycle begins with the process of Genchi Genbutsu, which is variously translated as “Real place, real stuff” or “Go and see for yourself.” The significance is that the automotive engineers are not supposed to be sitting around a conference table, talking about why the drill presses are breaking. They are supposed to be on the shop floor, watching the drill presses break.

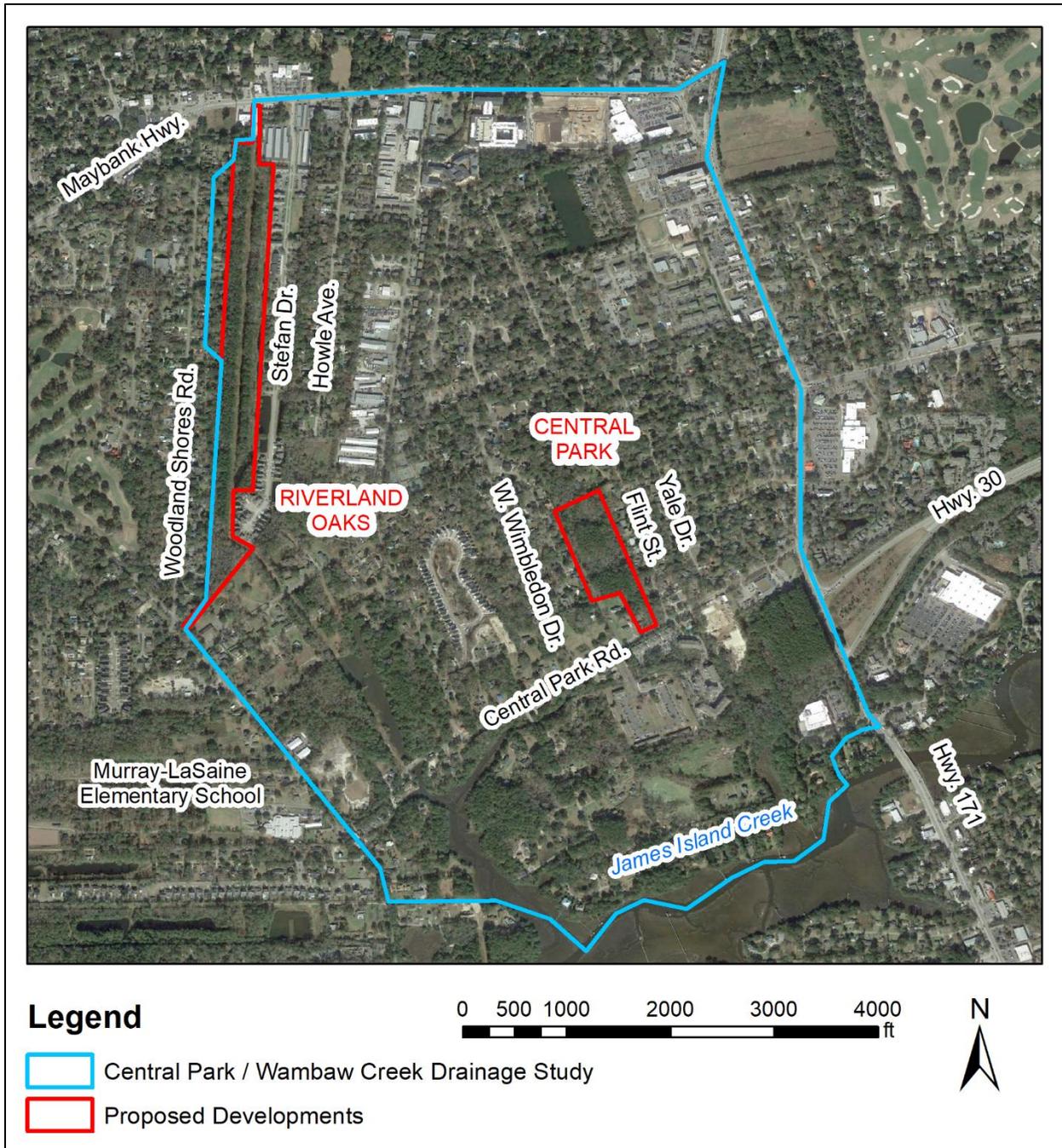


Figure 32. The City and County of Charleston are currently carrying out a drainage study of the Central Park / Wambaw Creek watershed. According to City of Charleston (2020c), “A basin-wide stormwater drainage model is needed to determine level of service for and condition of the existing system as well as the ability to assess the impacts of development on the existing system. Suggested possible drainage improvements as well as design recommendations and standards for future development within the watershed will be included in the final plan.” This area of the drainage study, which is scheduled for completion during 2020-2021, includes the proposed Central Park and Riverland Oaks developments. It is recommended that no developments within the drainage study area be approved pending completion of the drainage study, the implementation of its recommendations, and the assessment of the outcomes following implementation of the recommendations. Perimeter of drainage study traced from City of Charleston (2020c). Perimeters of proposed Central Park and Riverland Oaks developments traced from Seamon Whiteside (2020) and Hussey Gay Bell (2020b), respectively. Background is Google Earth image from January 10, 2019.

In the absence of knowledge, and especially when there is a real impediment to the acquisition of knowledge, such as a lack of resources, engineering judgement requires the application of the Cautionary Principle. One way of stating this principle is that, when faced with great danger and great uncertainty, one should follow an ultraconservative course of action, meaning that one should be ultraprotective of human life, property, and the environment. The Cautionary Principle could be as translated into the consideration of the Central Park and Riverland Oaks developments as follows: When faced with great danger (that additional developments will make a bad flooding situation even worse) and great uncertainty (because no meaningful stormwater modeling can be carried out with the current lack of knowledge), one should be ultraprotective of human life, property, and the environment (meaning that no additional developments should be approved at the present time).

The irony of this entire discussion is that the City and County of Charleston have been carrying out a drainage study in the Central Park / Wambaw Creek watershed, at an estimated cost of \$400,000, in the exact area of the proposed Central Park and Riverland Oaks developments (see Fig. 32), since 2019 and are scheduled to complete the study in 2020 or 2021 (City of Charleston, 2020c). According to City of Charleston (2020c), “The City and Charleston County are partnering on this project to inventory all the drainage features of this basin, create a model, and recommend any maintenance and infrastructure improvements. A basin-wide stormwater drainage model is needed to determine level of service for and condition of the existing system as well as the ability to assess the impacts of development on the existing system. Suggested possible drainage improvements as well as design recommendations and standards for future development within the watershed will be included in the final plan.”

Any reasonable person would see something wrong with making decisions regarding stormwater permits in advance of completion of a study that would provide a rational basis for making a decision about the permits. It would not be enough to simply complete the drainage study before making a decision about stormwater permits. It should be necessary to consider the recommendations of the study, implement the recommendations as appropriate, and then evaluate the impact of the recommendations, in terms of their ability to reduce flooding. In accordance with the Cautionary Principle, about three to five years should be necessary to determine whether the implementation of the recommendations has, in fact, reduced flooding in the vicinity of the proposed Central Park and Riverland Oaks developments.

CONCLUSIONS

The chief conclusions of this report can be summarized as follows:

- 1) James Island residents have documented, within the immediate neighborhoods of the proposed development sites, numerous examples of partially or fully blocked stormwater ditches and pipes, as well as infrastructure alterations for which the City has no records.
- 2) Media articles, social media posts, and photos and videos from residents were used to reconstruct 22 flooding events on James Island between May 1, 2015 – June 25, 2020.
- 3) These flooding events were compared with daily precipitation records to show that the probability of flooding is 10%, 50% and 100% for 24-hour precipitations equal to or exceeding 0.53 inches, 2.50 inches and 5.53 inches, respectively.
- 4) A comparison with local precipitation-frequency statistics showed that the probability of flooding is 59% and 100% for 24-hour precipitations with return periods equal to or exceeding 1 year and 4.9 years, respectively.

- 5) Since flooding is already expected for storms with a 1-year return period and is inevitable for storms with a 5-year return period, it should be assumed that devastating flooding with considerable total losses of homes and businesses would result from a true 100-year storm. On that basis, it is not possible to demonstrate that an additional development would not increase the probability of dwelling flooding and property damage, as required by the 2013 and 2020 stormwater manuals.
- 6) It is not possible to demonstrate that the peak discharge rate from a new development would not exceed the downstream stormwater capacity for 2-year and 10-year storms, as also required by the stormwater manuals, because the current stormwater system cannot accommodate even a 1-year storm.
- 7) The lack of records regarding alterations to the stormwater infrastructure and the poor condition of the stormwater infrastructure means that it is not possible to carry out any of the stormwater calculations that are required by the stormwater manuals.
- 8) The stormwater plans for the proposed Central Park and Riverland Oaks developments are being considered in advance of the completion of a three-year drainage study of the Central Park / Wambaw Creek watershed that should provide the knowledge base that is needed to make a rational decision regarding the stormwater plans.

RECOMMENDATIONS

No new developments in the Central Park / Wambaw Creek watershed should be considered prior to implementation and evaluation of the recommendations of the ongoing drainage study of the Central Park / Wambaw Creek watershed.

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Dr. Steven H. Emerman has a B.S. in Mathematics from The Ohio State University, M.A. in Geophysics from Princeton University, and Ph.D. in Geophysics from Cornell University. Dr. Emerman has 31 years of experience teaching hydrology and geophysics and has 66 peer-reviewed publications in these areas. Dr. Emerman is the owner of Malach Consulting, which specializes in hydrologic modeling, especially related to forestry, mining and urban development.

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