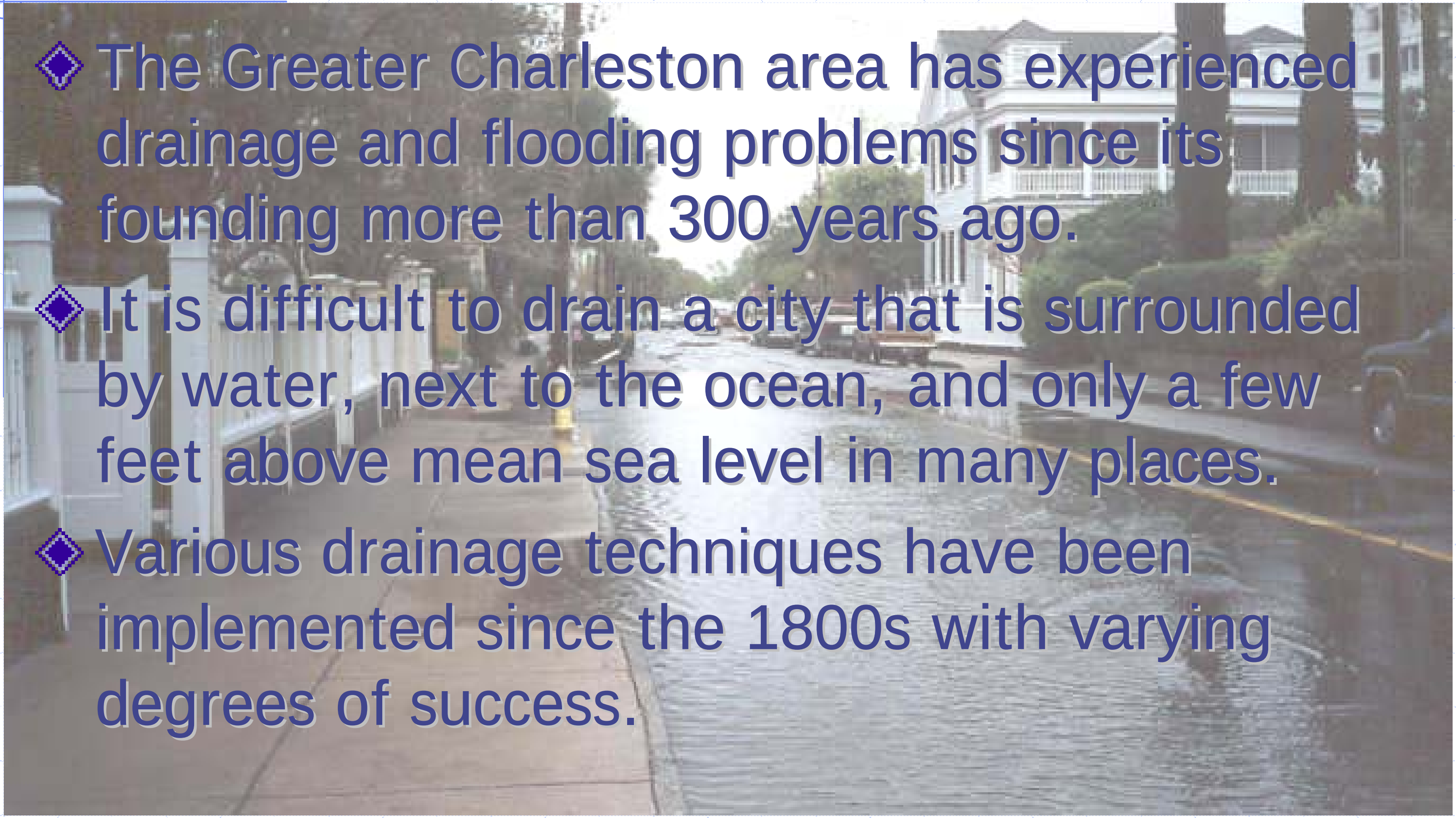
Why Does It Seem Like Charleston Always Floods When It Rains?

The Challenges of Draining a City That is Low, Flat, and Next to the Ocean

Table of Contents

- Introduction – 3
- Definitions – 5
- What Happens When the Rain Falls – 10
- Drainage Challenges in the Lowcountry – 18
  - #1: Tide Cycle – 19
  - #2: Storm Intensity and Duration – 25
  - #3: Collection System Size – 34
  - #4: Terrain – 39
  - #5: Inlets – 43
  - #6: Trash – 46
  - #7: Impervious Area – 52
- What the City is Doing About the Flooding – 55
- What Residents Can Do about the Flooding - 66

Introduction



- The Greater Charleston area has experienced drainage and flooding problems since its founding more than 300 years ago.
- It is difficult to drain a city that is surrounded by water, next to the ocean, and only a few feet above mean sea level in many places.
- Various drainage techniques have been implemented since the 1800s with varying degrees of success.

Introduction

- Despite the advances in our understanding of urban stormwater drainage and advances in technology, we are still unable to overcome some very basic challenges of stormwater ***hydrology*** (how rain accumulates and flows on the ground surface) and ***hydraulics*** (how water flows into inlets and through pipes)

Definitions

- Stormwater – Rain that does not soak into the ground (runoff). If all rain soaked into the ground, it would be of little concern to us.
- Impervious Surfaces – Hard surfaces that do not allow rain to soak in such as concrete, asphalt, buildings, etc. These surfaces contribute to the amount of runoff and how fast the runoff travels to the collection system.

Definitions

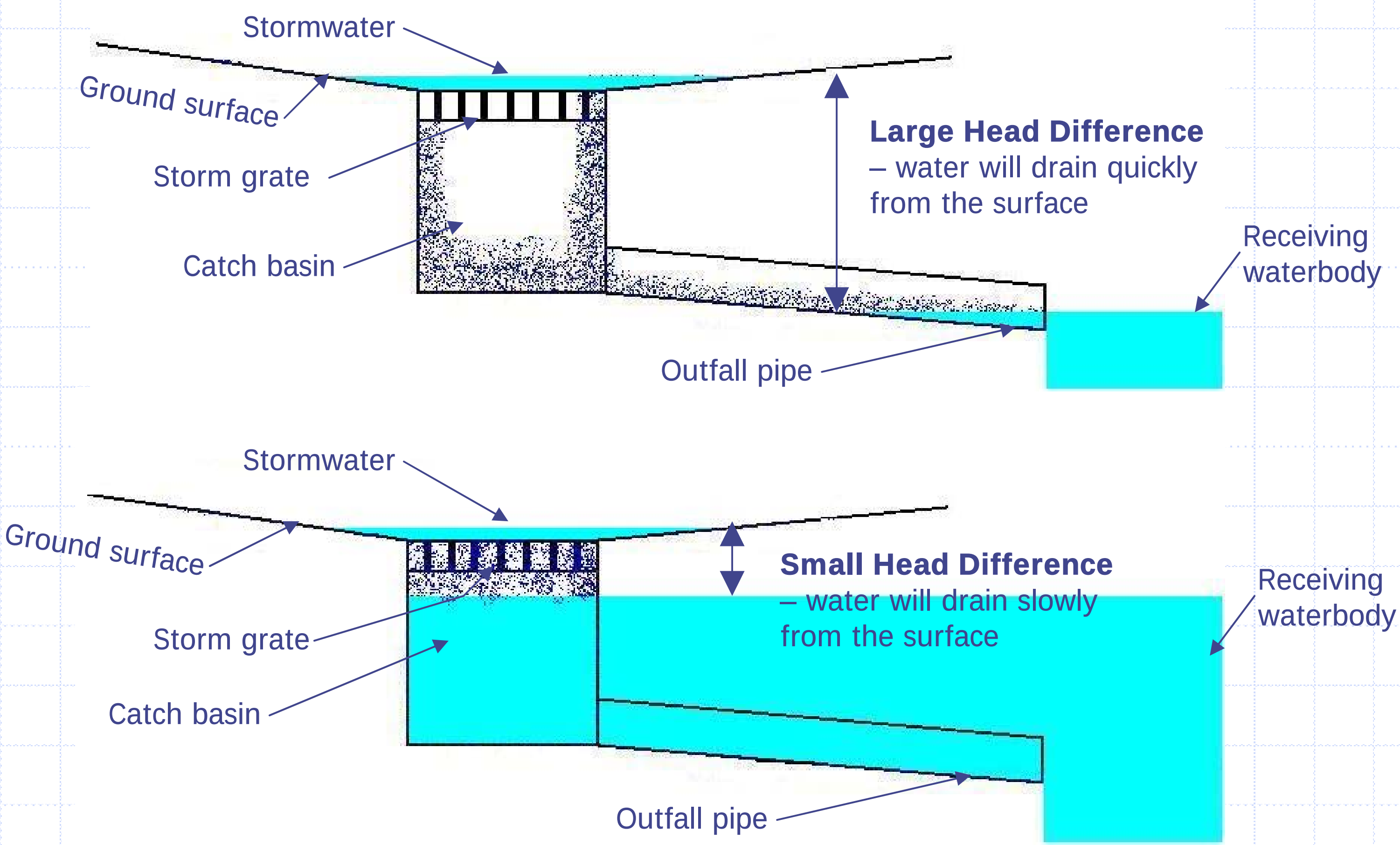
- Flow rate (Q) – How much water flows during a certain period of time; often measured in cubic feet per second (cfs)
- Outfall – The location where the stormwater exits the system to a water body (river, marsh, harbor, etc.). In Charleston, most of the outfalls are tidally influenced (a very important point to remember).

Definitions

- Head – The elevation (height) difference between two water surfaces.
  - This can also be thought of in terms of how much more <u>energy</u> the water at the higher elevation has compared to the water at the lower elevation.
  - The greater the difference in elevation (larger head) the more energy (and therefore speed) the water has to move through the stormwater system.
  - This energy can be “felt” by swimming to the bottom of a pool and feeling the pressure squeeze your head.

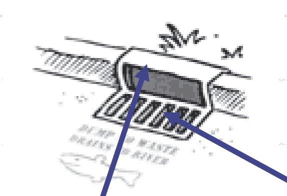
Definitions

- Head – difference in elevation of two water surfaces

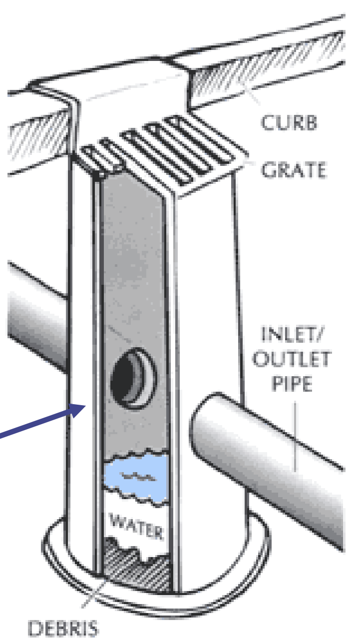


Definitions

- Storm grates, drop inlets, catch basins, and curb inlets – Stormwater surface collection structures



Catch basin



Combination curb and drop inlet

www.ci.farmington.mi.us/basincare.htm

What Happens When the Rain Falls?

- If all rain were slow and gentle, we would have no need for our “modern” stormwater systems.
- Just like all snowflakes and people are different, **ALL RAIN STORMS ARE DIFFERENT**. Rain never falls in the same way.
- The assumptions most people make about rain events are:
  - Rain falls at the same rate for the whole storm
  - Rain is the same amount over the entire area
  - Rain falls at the same time over the entire area.
- All these assumptions are false.

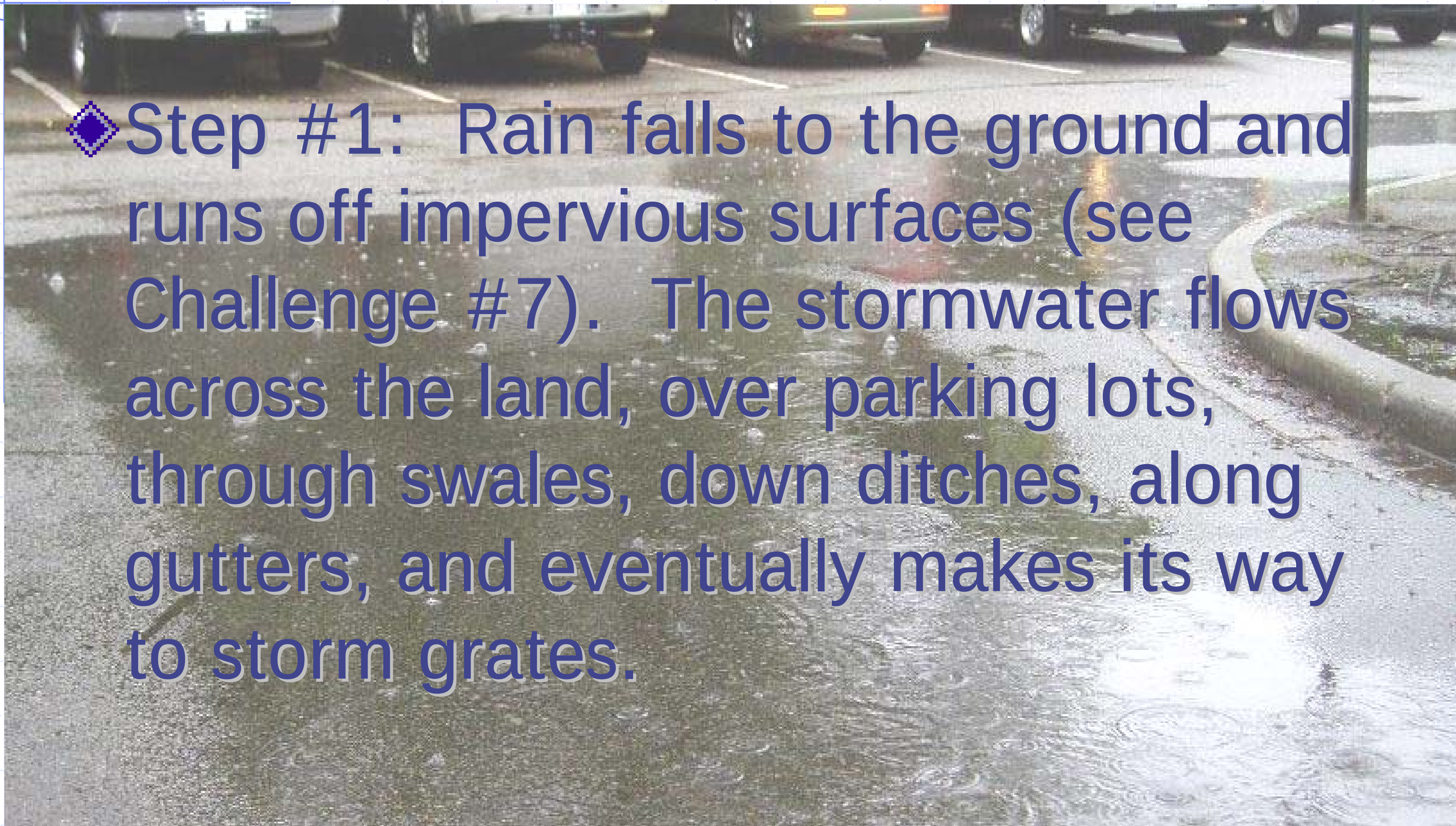
What Happens When the Rain Falls?

- Rain greatly varies spatially and temporally (over area and time).
- Anyone who has lived in the area during a summer knows that 4 inches of rain can fall downtown but across the river in Mt. Pleasant there was only ½ inch and the airport in North Charleston received no rain at all.
- This spatial variance to a slightly lesser degree can also occur on a much smaller scale, such as within a drainage basin.

What Happens When the Rain Falls?

- Similarly, during a storm event, there will be periods of high intensity rain, followed by low intensity, back to high intensity, then no rain, back to low intensity, and on and on and on...
- These spatial and temporal variances can combine in an infinite number of ways such that no two storms will ever be the same.
- As such, comparing two different storms is like comparing apples to tube socks to hubcaps.
- Therefore, systems must be designed for general rainfall patterns. (Think of it as trying to design a space suit that will fit 99 out of every 100 people.)

What Happens When the Rain Falls?

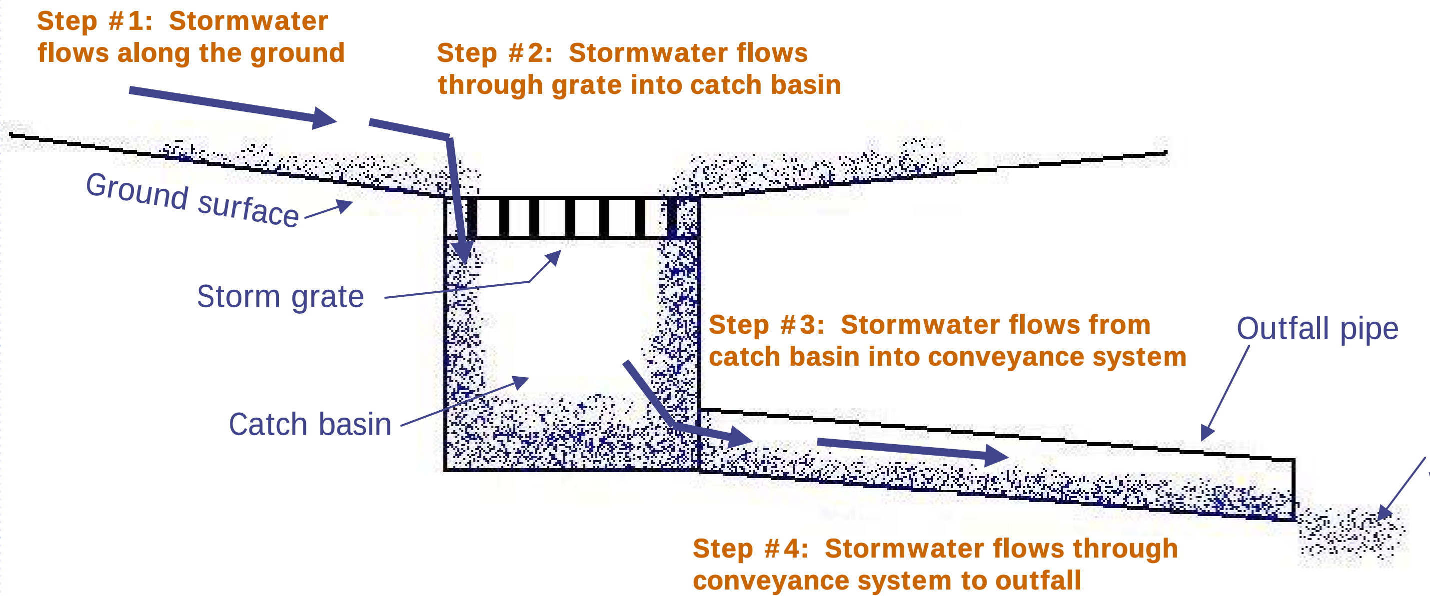


- Step #1: Rain falls to the ground and runs off impervious surfaces (see Challenge #7). The stormwater flows across the land, over parking lots, through swales, down ditches, along gutters, and eventually makes its way to storm grates.

What Happens When the Rain Falls?

- Step #2: The stormwater flows into the storm grate and is collected in the catch basin.
- Step #3: The stormwater flows from the catch basin into the system of stormwater pipes.
- Step #4: The stormwater flows through the conveyance system to the outfall.

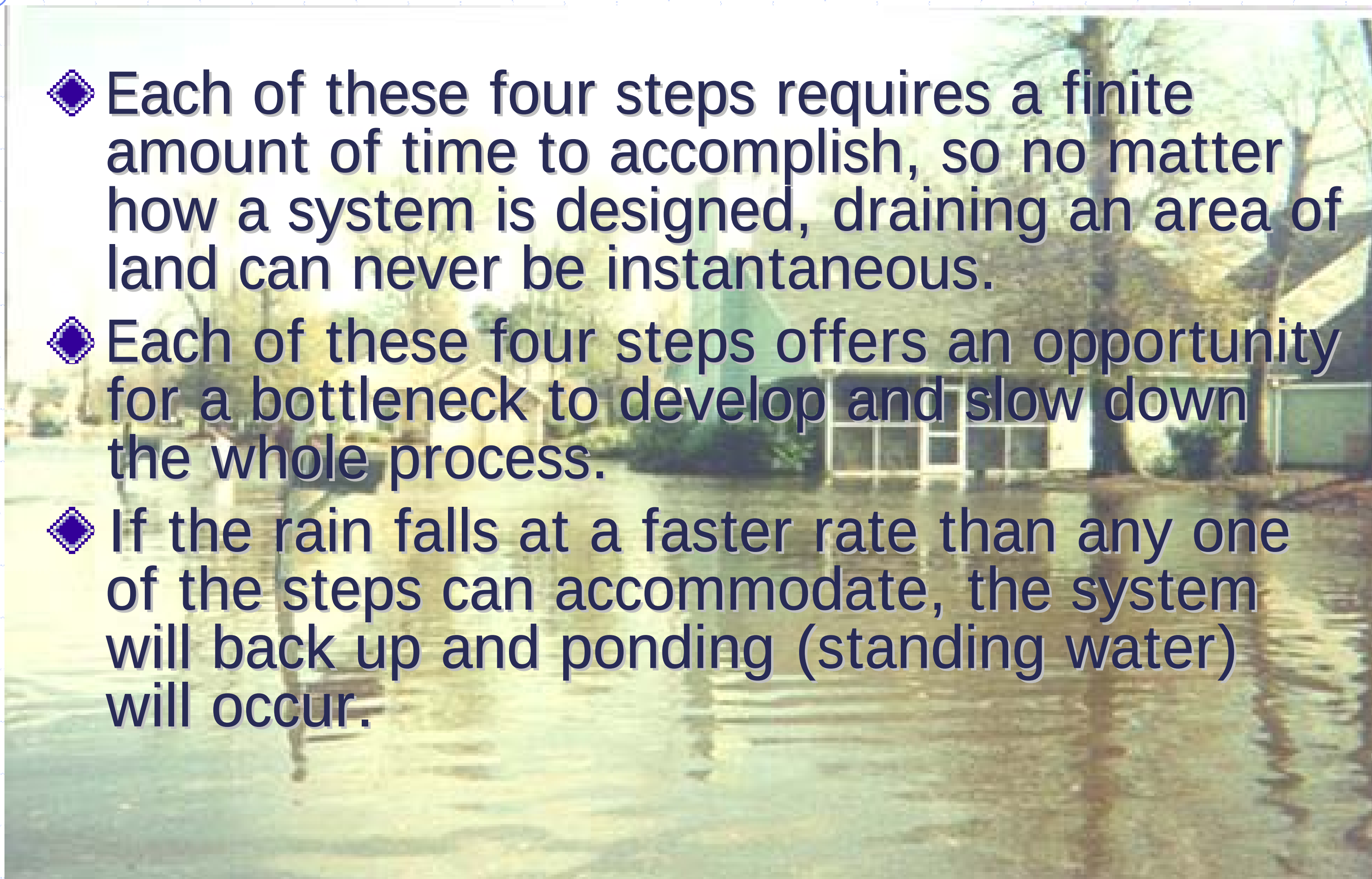
What Happens When the Rain Falls?



What Happens When the Rain Falls?

- The water moves to, into, and through the conveyance system by force of gravity (another important point to remember).
- The greater the ***head*** (difference in elevation between the inlet and the outfall), the faster the flow rate (Q in cfs) of the water.

What Happens When the Rain Falls?



- Each of these four steps requires a finite amount of time to accomplish, so no matter how a system is designed, draining an area of land can never be instantaneous.
- Each of these four steps offers an opportunity for a bottleneck to develop and slow down the whole process.
- If the rain falls at a faster rate than any one of the steps can accommodate, the system will back up and ponding (standing water) will occur.

Drainage Challenges in the Lowcountry

- The challenges we face in draining the City during and after a storm are both natural and man-made (anthropogenic) in origin

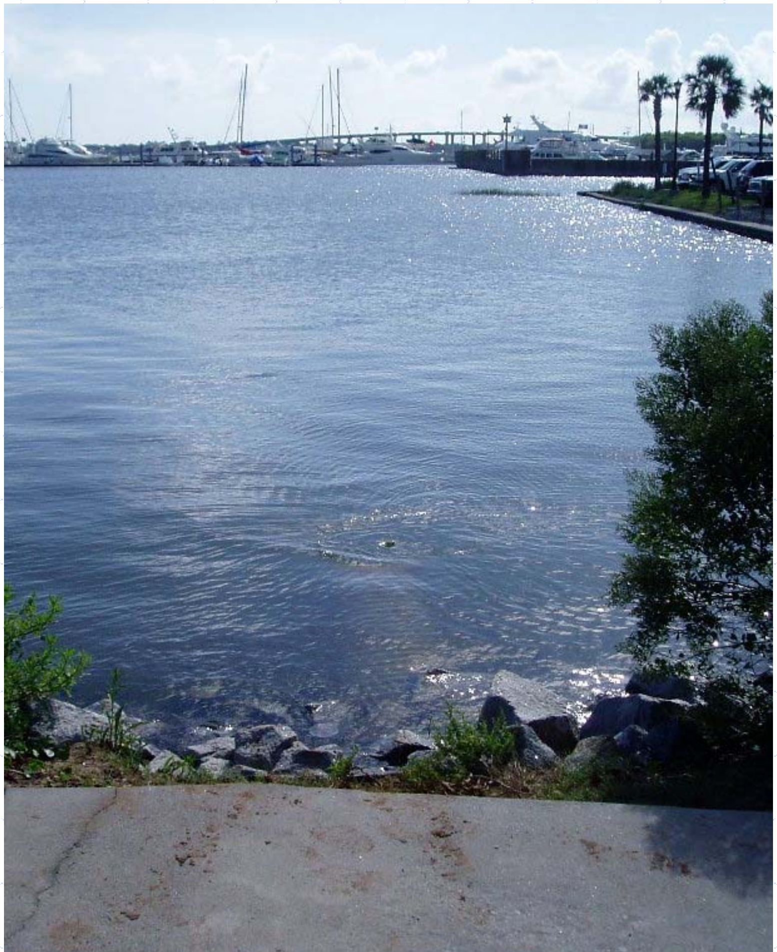
- Natural
  - Tide Cycle
  - Intensity and duration of storms
  - Terrain

- Man-made
  - Inlets
  - System size
  - Trash
  - Impervious cover

Challenge #1: Tide Cycle

- The height of the tide has one of the greatest impacts on how quickly stormwater will drain from the City.
- Most of the outfalls of the City drain to water bodies that are tidally influenced.
- Water seeks the lowest elevation (point of least potential energy) – i.e. water flows down hill
- At low tide, the water surface elevation (ocean, river, marsh, etc.) can be up to 7 feet lower than at high tide. 7 feet is a lot of head (energy) to move the stormwater to, into, and through the system.

Challenge #1 – Tide Cycle



High Tide

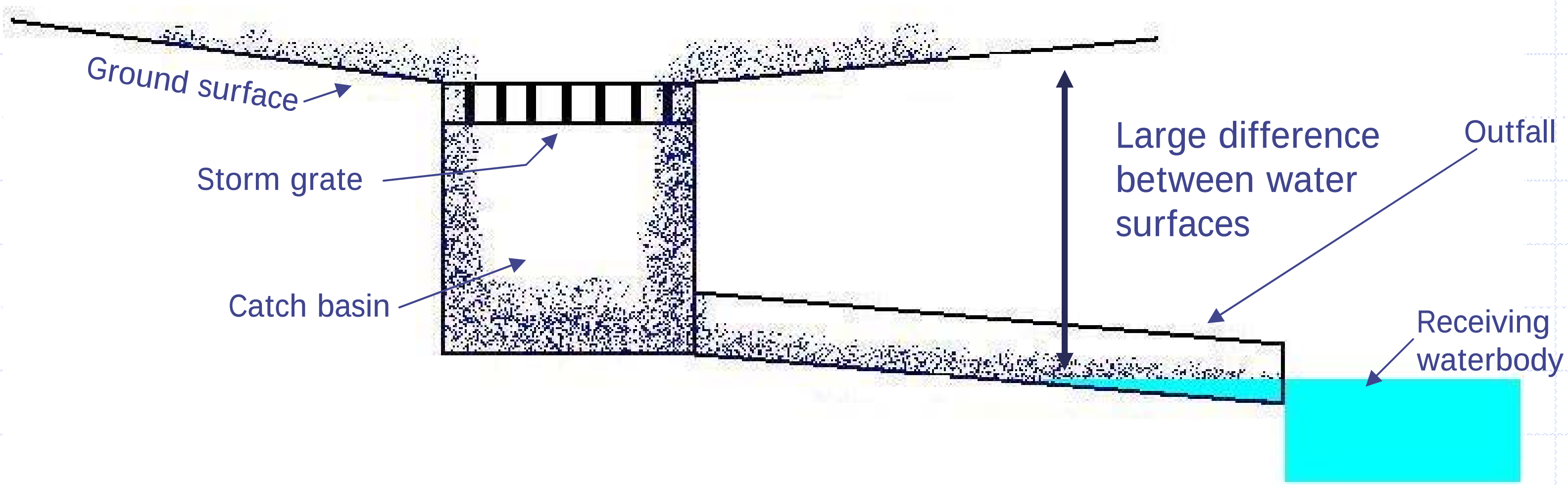
Low Tide

Challenge #1: Tide Cycle

- At high tide, much of the stormwater collection system (the pipes and ditches) is already full of sea water leaving little room for the stormwater runoff.
- The stormwater that has collected on the surface has no place to go because the pipes and ditches are full and ponding occurs.

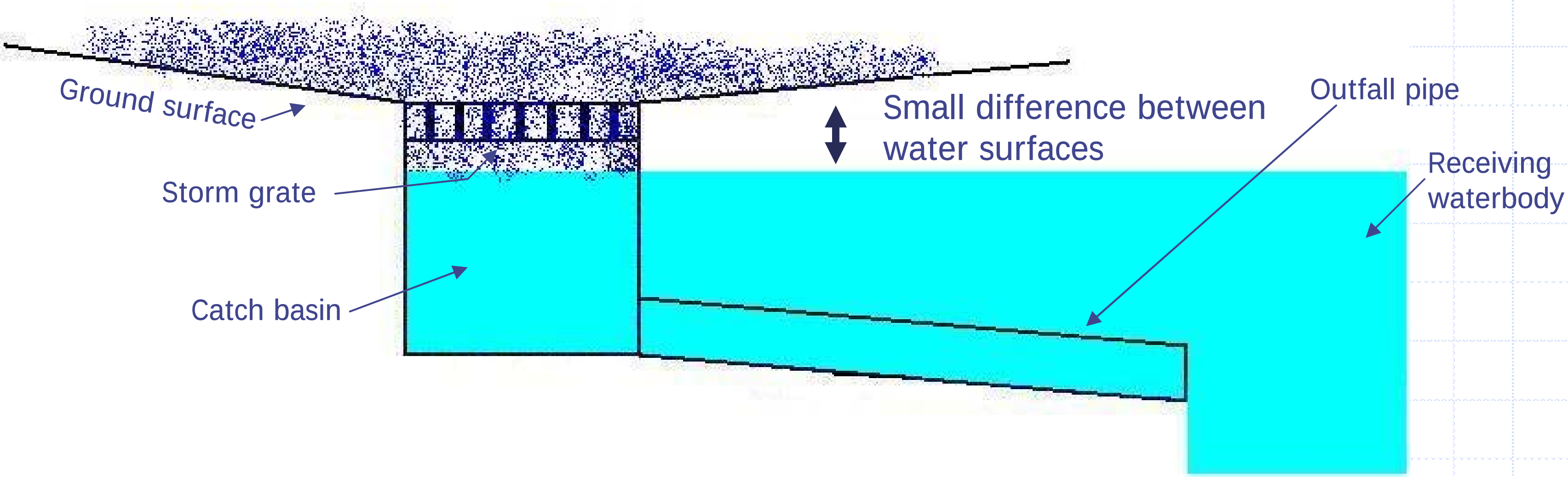
Challenge #1: Tide Cycle

- At low tide there is a greater head difference between the surface where the stormwater has collected and the surface of the water body. The larger head will allow the water to flow faster to, into, and through the system due to the greater potential energy.



Challenge #1: Tide Cycle

- At high tide there is a much smaller head difference. The water does not have nearly as much potential energy to push its way through the system and therefore drains much more slowly. Water can back up in the system and ponding may occur.



Challenge #1: Tide Cycle

- The difference between high and low tide can be 7 feet or more.
- Rain events that occur within two hours of high tide will drain significantly slower than rain events that occur during other times.
- Since the tide cycle is approximately 12 hours and the most flood-prone time is 2 hours before and 2 hours after high tide (4 hours total) there is a 1-in-3 chance that any rain storm will be adversely affected by high tide.

Challenge #2: Intensity and Duration of the Storm

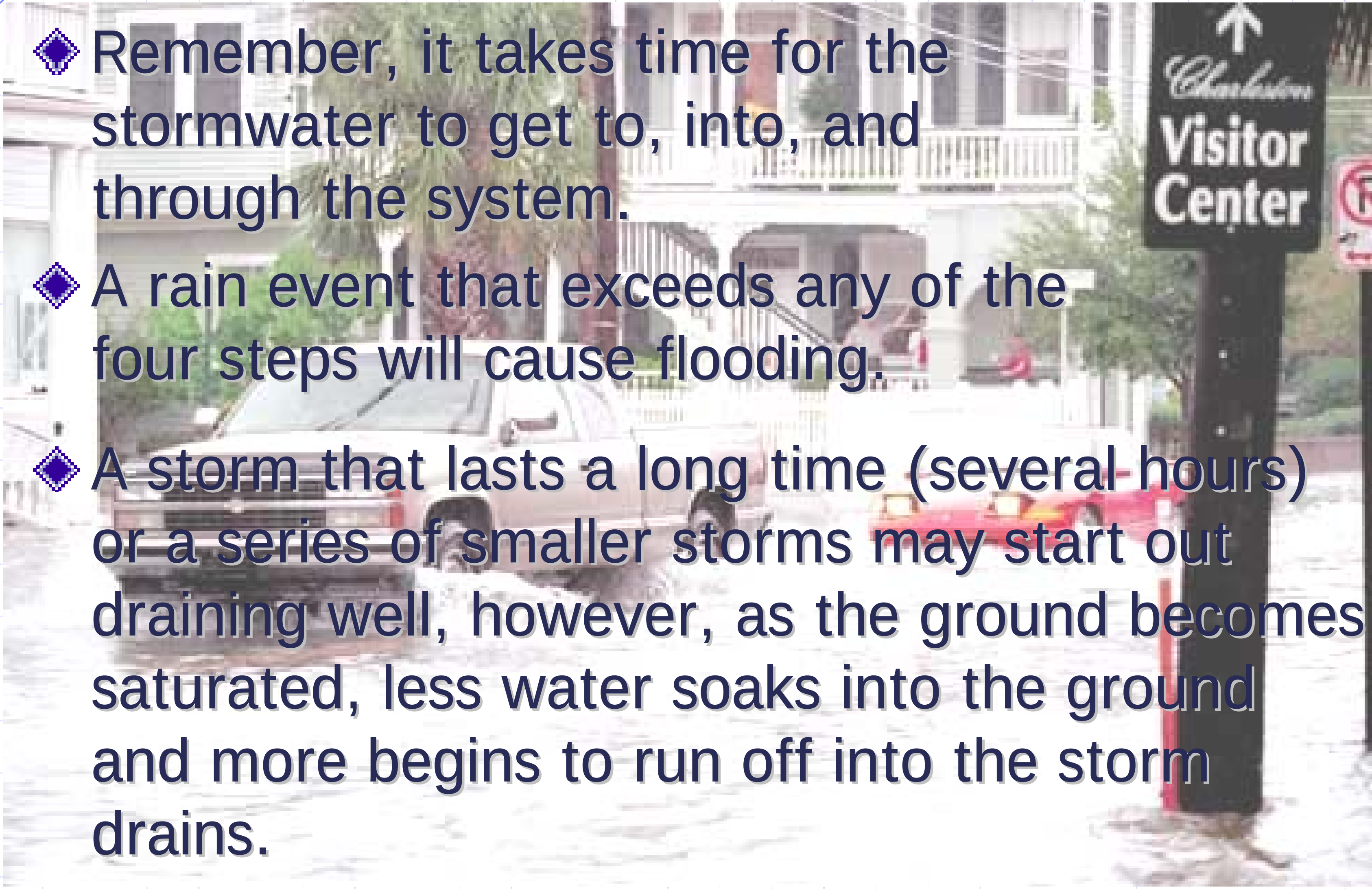
- Intensity is the rate at which the rain falls (how fast) and is often measured in inches per hour.
- Duration is the length of time it rains (how long).
- Dividing the total rainfall from an event (inches) by the duration of the event (hours), you can calculate the average intensity of the storm.

Challenge #2: Intensity and Duration of the Storm

- If either intensity or duration is great, there is generally no problem. We can get a 15 minute cloud-burst that only amounts to a ½-inch of rainfall. Or it can rain for 12 hours, but the 2 inches that fell is easily absorbed into the ground or slowly runs off and is collected by the stormwater system.
- However, if we get the 2 inches of rain in 15 minutes (8 inches per hour average intensity), there will be significant amounts of stormwater to be collected.

Challenge #2: Intensity and Duration of the Storm

- Remember, it takes time for the stormwater to get to, into, and through the system.
- A rain event that exceeds any of the four steps will cause flooding.
- A storm that lasts a long time (several hours) or a series of smaller storms may start out draining well, however, as the ground becomes saturated, less water soaks into the ground and more begins to run off into the storm drains.



Challenge #2: Intensity and Duration of the Storm

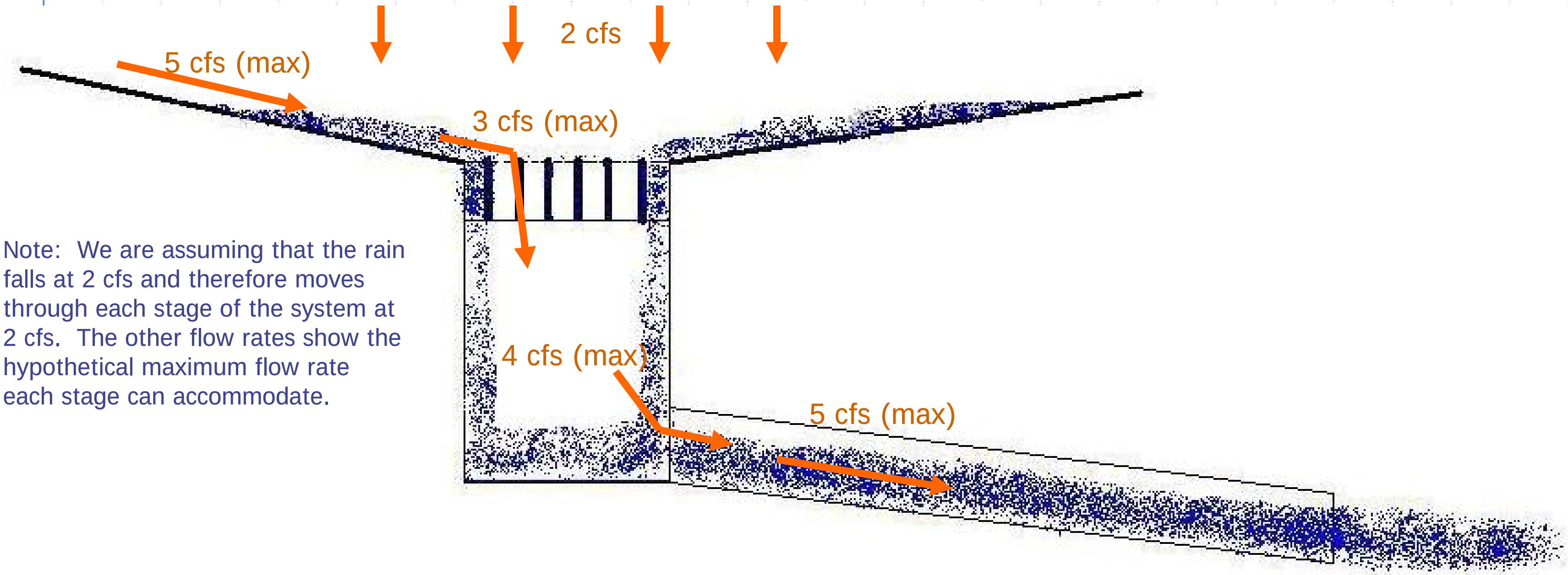
- Picture a partially clogged sink (or one with the stopper mostly closed).
- If you turn the water on slowly (a slow rain event), the sink (our stormwater system) may have no problem passing the water.
- If you turn on the water a little more (a moderate rain event), the sink may fill up a little, reach and maintain a certain level, and then continue to drain the water without filling any more.

Challenge #2: Intensity and Duration of the Storm

- When the water is turned on full blast (a high intensity rain event), the system is overwhelmed and the sink fills up. Once the water is turned off, the basin continues to drain, but still at a slow rate.
- Likewise, the stormwater collection system downtown and in other parts of the City can easily collect and accommodate slow to moderate storms (the majority of them) but is overwhelmed by more intense storms.

Challenge #2: Intensity and Duration of the Storm

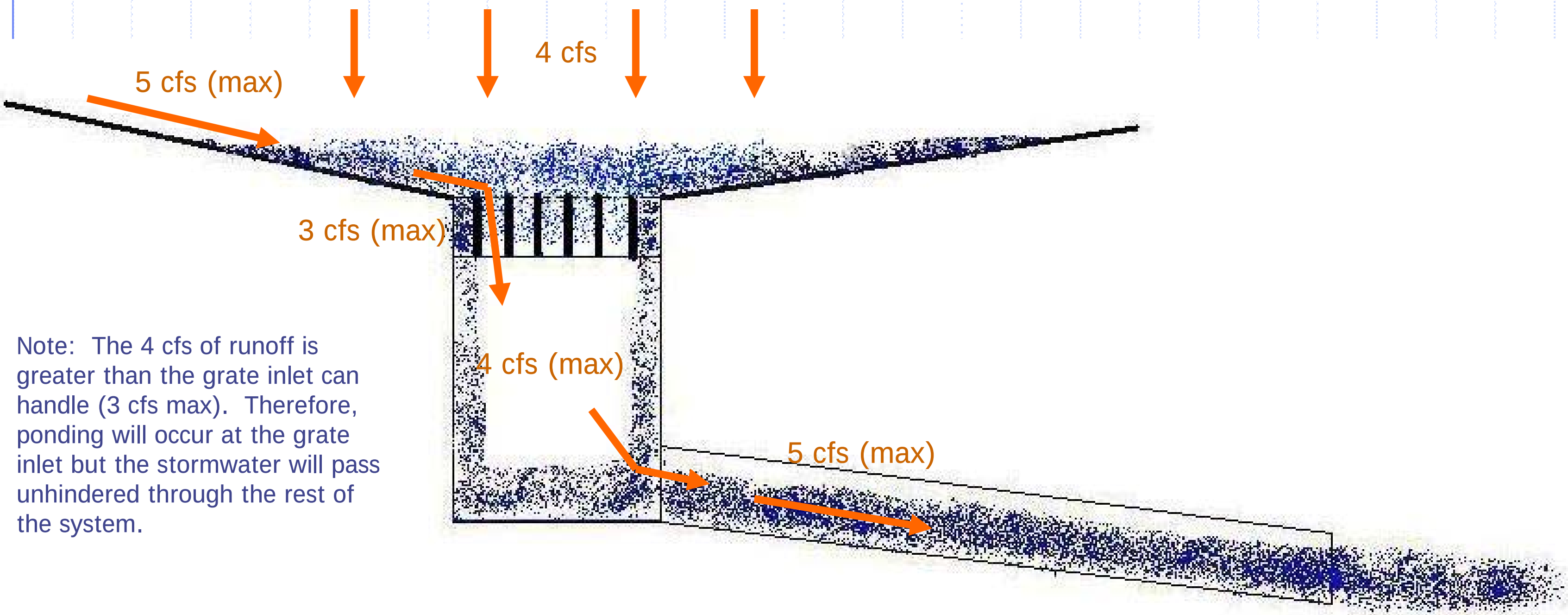
- A slow rain event (2 cfs runoff) that does not overwhelm any stage of the system



Note: We are assuming that the rain falls at 2 cfs and therefore moves through each stage of the system at 2 cfs. The other flow rates show the hypothetical maximum flow rate each stage can accommodate.

Challenge #2: Intensity and Duration of the Storm

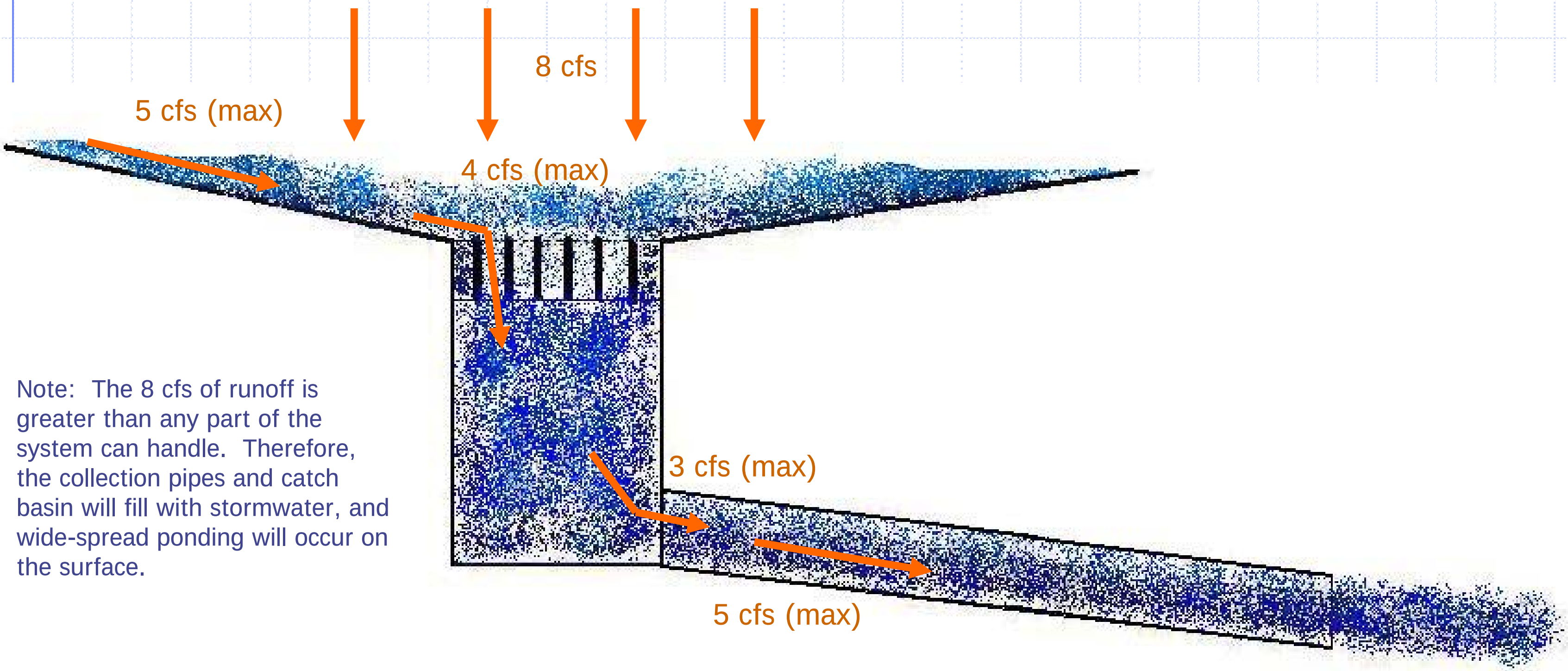
- A moderate rain event (4 cfs runoff) that may overwhelm one or more stages of the system



Note: The 4 cfs of runoff is greater than the grate inlet can handle (3 cfs max). Therefore, ponding will occur at the grate inlet but the stormwater will pass unhindered through the rest of the system.

Challenge #2: Intensity and Duration of the Storm

- An intense rain event (8 cfs runoff) that completely overwhelms the system



Note: The 8 cfs of runoff is greater than any part of the system can handle. Therefore, the collection pipes and catch basin will fill with stormwater, and wide-spread ponding will occur on the surface.

Challenge #2: Intensity and Duration of the Storm

- It is easy to design an unclogged drain to accommodate the flow from a faucet as we know the maximum flow rate from the faucet and can size the drain accordingly
- However, it is impractical to design the system to accommodate the largest possible rainfall.
- To do so would require enormous drains and pipes that would remain unused for the vast majority of time, increasing the cost of construction by orders of magnitude.

Challenge #3: Collection System Size

- For practicality and cost-effectiveness, new stormwater collection systems are designed to accommodate the runoff from a rain event of a certain intensity and duration, called the ***design storm***.
- Any rain event larger than the design storm will cause the system to back up.
- This design method is fairly effective when used, however, in a city such as Charleston where stormwater collection and conveyance was a 150-year afterthought, many of the pipes are not adequately sized.

Challenge #3: Collection System Size

- One solution to undersized pipes would be to install larger ones
- While this is an astute observation, two significant challenges limits it implementation.

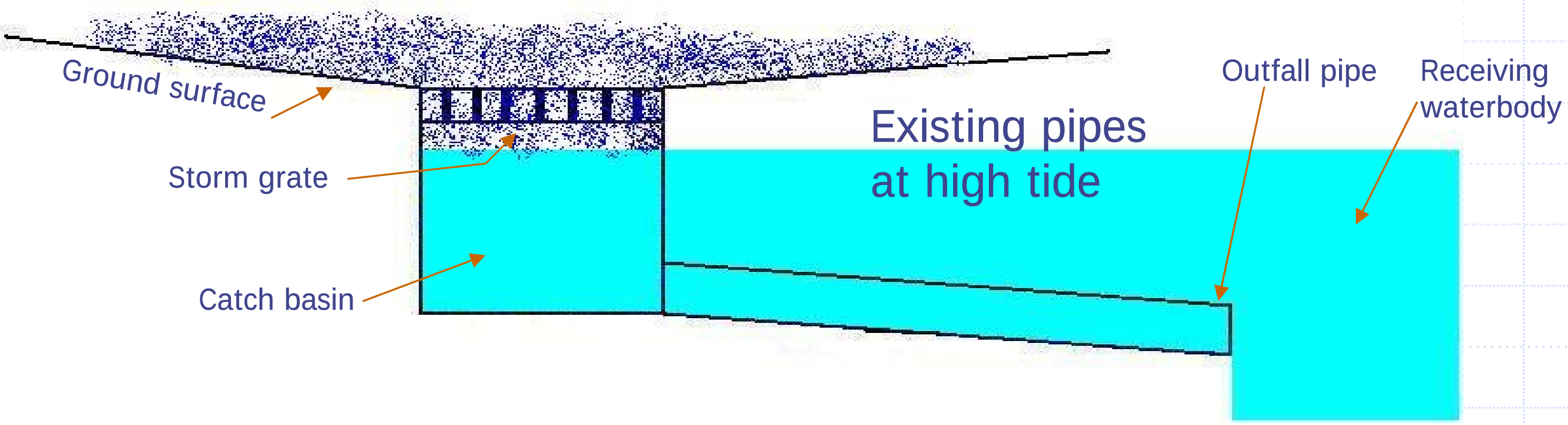
Challenge #3: Collection System Size

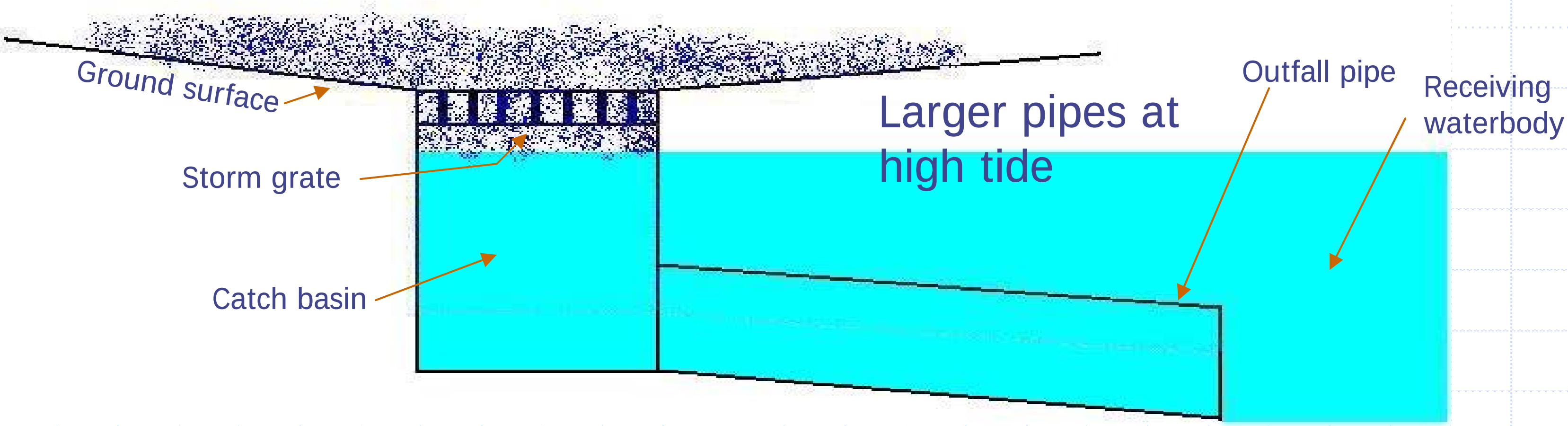
- One challenge is the limited space in which to put stormwater lines.
- Not only do we need to increase their size, but we need to ensure that they flow properly under the influence of gravity.
- The streets are the only practical place to put stormwater lines, but they are narrow and are filled with other utilities such as water, sewer, gas, electric, telephone, and cable.
- Space to construct new or larger stormwater pipes is quite limited.

Challenge #3: Collection System Size

- Another challenge is that larger lines must be placed deeper in the ground due to increasing the diameter of the pipe.
- If they were placed higher then they would stick out of the ground or not have the recommended amount of cover.
- Because much of the collection system is already full of water at high tide, placing the lines deeper in the ground will just cause them to fill up sooner with tidal water and will not net any advantage.

Challenge #3: Collection System Size





Challenge #4: Terrain

- Gravity moves stormwater across the land and to stormwater grates and inlets
- If we were in the Piedmont or the Upstate where there are hills and mountains with steeper slopes, terrain would be much less of a factor.
- Unfortunately, the Lowcountry has either very gentle slopes or completely flat land.
- The flatter the land, the slower the water will move, and the more time it will take to drain an area of land.

Challenge #4: Terrain

- To demonstrate this concept, grab the nearest large piece of plywood and a 2-by-4.
- Place the 2-by-4 on its side (on the 1.5" side), place one end of the plywood on the 2-by-4, and place the other end of the plywood on the ground.
- Pour a cup of water on the raised end of the plywood and note the speed of the water as it runs down the plywood. (Use a ball if a cup of water would cause too much of a mess.)

Challenge #4: Terrain

- Now, place the 2-by-4 on its flat side (the 3.5” side), again with one end of the plywood on the 2-by-4 and the other end on the ground.
- Pour another cup of water on the plywood and note that it flows a little slower down the plywood to the ground.

Challenge #4: Terrain

- For a third demonstration, place the plywood flat on the ground.
- Pour a third cup of water in the middle of the plywood.
- This is how water flows over land in the Lowcountry.

Challenge #5: Inlets

- The number and size of inlets will affect how quickly an area drains.
- With more inlets, there are more ways for the stormwater to enter the collection system.
- Also, with more inlets, the stormwater has less overland distance to travel, thus reducing the travel time and the time it takes to drain an area.
- Since the stormwater system is an afterthought in most urban areas, especially in cities that have been around for more than 100 years, the location and number of inlets is limited by factors such as location of existing structures and utilities.

Challenge #5: Inlets

- With larger inlet openings, there is more open surface area and the inlet can accept more stormwater.
- There is, however, a limit to the size of the openings that are allowable for inlets since large openings are a safety hazard.
- Also, large inlets are not effective if the system to which they drain is unable to accommodate the flow from them (see Challenge #3).

Challenge #5: Inlets

- Again, going back to the example of the partially clogged drain, the size of the inlet can be represented by the degree of the clog.
- The more clogged the drain is, the slower the water will drain from the basin.
- While an unclogged sink drain might best be represented by a giant 10-foot hole in the ground to collect stormwater, the practicality of the solution is somewhat questionable.

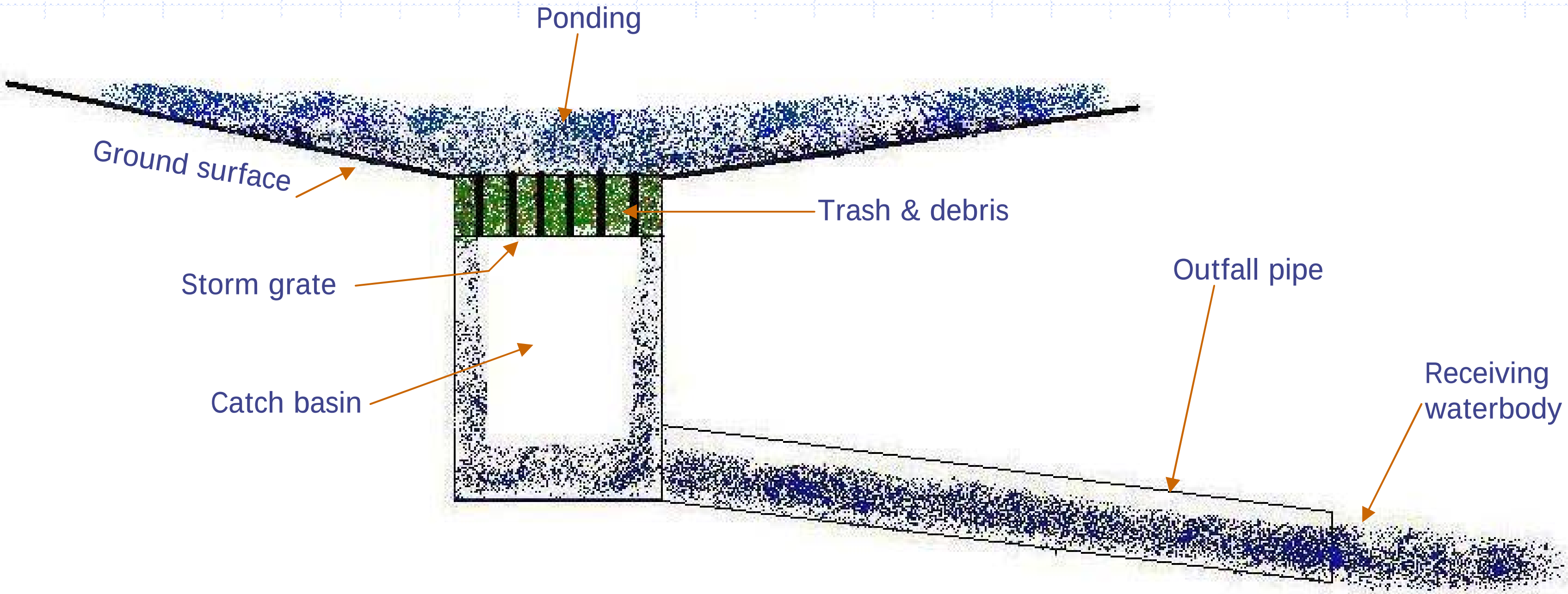
Challenge #6: Trash

- Arguably, the biggest detriment to the surface collection system is trash and debris.

There is an inlet under all those leaves.

- Common items ranging from newspapers, wrappers, and plastic grocery bags to pine straw, bark mulch, and live oak leaves will quickly reduce the amount of water that can flow into the system and cause flooding.

Challenge #6: Trash



Trash and debris caught on and in storm grates causes ponding on the surface.

Challenge #6: Trash

- During every rain event, the City receives scores of calls to remove trash and debris from storm drains.
- Since the City has a finite amount of people and resources, many of whom are attending to critical roads and intersections to maintain traffic flow for emergency vehicles, we cannot be everywhere at once.
- Many of these calls are preventable if residents take the time to clean off storm drains before the storm or after dangerous weather conditions have passed.
- Residents can help themselves by helping us.

Challenge #6: Trash

- Many residents may not know that it is the responsibility of the property owner and/or renter to remove and properly dispose of all trash and debris from their property.
- Charleston City Code, Section 28-7 states it is unlawful to dump, deposit, or otherwise cause any material to be placed within the stormwater system.

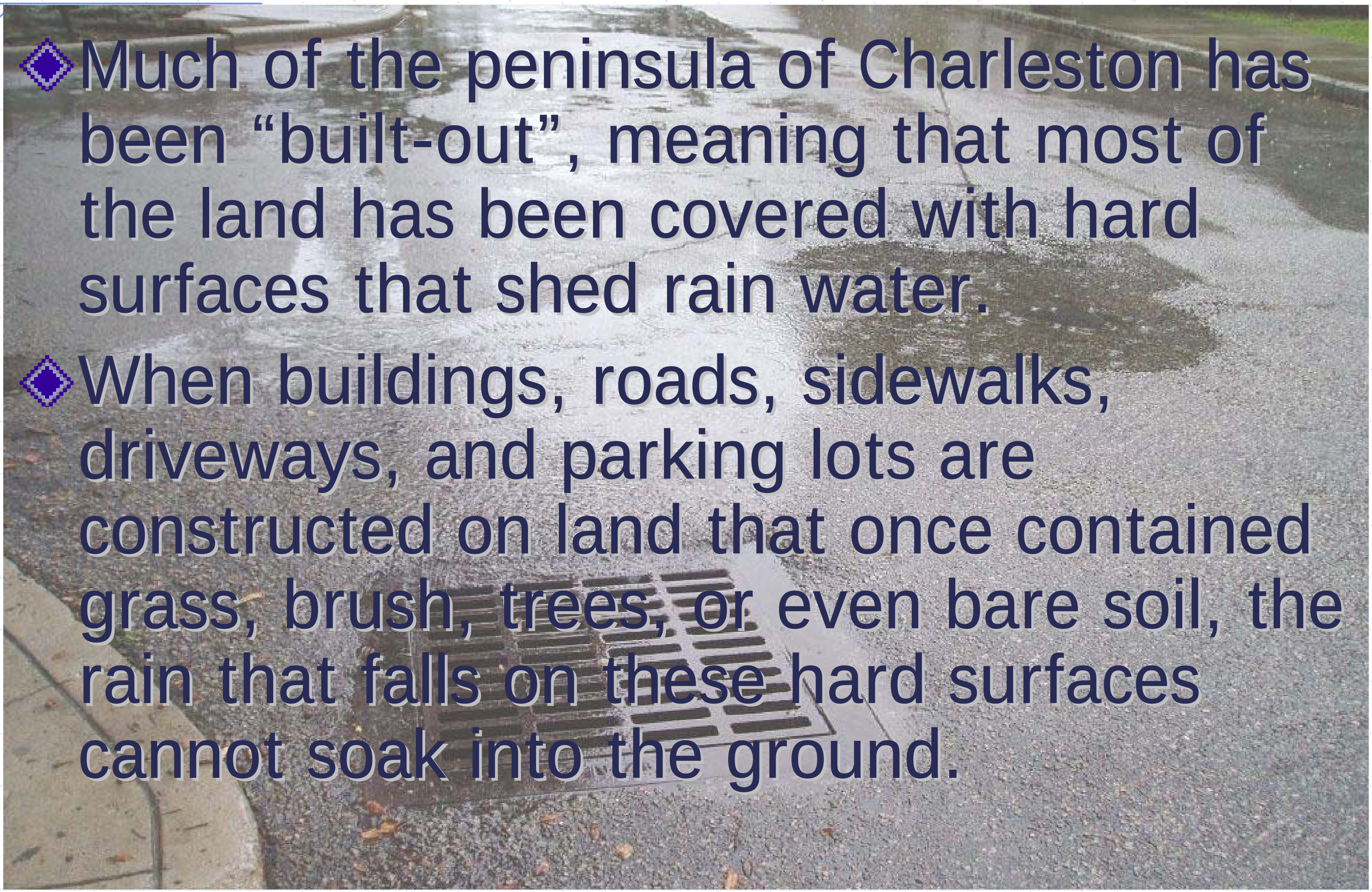
Challenge #6: Trash

- Also, Charleston City Code, Section 14-5 states that:
  - The owner or occupant is required to keep the property free of litter and debris
  - The property must be kept clean and free of debris up to and including the sidewalk, curb, and gutter
  - It is unlawful to push trash or debris into the street

Challenge #6: Trash

- Property owners and renters are required to clean up all loose trash, garbage, and debris from their yards, sidewalks, loading docks, curbs, and gutters.
- Since many of the stormwater inlets are within the gutters on City streets, it falls to the property owners and renters to help keep them clean.
- Those who do not keep these areas clean are in violation of City Code and can be cited and fined.

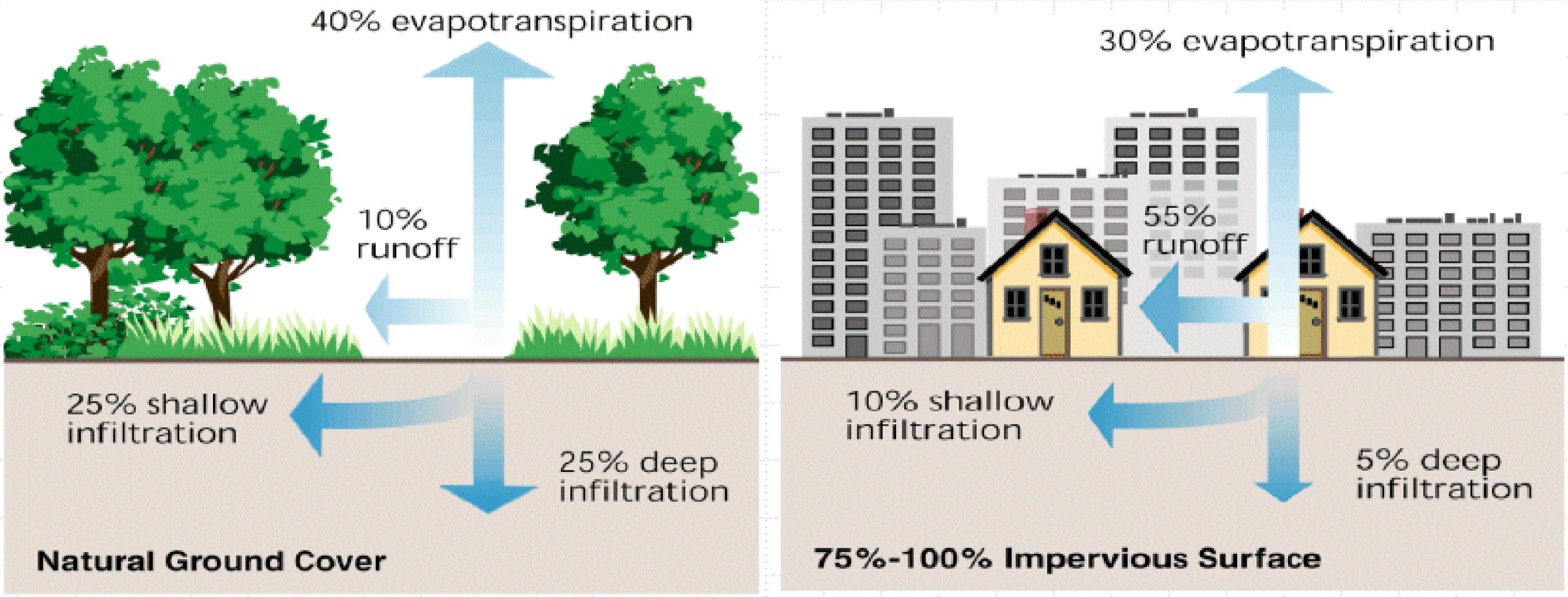
Challenge #7: Impervious Cover



- Much of the peninsula of Charleston has been “built-out”, meaning that most of the land has been covered with hard surfaces that shed rain water.
- When buildings, roads, sidewalks, driveways, and parking lots are constructed on land that once contained grass, brush, trees, or even bare soil, the rain that falls on these hard surfaces cannot soak into the ground.

Challenge #7: Impervious Cover

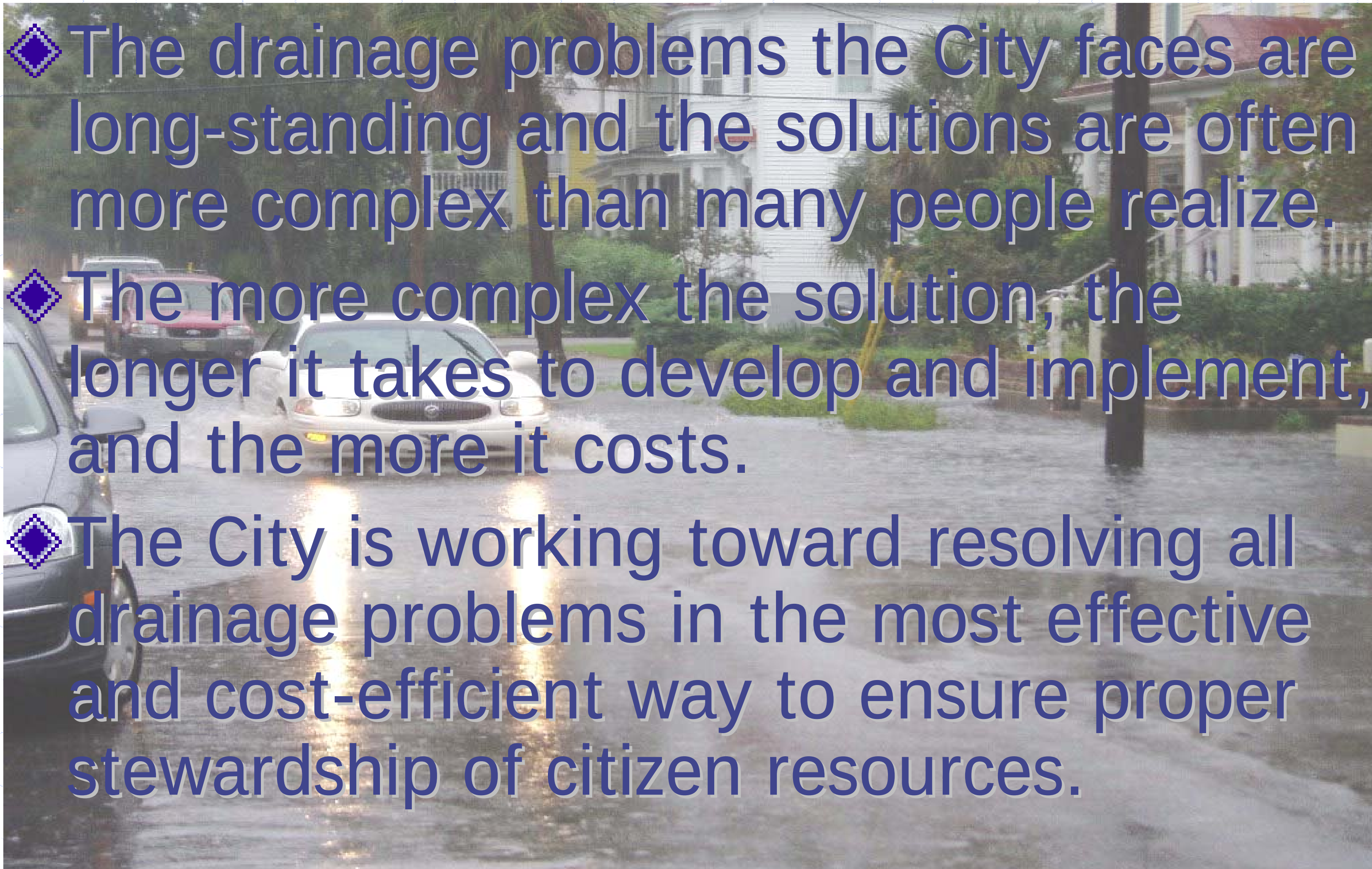
- Instead, the water that runs off these ***impervious surfaces*** must find its way across the land, into the gutters, and down the storm drains. The stormwater volume is greatly increased since much of the rain now runs off instead of soaking into the ground.



Challenge #7: Impervious Cover

- Also, smooth, hard surfaces like asphalt and concrete increase the speed of the stormwater as it makes its way to the collection system.
- Combine these two factors, and we now have greater volumes of stormwater rushing more rapidly to drains that may be clogged with trash and full of seawater at high tide causing flooding.

What the City of Charleston is Doing About the Flooding



- The drainage problems the City faces are long-standing and the solutions are often more complex than many people realize.
- The more complex the solution, the longer it takes to develop and implement, and the more it costs.
- The City is working toward resolving all drainage problems in the most effective and cost-efficient way to ensure proper stewardship of citizen resources.

What the City of Charleston is Doing About the Flooding

- The most practical solution for the flooding is to build pump stations for the most flood-prone areas.
- The pump stations will decrease the length of time it takes for the water of a flooded area to drain by providing the necessary energy (head) to the water, even at high tide.
- Once the stormwater reaches the pump station under non-tropical system conditions (i.e. no storm surge), the pumps will be able to push it into the water bodies without needing to wait until high tide passes.

What the City of Charleston is Doing About the Flooding

- However, there are limitations to how much flooding the pump stations will be able to alleviate.
- The pump stations are unable to increase the speed with which the water moves to, into, and through the collection system.

What the City of Charleston is Doing About the Flooding

- Remember, there are four potential bottlenecks as described above that may slow the stormwater during its journey to the pumps:

1. Overland flow
2. Flowing into the storm grate
3. Flowing into the conveyance system
4. Flowing through the conveyance system

What the City of Charleston is Doing About the Flooding

- If the rate at which the rain is falling exceeds the rate of any of the potential bottlenecks, the water will begin to back up and will eventually create ponding on the surface (standing water).
- The pumps will be able to push against any water level that does not significantly exceed high tide, but they cannot completely overcome the other six challenges to the Lowcountry’s drainage (rainfall rate, system size, terrain, inlets, trash, and impervious cover).

What the City of Charleston is Doing About the Flooding

- Two pump stations have already been constructed on the peninsula
  - The Concord Street pump station serves the East Calhoun basin encompassing Calhoun St. from the Cooper River to King St., King and Meetings Sts. from Burns Lane to Reid St., and the adjacent blocks
  - The MUSC pump station mainly serves the area surrounding the new hospital

The Concord Street Pump Station

- The Concord Street pump station is located near the Maritime Center over a concrete-lined shaft that extends approximately 150 feet below ground.
- An 8-foot diameter concrete-lined tunnel runs from the shaft, up Calhoun St. to Marion Square and then up Meeting St. to Mary St., ranging in depth from 110 feet to 150 feet below ground.
- Stormwater is collected on the surface, drops from the surface through a few dozen small-diameter shafts to the deep tunnel, and then flows through the tunnel to the pump station.

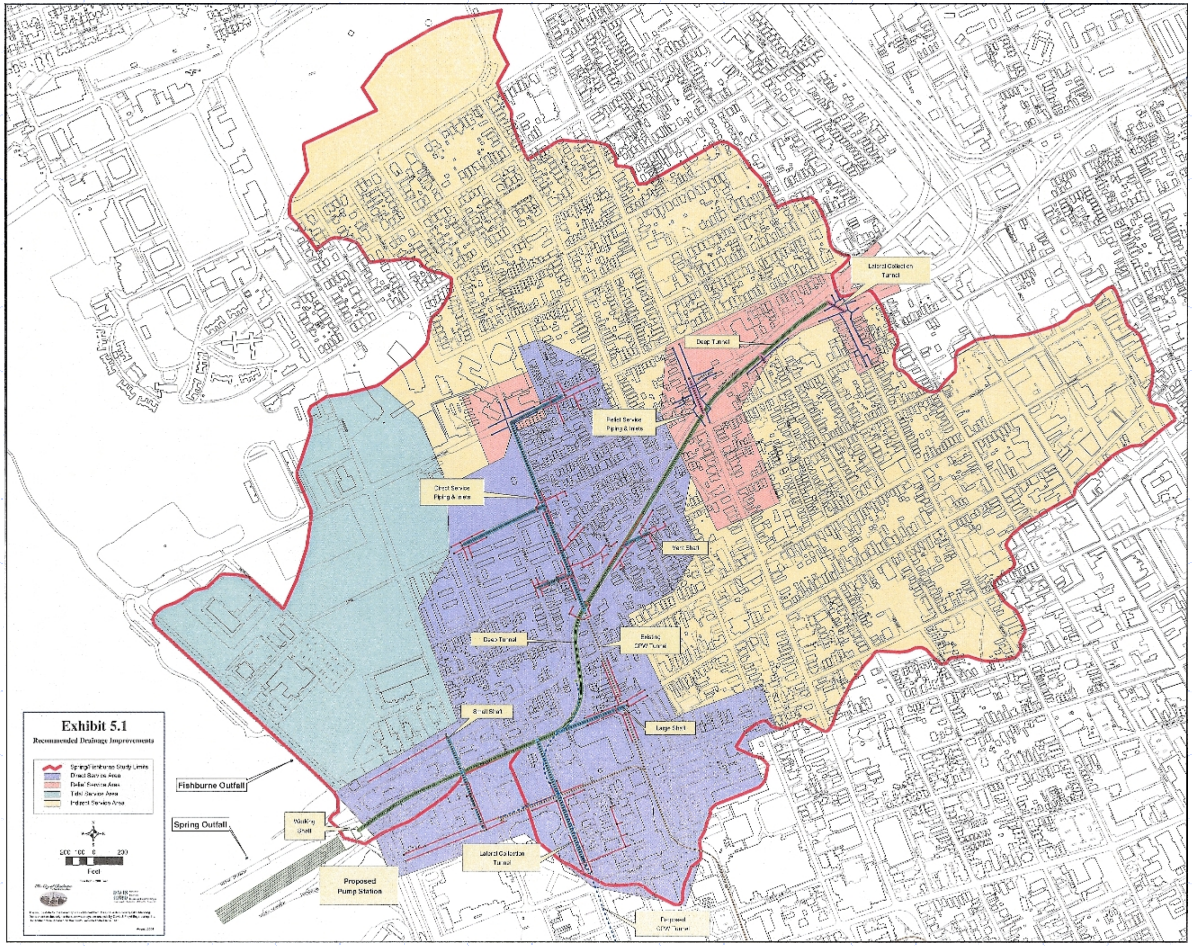
The Concord Street Pump Station

- The pump station then pumps the stormwater into the Cooper River with four large pumps, each capable of pumping 34,000 gallons per minute.
- This innovative method of removing stormwater is able to decrease the effects of many of the challenges to draining the City, however pump stations and tunnels are very expensive to construct.
- Planning and construction is currently underway to connect the Market Street drainage basin (encompassing Cumberland and Market Sts. from Concord St. to King St.) to the Concord Street pump station using another deep tunnel.

The Spring/Fishburne/US17 Drainage Improvement Project

- Final design has been completed to build a similar pump station and deep tunnel to alleviate flooding in the Spring and Fishburne drainage basins (the Spring/Fishburne/US 17 Project)
- The two basins run from the hospital complex north to Hampton Park including Burke High School, the Crosstown (Hwy 17) from the Ashley River Bridges to Meeting Street, and many adjacent neighborhoods.

The Spring/Fishburne/US17 Drainage Improvement Project



Approximate Spring/Fishburne Drainage Improvement Project Boundaries

The Spring/Fishburne/US17 Drainage Improvement Project

- The Spring/Fishburne basins cover almost one-fifth (20%) of the peninsula
- It is by far the single largest project the City has undertaken. Design alone has cost the City over $5 million. Construction estimates exceed $100 million.
- As with any complex project, planning, design, and construction will take several years to execute.

What Residents Can Do About the Flooding

- Residents can help themselves by helping the City.
- Residents have an enormous influence on one of the biggest drainage challenges we face in the Lowcountry: **TRASH**.
- If residents take an active role in keeping trash and debris off of streets and sidewalks and out of the storm drain system, the effect it has on flooding can be significantly decreased.

What Residents Can Do About the Flooding

- As discussed in point #6 above, residents and business owners are responsible for keeping the areas in front of their businesses and residences (including the sidewalk, curb, and gutter) clear of trash and debris.

What Residents Can Do About the Flooding

- While the City has a regular street sweeping program, we cannot have all the streets clean and clear before all storms.
- Residents are encouraged to be on the lookout for anything that could potentially be carried to and deposited on a storm drain.

What Residents Can Do About the Flooding

- Even if trash has been picked up and properly disposed, trash cans and dumpsters can pose a hazard to storm drains.
- They can be picked up by a few inches of water and easily overturned, spilling their contents (which residents just spent time and energy cleaning up) onto the ground to be carried away and deposited on a storm drain.
- Keep trash cans and dumpsters properly secured to prevent them from floating and overturning.

What Residents Can Do About the Flooding

- Many residents will take care of their trash, but will not stoop to pick up trash that someone else may have dropped.
- The Department of Public Service has heard countless times that “it’s not my trash” on a storm drain in front of their house or business that has created a clog and is causing the water to rapidly rise.
- Unfortunately, this thinking could cost you or someone in your neighborhood thousands of dollars in flooding damages as well as the headache of having a home or business disrupted.
- Take the time to remove the debris and you could save yourself and others money and aggravation.

What Residents Can Do About the Flooding

- The City of Charleston has stormwater crews that regularly clean the surface collection and conveyance systems and to aid with drainage complaints.
- During storm events, though, these crews are out maintaining the storm drains along major roads and at major intersections to ensure safe passage for emergency vehicles.
- Since crews are out performing emergency duties, they may not be available to respond immediately to non-life threatening flooding.

What Residents Can Do About the Flooding

- When residents notice a clogged drain near their home or business, they are encouraged to try to remove the trash and debris from the drain surface (once all dangerous weather conditions have passed) before calling the Stormwater Department.
- If residents have attempted to remove the clog but are unable, they can call the Stormwater Department at 724-7367.