# REPORT

# ON

# INFILTRATION AND INFLOW IMPACTS

# ON

# THE CITY OF COLUMBUS

# SEWER SYSTEM

## BACKGROUND

In 2002 and 2004, the City of Columbus entered into two consent orders with the Ohio Environmental Protection Agency, one for sanitary sewer overflows and one for combined sewer overflows. The 2002 consent order requires elimination of sanitary sewer overflows and water in basement events. The 2004 consent order calls for a reduction in combined sewer overflows. In 2005, the City submitted a Wet Weather Management Plan to the Ohio Environmental Protection Agency to comply with the consent order requirements for sanitary sewer overflows and combined sewer overflows.

The Wet Weather Management Plan, which was conditionally approved by the Ohio Environmental Protection Agency in 2009, recommended collection system and wastewater treatment plant improvements. A large portion of the combined sewer system and wastewater treatment plant improvements have since been constructed. However, the large sanitary sewer system improvements have not yet started.

Sanitary sewer overflows and water in basement events occur when rainwater finds its way into sanitary sewers that are not designed to handle large amounts of rainwater. This is referred to as infiltration and inflow (I/I). The Wet Weather Management Plan recommended controlling these sanitary sewer overflows in large part by constructing two deep tunnels, known as the Alum Creek Relief Tunnel and the Olentangy Relief Tunnel. Tunnels would take the excessive water in the sanitary sewers and transport it to the wastewater treatment plants.

In 2012, the City began looking at whether it could control sanitary sewer overflows without relying solely on tunnels by eliminating the excessive rainwater which enters collection system as infiltration and inflow from getting into the sanitary sewers in the first place. This would require reducing or eliminating infiltration and inflow from private property, as a majority of the infiltration and inflow in Columbus' system is coming in from private property.

On September 15, 2015, the City of Columbus submitted its *Integrated Plan and 2015 WWMP Update Report* to Ohio EPA. This Plan was the result of the analysis the City performed to determine if it could solve its SSO and WIB problems without relying solely on tunnels. The Plan presented a preferred alternative, known as Blueprint Columbus, that would focus primarily on solving SSOs and WIBs by removing I/I. The Plan includes a 20 year schedule for eliminating SSOs, and includes some gray infrastructure as well. The Plan is available at www.columbus.gov/blueprint.

The purpose of this Report on the Impact of Inflow and Infiltration is to document and summarize available information regarding the impact of infiltration and inflow on sanitary sewers in general, and more particularly on Columbus' sanitary sewer system, including private property impacts.

**DEFINITIONS**

**Consent Orders** - The 2002 SSO Consent Order and the 2004 CSO Consent Order entered between Ohio Environmental Protection Agency and the City of Columbus.

**Designed Sewer Relief** - A structure in a sanitary sewer system constructed prior to the Clean Water Act to allow overflow from the sanitary system if flows are high. Typically installed to reduce water in basement occurrences, with the overflow discharge to the environment through a connection to a storm sewer or directly to a waterway.

**Downspouts** - The vertical infrastructure installed to carry rain collected in gutters from a roof to the ground.

**Infiltration** - Stormwater and groundwater that enter a sanitary sewer system through such means as defective pipes, pipe joints, connections, or manholes. Infiltration does not include inflow.

**Inflow** Stormwater and groundwater that enters a sanitary sewer system, from such sources as, but not limited to, roof leaders; cellar, yard and area drains; foundation drains; cooling water discharges; drains from springs and swampy areas; manhole covers; cross connections from storm sewers; combined sewers; catch basins; storm waters; surface runoff; street wash-waters; or drainage. Inflow does not include, and is distinguished from, infiltration.

The combination of infiltration and inflow.

**I/I**

**Private Sanitary Lateral** - The pipe from a building to the public sewer that carries wastewater.

**Sanitary Sewer Overflow** - An overflow, spill, or release of wastewater from a sanitary sewer system.

**Water in Basement Event** - Wastewater backups into buildings that are caused by wet weather flow conditions in a sanitary sewer main. Water in basement events do not include dry weather events.

## CITY OF COLUMBUS SEWER SYSTEM

The City of Columbus sewer system contains combined sewers, sanitary sewers and storm sewers:

- The combined sewer system covers approximately 7% of the total City of Columbus sewer service area [1] and contains 156 miles of combined sewer [2]. These sewers collect both sanitary waste from homes and businesses and combine it with rainwater collected from streets and roofs. The combined sewer system serves the downtown area and older areas proximate to the downtown area. The combined sewer system is not the focus of this report and will not be discussed further.
- The sanitary sewer system accounts for 93% of the serviced area [1], totaling approximately 2,481 miles with sewer sizes ranging between 8 inches to 13 feet in diameter [2]. 81% of these sewers are less than 18 inches in diameter [2]. These sewers are intended to collect only sanitary waste from homes and businesses.
- In addition to the combined sewer system and the sanitary sewer system, approximately 1,757 miles of storm sewers, carrying water from rain storms, are within the City's boundary and run in parallel with the sanitary sewers [2].

### Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are discharges of wastewater from the sanitary sewer system into the environment. Most sanitary sewer overflows occur at a designed sanitary relief (DSR) point during heavy rain events. Designed sanitary reliefs are locations where the sanitary sewer is deliberately connected to a storm sewer. These connections were created in the past before the present requirements of the Clean Water Act and were installed to protect basements from flooding when the sanitary sewer becomes surcharged. When the sanitary sewer becomes surcharged, the designed sanitary relief allows the excess flow to discharge into a storm sewer, and from the storm sewer into rivers or streams. This event is known as a sanitary sewer overflow.

In the City of Columbus there are 70 designed sanitary relief locations, down from 100 at the time of the consent order [2]. These sites are owned and monitored by the City of Columbus. The designed sanitary relief locations are noted on Figure 1. Records of the occurrences and volume of overflows (if known) are maintained by the City as required by the consent decrees and the data is updated monthly [3]. Figure 2 summarizes the City's history of sanitary sewer overflow activations over the last five years.

Sanitary sewer overflows are prohibited by the Clean Water Act [4]. As noted above, in 2002, the City of Columbus and Ohio Environmental Protection Agency (EPA) entered into a consent order which requires the City to stop sanitary sewer overflows and water in basement events [5].

Sanitary sewer overflows to the environment are a public health threat. Sewage contains a variety of harmful pathogens which can cause illness if ingested [6]. Sanitary sewer overflows empty into local streams where people can be at risk of exposure when swimming in the water, through drinking from a contaminated water supply, or eating contaminated fish or shellfish [7].

Water In Basements

Wet weather water in basement events occur when the City's collection system is full and sewage backs up into basements. This report focuses on water in basement events that are a result of flow conditions in the sanitary sewer main, not the private sanitary lateral which connects the building to the sewer system. The City of Columbus tracks water in basement reports and investigates their cause. Elimination of water in basement events is a requirement of the sanitary sewer overflow consent order.

Exposure to sewage from a water in basement event persists through the time of cleanup and restoration [6]. Water in basement events also create an environment that promotes mold growth which can cause health issues for the inhabitants [6]. It has been the policy of the City to reduce water in basement events due to human health concerns. In July of 2004 the City of Columbus began the Project Dry Basement program which installs backflow prevention devices for single and two-family houses in order to reduce citizen exposure to sewage [9]. Figure 3 shows the locations in the City where water in basement events occurred between August 1, 2012 and July 31, 2013.

## INFILTRATION AND INFLOW CAUSE SANITARY SEWER OVERFLOWS AND WATER IN BASEMENT EVENTS

During dry weather, Columbus' sanitary sewer system provides a high level of performance. However, during some wet weather events sanitary sewers become surcharged, which causes the sewer to discharge through a designed sanitary relief, which is known as a sanitary sewer overflow. The surcharging in the sewer happens when rainwater in the form of inflow and infiltration enters the sanitary sewer system and exceeds sewer capacity.

Inflow refers to rainwater that enters the sanitary sewer directly. For instance, rainwater can enter the sanitary sewer system via flooding around an open manhole lid. Rainwater can also enter the sanitary sewer system through downspouts that are directly connected to a private sanitary lateral. Direct downspout connections to the sanitary sewer are illegal. In 1907 City Council enacted an ordinance which prohibited connections of downspouts to the sanitary sewer system [10]. In 1927, an additional ordinance was enacted that provided the City with the authority to remove any such connections [10]. Downspouts are supposed to discharge to the storm sewer system or storm lateral. However, there are still some illegally connected downspouts on Columbus' system [1]. Sump pumps may also be illegally connected to private sanitary laterals [11].

In the above instances rainwater is directly flowing into the sanitary sewer system. Inflow has a very fast response and causes a rapid increase in flow in the sanitary sewer system.

The infiltration pathway is slower, but generally has a longer duration in comparison to inflow sources. Infiltration sources into the sanitary sewer system include cracks in pipes surrounded by groundwater, non-watertight joints in pipes and foundation drains that collect water from around a house that then discharge into the private sanitary lateral.

Sanitary sewers are not designed to carry large amounts of rainwater. A reasonable factor of safety is included in the design of sewers to guard against some infiltration and inflow.

> *According to the City of Columbus Sanitary Sewer Design Manual the sewers installed in the City of Columbus do allow for approximately 1,940 gallons of infiltration per day for each acre (0.003 cfs/acre) contributing to the sewer. This is part of the sewer's designed capacity* [12]*.*

Thus, the sources of inflow and infiltration discussed above may cause the sanitary sewer to become overwhelmed during heavy rain events beyond the designed sewer capacity. This results in sanitary sewer overflows and water in basement events.

The impact of inflow and infiltration on the City of Columbus' sanitary sewers has been studied extensively. As discussed, the City submitted a Wet Weather Management Plan to the Ohio Environmental Protection Agency in 2005 to address the consent order requirements. The WWMP identified twelve Priority Areas where significant sanitary sewer overflows and water in basement events were occurring. In 2006 the infiltration and inflow studies were initiated based on the WWMP recommendation, and once started the areas of study were expanded well beyond the initial Wet Weather Management Plan recommendations. In total over 10,000 acres have been studied [13]. The purpose of the studies was to determine the sources of infiltration and inflow in the areas where sanitary sewer overflows are occurring.

In conjunction with the infiltration and inflow studies performed by the City since 2006, the City has and continues to utilize an extensive network of sanitary sewer system flow meters and rain gauges to collect data on the sewer system wet weather performance. The City also operates and maintains an extensive and detailed computer model of the collection system based upon the data collected by the flow meters and rain gauges. The system flow metering and computer modeling has identified a total of 18,000 additional acres that contribute significant infiltration and inflow that is causing sanitary sewer overflows and/or water in basement events [14].

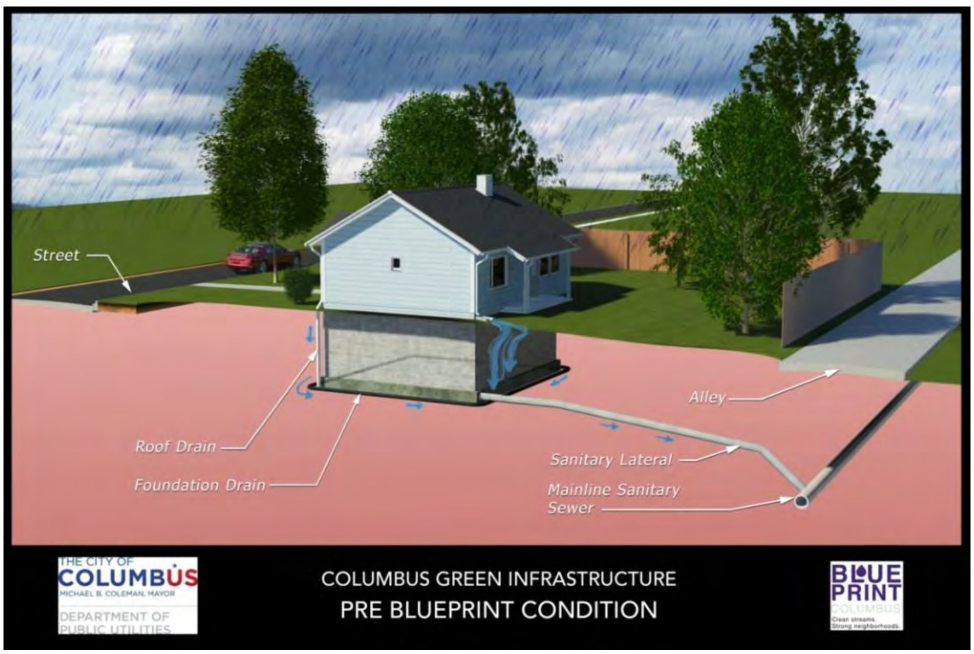
The 18,000 acres of significant infiltration and inflow have been designated as “Blueprint Columbus” target areas for inflow and infiltration reduction, and are shown on Figure 4. The City used it model to predict the results of applying inflow and infiltration technologies to these 18,000 acres. The result is result is a dramatic lowering of incidences of SSOs and WIBs. However, to eliminate the overflows will also require some additional gray infrastructure, such as relief pipes. The details of the model results and the exact plan for elimination can be found in the Sept. 15, 2015 Integrated Plan.

**INFILTRATION AND INFLOW STUDY FINDINGS**

The infiltration and inflow studies discussed above analyzed both public and private sources of infiltration and inflow. Private sources of infiltration and inflow are entering the City's system from private property, as opposed to entering directly into the City's system from publicly owned property such as the right-of-way. In general, it was found that more than half of the infiltration and inflow was getting into the sanitary system from private sources [13, 15]. As discussed in this section, that finding is consistent with other studies that have been performed around the country.

<u>Residential Sources of Private Infiltration and Inflow</u>

As shown in the illustration, the private sanitary lateral connects the home to Columbus' sanitary sewer main. This illustration also points out the ways that an individual home can contribute infiltration and inflow to the sanitary sewer.




The inflow source shown on the figure is a roof drain (downspout) that is directly connected to the foundation drain. This connection would rapidly fill the foundation drain with rainwater and enter the private sanitary lateral feeding the sanitary sewer. This connection was made illegal in 1907 [10].

The rainwater in the foundation drain can enter the private sanitary lateral through the 4 inch to 6 inch transition in the lateral and other joints on the lateral. The 4 inch to 6 inch transition connects the house plumbing (4 inches in diameter) with the private sanitary lateral (6 inches in diameter). This connection is typically not water tight. The joints on older clay lateral pipes are typically not watertight either.

Two potential infiltration pathways are shown. The first is a downspout emptying on a splash block that is near the foundation of the house. The rain percolates through the soil then collects in the foundation drain which connects (directly or indirectly) to the private sanitary lateral. The second source is cracks and imperfect joints in the private sanitary lateral itself. These cracks and imperfect joints allow groundwater and stormwater from the lawn area above to leak into the private sanitary lateral into the sanitary sewer system.

These conditions are typical for houses in the Blueprint Columbus areas as indicated in Figure 4, and lead to infiltration and inflow greater than designed capacity.

<u>Columbus' Infiltration and Inflow Studies Confirm Private Residential Contribution</u>

Approximately 20% of properties tested during Columbus' infiltration and inflow studies conducted since 2006 indicated that infiltration was occurring at the 4 inch to 6 inch transition in the lateral [13]. These studies also indicate that infiltration and inflow into private sanitary laterals was either the primary source or a very significant contributor to excessive water into the sewer system [13].

In the infiltration and inflow studies done in the Linden/Northeast Area study area, approximately 60% of infiltration and inflow was attributed to the downspouts, sanitary laterals, sump pumps or foundation drains found on private property [13]. For the James/Livingston area 42% of tested properties had sanitary lateral infiltration [13].

In addition to the infiltration and inflow studies, another pilot study performed by the City confirms the substantial contribution of infiltration and inflow from older homes. In certain areas of Clintonville, there were frequent water in basement events and surcharging (overwhelmed) sewers. Between July 2005 and March 2007 the City rehabilitated mainline sewers and manholes within the public right-of-way in this area to address the infiltration and inflow problem [17]. However, after sealing the public side of the sanitary sewer system, monitoring showed only limited infiltration and inflow reduction. This indicates that private sources continue to contribute substantially to the problem.

To further test the contribution of private sources of infiltration and inflow, the City of Columbus then implemented a voluntary private sanitary lateral rehabilitation program for Clintonville. Two areas, totaling 216 households, were selected for the voluntary program [18]. Testing in the area indicated between 5-8% of the houses had downspouts directly connected to the private sanitary laterals, 51-53% of the homes had foundation drains connected to the private sanitary laterals, and 33-35% of the homes had experienced water in basement events [18]. The foundation drains were the main component contributing to infiltration and inflow from the private sources [18]. Between 86% and 87% of the residents volunteered for private sanitary lateral replacement/repair [19]. Continued monitoring indicates that the voluntary private sanitary lateral repair project was effective at reducing infiltration and inflow by approximately 30% [20].

For Columbus' system, the studies determined that there are two main sources of infiltration and inflow from private sources: private sanitary laterals in poor condition, and downspouts directly or indirectly connected to the sanitary sewer by the foundation drain. Each of these two sources of infiltration and inflow are discussed in more detail below.

Other Cities' Studies Also Confirm the Private Contribution

In Duluth, Minnesota a program to disconnect foundation drains from private sanitary laterals proved to be very successful in achieving substantial reductions in wet weather peak flows, volumes, and sanitary sewer overflow activations [21].

New Castle County, Delaware also embarked on a program to eliminate illegal private inflow sources to the sanitary sewer including sump pumps, punctured floor drains, and leaky basement drains. After a pilot program was implemented reductions in wet weather peak flows and volumes were observed in the sanitary mainline sewers, including a 55% reduction in peak wet weather flow rate, and a 27% reduction in total storm volume based on flow metering data [11].

Johnson County, Kansas had issues with water in basement events and sanitary sewer overflows. After disconnecting unpermitted inflow sources on private property, water in basement complaints have decreased and sanitary sewer overflow activations and volumes have been reduced [16].

The Water Environment Research Federation analyzed twelve projects conducted by six utilities across the country for their effectiveness in reducing peak infiltration and inflow. The results showed that infiltration and inflow improvements conducted in the public right-of-way provided little reduction in peak infiltration and inflow, most projects showed a reduction of 5% or less. However, projects that addressed private sanitary laterals realized significant reduction in peak flow and reductions between 50 and 70% were realized [22].

## PRIVATE INFILTRATION AND INFLOW

As discussed above, Columbus studies have determined that there are two main contributors of private infiltration and inflow to the system: laterals in poor condition, and foundation drains. This section will discuss the problem and the solution.

### Private Sanitary Laterals

The United States Environmental Protection Agency recognizes that approximately half of the total length of a sewer system is on private property [16]. This means there are over 2,500 miles of private sanitary laterals in Columbus' sewer system that are potential sources of infiltration and inflow to the sanitary sewer system.

In Columbus the infiltration and inflow studies showed that houses constructed before 1965 have a higher likelihood of leaky and/or defective private sanitary laterals. Construction of private sanitary laterals was improved after the plumbing code and plastic pipe updates that occurred in the 1960s; nonetheless, these laterals will also deteriorate over time. [23].

The studies analyzed by the Water Environment Research Federation indicated that replacement or lining of laterals were effective methods for repairing private sanitary laterals [22]. The study indicated that cured-in-place-pipe lining has been successfully used; however, at the time of the research this technology had not been widely used. Cured-in-place-pipe lining creates a new pipe within the existing pipe that has no joints, or cracks that can introduce infiltration into the pipe. The study also describes several instances where total replacement of the private sanitary lateral was the focus of the study. This would require excavation of the current private sanitary lateral and installation of a new lateral [22].

Recently, cured-in-place-pipe technology has become more widely used for repairing both the sanitary sewer system and private sanitary laterals. There has been a rapid growth in the application of cured-in-place-pipe technology because it is recognized as being cost effective in reducing infiltration and inflow [24].

The City of Columbus has used cured-in-place-pipe to repair mainline sanitary sewers for many years. Columbus, through small pilot projects, has also tested cured-in-place pipe to repair private sanitary laterals. The City finds this technology effective to reduce infiltration and inflow.

Cured-in-place-pipe, and if needed, complete private sanitary lateral replacement are effective methodologies that can be utilized to reduce the infiltration and inflow from private sanitary laterals.

Pipe bursting is another trenchless technology that can be an effective remediation technology. This technology involves destroying the old sewer and replacing it with a new pipe.

Foundation Drains

Current state and national building codes require that homes have their rooftops drain to gutters which channel the water to the downspouts that are connected to storm laterals which, in turn, take rainwater to the street or discharge the rainwater away from the house foundation [25]. It has been illegal to have downspouts directly connected to sanitary sewers in Columbus since 1907 [10]. The infiltration and inflow studies found that houses constructed before 1935 have a higher likelihood of directly connected downspouts.

In addition, current standards require that the foundation drains be connected to a sump pump that also discharges to the street or away from the house. This has been part of the Columbus City Code since 1963 [26]. Foundation drains on houses built before 1963 were legally connected (directly or indirectly) to the private sanitary lateral, and thus connected to the City's sanitary sewer.

While direct connections of roof water to the sanitary sewers are now prohibited, roof water is still having a major negative impact on the sanitary sewers for two reasons. First, the infiltration and inflow studies have found that some downspouts are still directly connected to the sanitary sewers, although a relatively small number of houses are connected in this way [13].

Secondly, roof water is also impacting the sanitary sewer through indirect connections to the foundation drains. Studies have determined that if water is discharged to the ground near the home, the water migrates down the side of the foundation to the foundation drain, and through the foundation drain to the City's sanitary sewer [13]. This indirect connection is more common and a more significant contributor than direct connections.

System flow metering and computer modeling performed by the City was used to determine the extent of the indirect connection caused by the foundation drain. The City of Columbus has maintained an extensive computer-based sewer system model since 1988. This model is continuously refined and updated to the latest standards of performance. The model provides information concerning the performance of the sewer system under varying circumstances. The sewer system model indicates that a four to six foot area around a house could be a significant source of infiltration to the sewer system. This area collects both direct rain and runoff from the roof via gutters and downspouts that are not connected to the street. This rainwater percolates through the soil and collects around the foundation drain which introduces water to the private sanitary lateral in areas where sump pumps are not installed. Therefore, it is recommended that roof water be discharged at a distance of at least seven feet from the house, so as to not impact the foundation drainage [14].

In order to prevent roof water from indirectly being connected to the sanitary sewer, it is necessary to move the downspout discharges more than seven feet from the house and the grade from the house must slope downward from the house [14]. Simply discharging downspouts to small splash blocks is ineffective at reducing infiltration and inflow; water from the downspout quickly finds its way to the foundation, and then goes to the foundation drain. Removal of this defect is known as roof water redirection.

Replacing or adding storm laterals which carry downspout flow to the street, and downspout disconnection, are the most effective way to eliminate roof drainage from entering the private sanitary lateral.

## SUMP PUMPS AND DISCONNECTION OF FOUNDATION DRAINS PROVIDE HIGHEST LEVEL OF PROTECTION

As discussed above, foundation drains are a significant source of infiltration and inflow. Roof water redirection will greatly reduce this contribution.

However, while roof water redirection will reduce the contribution of infiltration and inflow from foundation drains, it will not eliminate it, as the foundation drain is still connected to the separate sanitary sewer. Additional reductions can be achieved if the foundation drain is physically disconnected and the 4 inch to 6 inch connection is sealed. Such a disconnection would require installation of a sump pump.

Sump pumps collect water from the foundation drain and discharge the water to the street. Typically, sump pumps discharge to the street curb through a storm lateral then drain to the inlet of the storm sewer system.

Sump pumps could collect a large amount of water and pump it out to the street, or at least seven feet from the house. Sewer system modeling incorporating varying levels of sump pump installations revealed that sump pumps have a significant impact on the amount of infiltration observed in the sanitary sewer system. These results highlight that discharge of rainwater at a distance of at least seven feet from the house and sealing the 4 inch to 6 inch connection could significantly control infiltration into the sewer system [14].

However, not all homes have sump pumps. Sump pumps became a requirement as part of the changes in the Columbus City Code in 1963 [26]. All new homes constructed since 1963 have sump pumps that commonly discharge to the street.

While lateral lining and roof water redirection should provide a significant reduction in inflow and infiltration, sump pumps provide a higher level of protection. Therefore, where possible, the City would like to install sump pumps in the affected areas. [18].

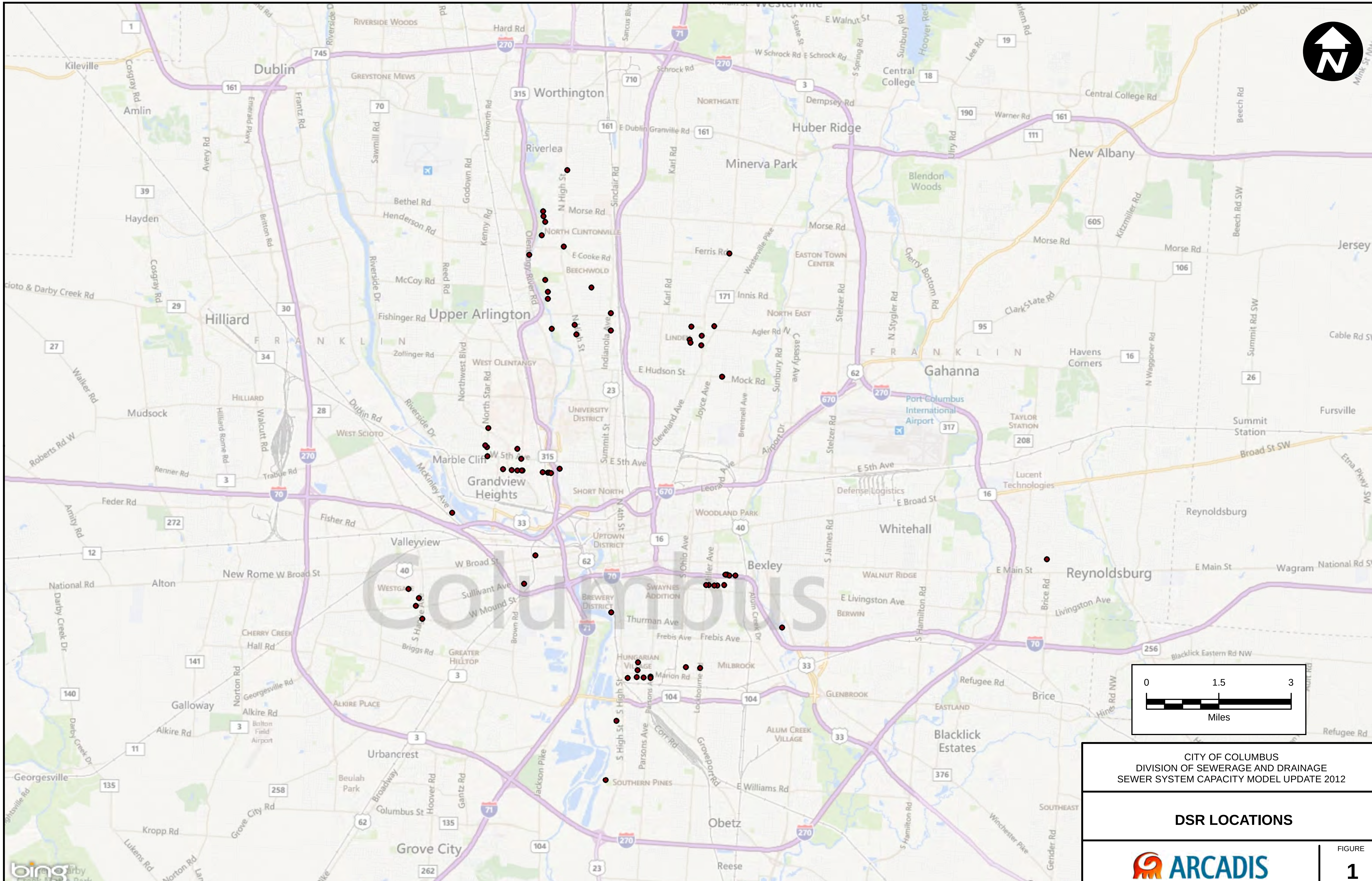
**CONCLUSION**

The City of Columbus is under consent orders to eliminate sanitary sewer overflows and water in basement events. These events occur when the sanitary sewer becomes overloaded as a result of infiltration and inflow into the separate sanitary system. In Columbus, the majority of the infiltration and inflow is coming from private property, and more specifically, from residential laterals that are in poor condition, and from residential downspouts that are connected directly or indirectly to the sanitary sewer. Columbus' sanitary sewer overflows and water in basement events are caused by the infiltration and inflow coming from these residential areas, which comprise approximately 18,000 acres.

Modeling has confirmed that addressing the infiltration and inflow from these areas will reduce sanitary sewer overflows and water in basement events in these areas. It is recommended that the infiltration and inflow problem be addressed by the City taking the following steps in the Blueprint areas (Figure 4):

- Continuing to line its main line sewers;
- Lining all private residential laterals;
- Installing sump pumps where possible; and
- Redirecting downspout discharge at least seven feet from the homes.

Together, these steps should significantly mitigate the impact of inflow and infiltration and thus lead to the elimination of sewer overflows and water in basement events.




CITY OF COLUMBUS
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SEWER SYSTEM CAPACITY MODEL UPDATE 2012

**DSR LOCATIONS**

ARCADIS

FIGURE
1

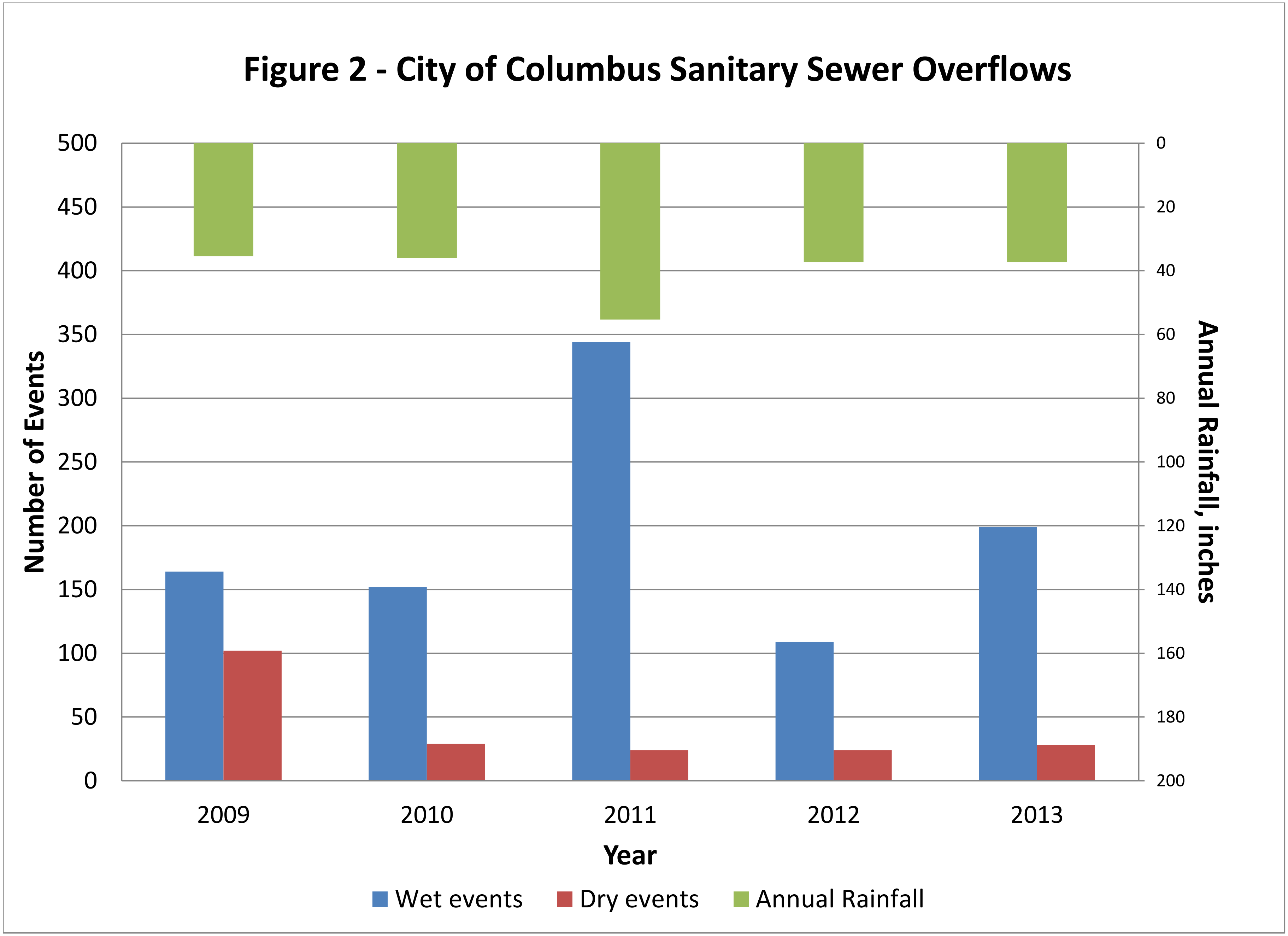
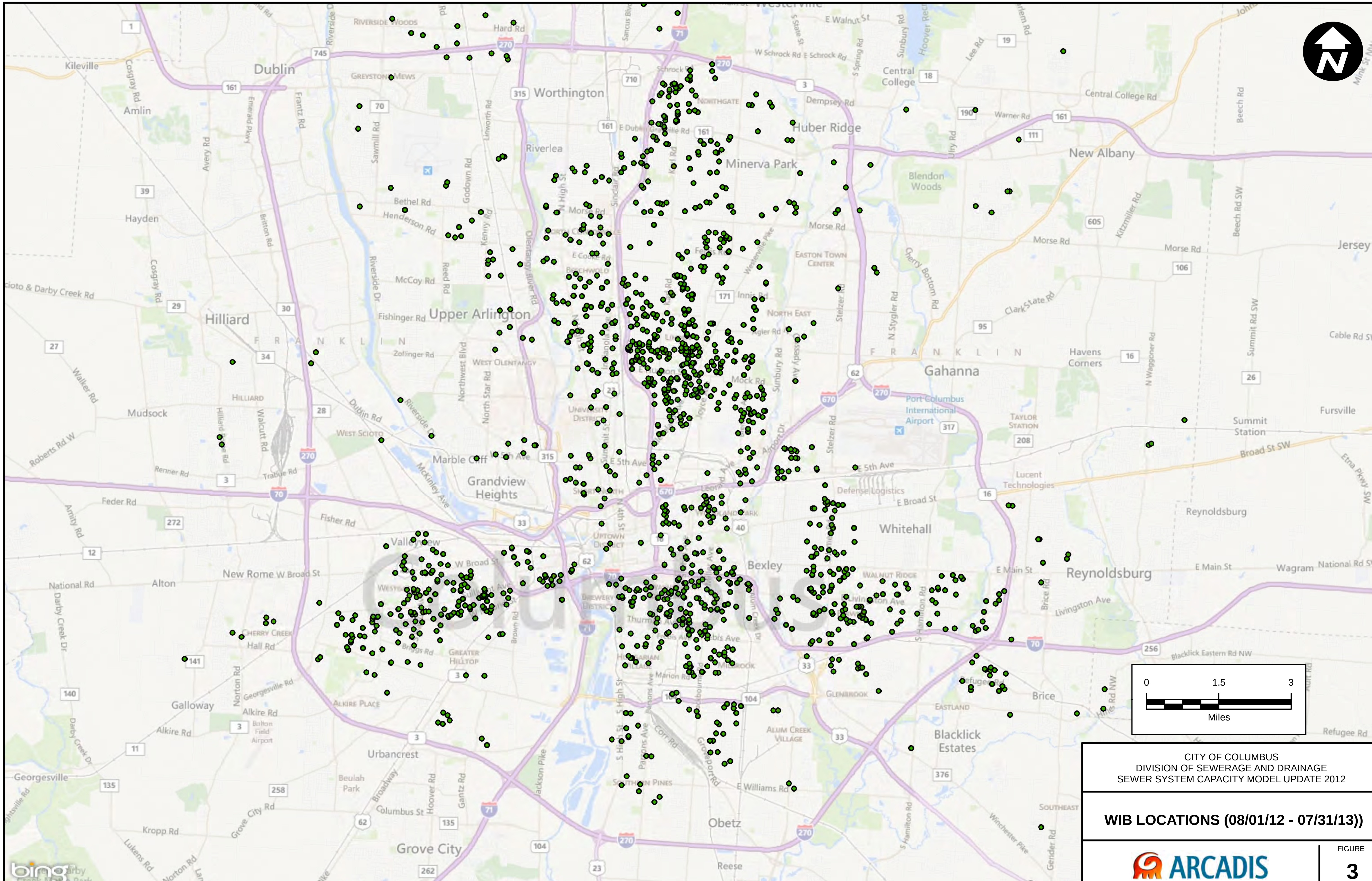


Figure 2 - City of Columbus Sanitary Sewer Overflows
Number of Events
500
450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
Annual Rainfall, inches
2009
2010
2011
2012
2013
Year
Wet events
Dry events
Annual Rainfall

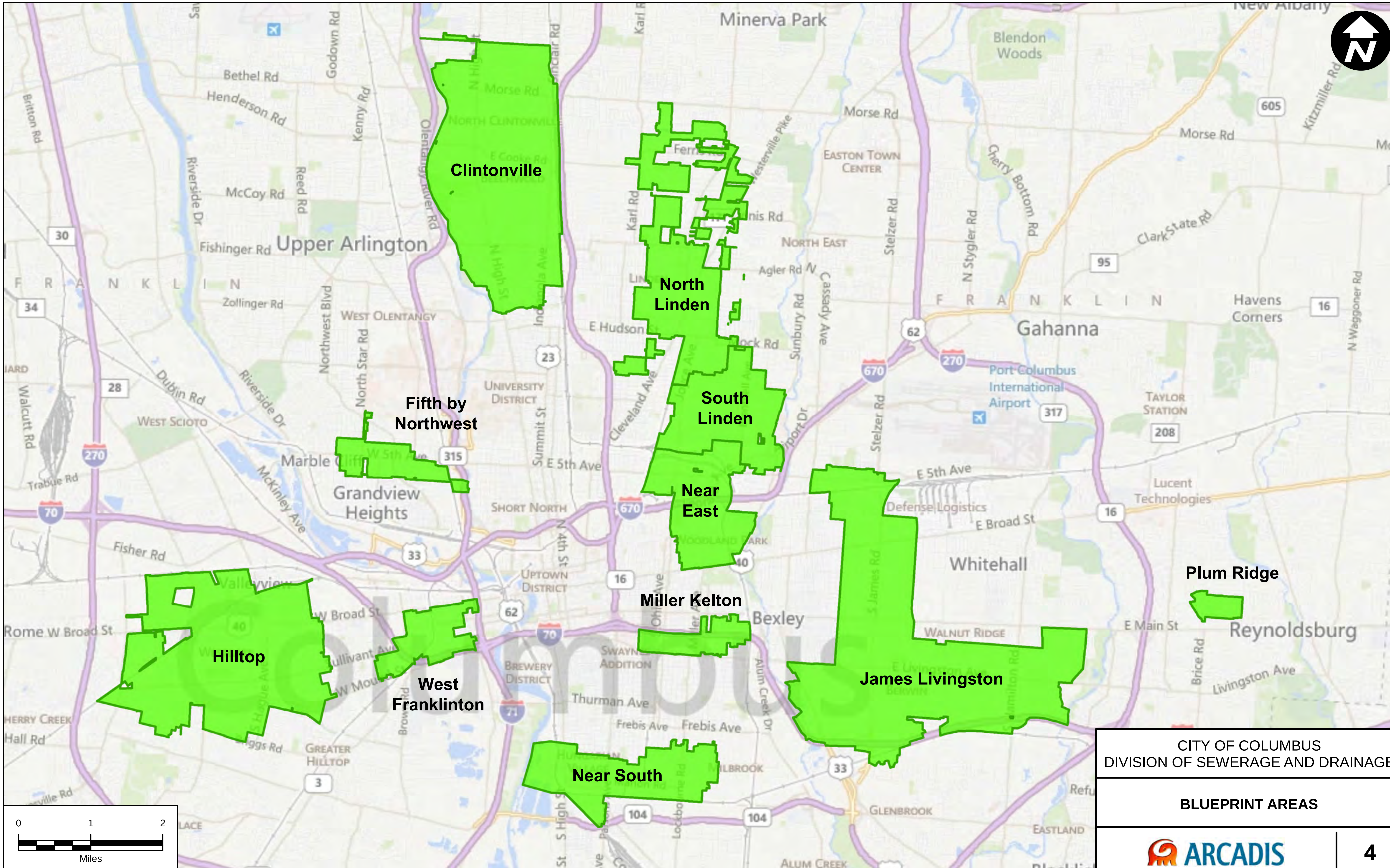



CITY OF COLUMBUS
DIVISION OF SEWERAGE AND DRAINAGE
SEWER SYSTEM CAPACITY MODEL UPDATE 2012

**WIB LOCATIONS (08/01/12 - 07/31/13))**

ARCADIS

FIGURE 3


Clintonville
North Linden
South Linden
Fifth by Northwest
Near East
Plum Ridge
Miller Kelton
Hilltop
West Franklinton
James Livingston
Near South
0 1 2
Miles
CITY OF COLUMBUS
DIVISION OF SEWERAGE AND DRAINAGE
BLUEPRINT AREAS
ARCADIS
4

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