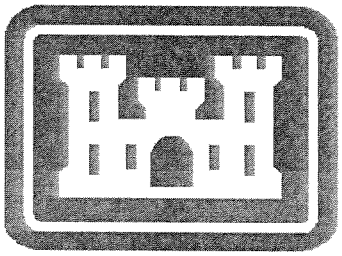

**US Army Corps of Engineers**
Philadelphia District

# Southeastern Pennsylvania Environmental Assistance Program

(Section 566 of Water Resources Development Act of 1996)

# Logan (Feltonville) Sinking Homes Study Philadelphia, PA

Prepared By

**U.S. ARMY CORPS OF ENGINEERS**
**PHILADELPHIA DISTRICT**

**JULY 2000**

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# EXECUTIVE SUMMARY

***Description/Background of Project:***

Although residents had previously complained of sinking homes in the Logan neighborhood, it wasn't until a gas explosion in February 1986 demolished one house and severely damaged two adjacent homes that attention was brought to the problem. Following that incident, a report by the City revealed that 957 homes were affected by the subsidence problem. Recently, residents in the adjacent Feltonville neighborhood also complained of severe settlement of their foundations. These homes were apparently built on loosely compacted, miscellaneous fill comprised of ash and cinders mixed with varying amounts of construction debris, such as wood and brick, and soil which was used to fill in the historic Wingohocking Creek bed. The subsidence problems which occurred can arise from a variety of factors – the type of fill used (in this case ash/cinder as opposed to soil), the amount of compaction performed during the installation, and subsequent exposure to water from utility leaks or other causes. The City of Philadelphia, through Senator Specter, Senator Santorum, and Representative Brady, has requested the assistance of the US Army Corps of Engineers to investigate the problem.

***Scope of the Engineering Study:***

The focus of the project was to gather and develop data to perform a preliminary analysis of the potential magnitude, extent, and scope of the problem and its possible causes. The study area lies in a portion of the Wingohocking basin, where various filled-in tributaries drained into the Wingohocking Creek. The United States Army Corps of Engineers (USACE) defined the horizontal and vertical extent of the original creek bed. A topographic change map has been prepared to show the distribution of fill by measuring topographical changes from a century ago. Limited geophysical investigations were performed in the basin to verify the location of the fill, characterize the soil conditions, and help ascertain the accuracy of the topographic change map. Also, a cursory building exterior assessment was performed to identify any structures that were in imminent danger of failure, settlement and its correlation to the depth of fill, or if any structures had signs of continuing rapid settlement/movement. Sewer line lateral inspections have been performed on ten homes. Laterals are the connections from the house to the City sewer system and are privately owned and maintained by the individual homeowners. Finally, drawings of water, gas, and sewer mains have been obtained from the City in various formats, including hard copy and georeferenced digital images. Digital images of sewer lines have been incorporated into Geographic Information Systems (GIS) applications to support future investigations of these lines and their correlation to subsidence problems. This study presents findings and provides recommendations for more comprehensive studies required to design remediation efforts.

***Funding:***

This is an environmental assistance project authorized by the Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the Water Resources Development Act

(WRDA) of 1996. Funding in the amount of $150,000 has been authorized to complete this initial engineering study.

This initial engineering study presents preliminary findings only and future reports, inspections, design, and/or construction under the Section 566 authority (Appendix F) would require a non-Federal Sponsor (City of Philadelphia, for example) who understands and is willing to participate in the cost sharing (75% Federal, 25% non-Federal) of such efforts. Future work to be accomplished under this authority would be limited to publicly owned facilities that would be in compliance with the implementation guidance established for Section 566 (water-related projects). Funding of studies and projects under Section 566 authority is presently a low budgetary priority.

***Findings:***

The topographic change map completed by the USACE provided surface elevation changes for the Wingohocking Creek in the Feltonville study area. The map assists in defining the depth and extent of the fill and assisted in focusing the areas of investigation for further subsurface and building assessment investigations.

The USACE map utilized detailed pre-development topography on which to base a higher resolution investigation of surface elevation changes to produce maps which show the possible or probable depth of fill. This was accomplished with the City of Philadelphia Streets Department maps which showed five-foot contour intervals dating back to the early twentieth century.

Based on the results of investigation conducted by the Philadelphia District, it has been determined that portions of the Feltonville section of Philadelphia are situated on the reclaimed valley of the former Wingohocking Creek that has been filled in with miscellaneous fill including ash and cinders. During the subsurface investigation, a layer of miscellaneous fill comprised mostly of ash and cinder mixed with varying amounts of building debris (decomposed brick, glass, and wood), coal, and soils (sand, silt, clay, and gravel) was encountered. In some locations, this layer exceeds depths of 40 feet.

Combined with the exterior structural investigation conducted, it appears that the majority of the settlement exhibited by the residences in the Feltonville section is due to the elastic (capable of being altered) settlement of the granular-like materials (ash and cinder) used to fill in the former valley of the Wingohocking Creek. The layer of miscellaneous fill is the major contributing factor to the settlement occurring in the area. The portions of the Feltonville section that are not filled are founded on the native material, either the highly decomposed rock or bedrock itself, and are not subjected to any significant settlement.

The fill material is loose and apparently was placed with little to no compactive effort. By today's standards of suitable foundation materials and compactive efforts, the ash and cinder fill would be considered unacceptable. Loosely compacted ash and cinder fill is a poor foundation material, and its unique physical properties make it susceptible to excessive settlement with changes in conditions. The most prevalent is the presence of water. The presence of water in the

loosely compacted fill material can lead to additional settlement beyond that which occurs immediately. The rising and lowering of the groundwater table, which can happen either naturally over time or by methods such as pumping (dewatering operations), has an effect on the amount of settlement that can occur. In addition, subsurface erosion due to the flow of the groundwater and/or the introduction of water/wastewater from house laterals or street sewers can contribute to the problem. Currently, there is no evidence indicating that the former creek is still flowing.

Broken and misaligned sewers and laterals, as found in the study area, contribute to subsurface erosion/differential settlement which has significant impacts on the structural integrity of a building. At several locations the settlement was severe enough to notice significant differences in the grade elevation of the curbs and pavement of the streets. This could be attributed to broken sewer laterals or the sanitary sewer lines themselves.

Many of the buildings in the Feltonville area that were assessed showed visual signs of distress caused by differential settlement. In general, the amount of distress coincided with the original location of the Wingohocking Creek and the fill depths that had been mapped. Some of the row homes experienced more distress than others even though the depths of fill may have been similar. From the exterior, it appears that some of the structures are experiencing significant stress and are progressively becoming more unstable with time. This would have to be determined by a complete structural inspection of the row homes on an individual basis. As a rule, the end units show more signs of distress than homes in between them.

***Recommendations:***

Based on the results of this study, the following recommendations are provided to further investigate and monitor/minimize the likelihood of a future subsidence problem:

- Utilizing Streets Department data, analyze and provide more detailed, localized depth of fill maps for the remainder of the former creek bed, downstream of the Feltonville study area, to include completion of data digitization for water, gas, and sewer lines. The cost estimate to complete this effort is approximately $30,000 total with an estimated six month time period.

- City of Philadelphia should ensure that foundation design criteria, for new structures built within the fill zones, requires that the buildings be founded on suitable ground and that detailed, Professional Engineer "certified" subsurface and foundation analysis be performed.

- During the replacement or repair of any utilities in the Feltonville neighborhood that may be founded on fill material, the City of Philadelphia should ensure that the utilities are set and backfilled with compacted structural fill.

- Perform an inventory of the structures that show signs of distress caused by settlement within the fill area. Establish a geographic information system (GIS) database which would be updated with inspection reports.

- Perform a semi-annual or annual inspection to update or supplement the inventory. Any structures showing signs of continuing or rapid change should be inspected more thoroughly, including interior foundation walls.

- Establish a standard procedure for which a detailed structural inventory would be performed and damage prevention measures would be instituted at locations where construction activities (i.e., deep excavations, dewatering, pile driving, fill compaction etc.) are undertaken that might disturb the fill or could impact structural integrity of homes. This would include proper design of construction methods, certified by a registered professional engineer, which are to be utilized in the areas of fill. Damage prevention measures should include additional real time monitoring during such activities.

- Ensure proper design of future construction methods/work which could impact structural integrity of homes built on fill.

- Establish survey reference points on the structures that have shown the most signs of settlement, particular the structures at the ends of rows, and monitor the movement annually by field survey.

- Perform a detailed structural inspection of the homes at the following locations:

  Luray Street, between 6th Street and 7th Street,
  Courtland Street, north side between 6th and 7th Street,
  Courtland Street between 7th Street and 8th Street,
  Reese Street, between Wingohocking Street and Annsbury Street,
  Raymond Street, between 3rd Street and 5th Street, and
  Annsbury Street, between 4th Street and 5th Street.

- Develop a design, certified by a registered professional engineer, for providing structural support to row homes where a gap is created by removal of an abandoned home.

- Provide structural support, designed by a registered professional engineer, for any new end unit created by the removal of an abandoned end unit that has been demolished and removed.

- Establish a telephone number or mailing address for residents to call or write if they notice changes in their particular structures.

- Establish a hotline for residents of the area so that priority can be given to shutting off open fire hydrants.

- Philadelphia Water Department should begin immediate inspection of sewer and water infrastructure in areas of fill to verify integrity; repair if necessary. The cost estimate to complete the inspection of the infrastructure is approximately $150,000 total with an estimated six month or more time period, depending on the level of effort. Design and construction costs would later be based on the results of the inspection.

- Inspect homeowner laterals in areas of fill to ensure integrity/proper drainage utilizing video and dye test techniques; repair and replace as necessary with PVC or other piping less susceptible to deflection.

- Inspect homeowner rainwater conductors to ensure integrity/proper drainage; repair and replace as necessary. Address the issue of large trees clogging rain conductors.

- Investigate impact of large trees along the sidewalks which could be damaging sewer/lateral integrity; replace with a variety less conducive of damage.

- The unique phenomenon of sinking homes, resulting from decades of inconspicuous subsidence, poses a dilemma for effective government intervention. Smaller governments have difficulty bearing the burden of the corresponding monetary responsibilities required to address such disasters which, in this instance, involved the condemnation of homes and relocation of residents. Most homeowners' insurance policies do not cover subsidence-related problems. A more prudent approach by government would be to utilize investigative/preventative measures to minimize or eliminate such occurrences. The fact that this particular problem is rooted to historic, diverted creeks and streams, however, tends to associate the issue to a water-related infrastructure project eligible for assistance under Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the WRDA.

# SECTION 2.0
# DESCRIPTION/BACKGROUND OF PROJECT

## 2.1 Study Area

The Feltonville neighborhood is a small community located in the North section of Philadelphia. It is an area of approximately one square mile, bounded by the area between Roosevelt Boulevard to Hunting Park Avenue, 8th Street to "H" Street. Feltonville, southeast of 5th Street and Roosevelt Boulevard, is one of the old towns of Philadelphia, named after an early settler.

Feltonville was built in the early 1900's as Philadelphians migrated north, following the Reading Railroad and the Broad Street Subway, whose northern stretch opened in 1928. The area lies within the Wingohocking basin, an approximately seven-square-mile region where various tributaries drained into the Wingohocking Creek. At the turn of the century, however, plans were drawn to reroute the creek through brick and mortar encased sewers. The stream valley was then filled with varying natural/artificial materials. This included either soil which was moved from higher ground or, coal ash/cinder which was an abundant byproduct of homes and industry during the period. This practice became common throughout the region and continued long after the Civil War, as Philadelphia's labyrinth of stream and creek valleys hampered development and progress.

Feltonville became one of the city's first "suburbs." The oldest section of the neighborhood, perhaps, lies from 5th Street to "B" Street, Courtland to Roosevelt Boulevard. This area contains a mix of housing types with two-story frame and brick singles, two-story brick twins and two-story brick rows, and some commercial buildings. There is a newer section from Whitaker Avenue to "H" Street, Wyoming Avenue to Annsbury Street, which has cinder block, brick-faced homes. Most other homes in Feltonville are two-story brick row homes. In the southern section, west of Juniata, there are industrial properties. The area from Hunting Park Avenue to Wingohocking Street, east of 2nd Street, is almost entirely industrial, except for the large Greenmount Cemetery.

Modern expansion, however, was not without its problems. Some homes which were built on the filled-in Wingohocking Creek bed began to exhibit settlement cracks. Several incidences in Philadelphia throughout the last century have occurred in which a street or home have sunk into a collapsed sewer which had been undermined by water or adverse loads imposed by increasing traffic and development. On other occasions, homes began to settle into the unstable/uncompacted fill on which the homes were built.

Since 1986, more than 900 homes have been demolished in the adjacent Logan neighborhood because of severe settlement of their foundations. These homes were apparently built on the coal ash and/or cinder fill which was used to fill in the Wingohocking creek bed. Although residents had previously complained of sinking homes, it wasn't until a gas explosion in February 1986 demolished one house and severely damaged two adjacent homes that attention was brought to the problem. Following that incident, a report by the City revealed that 957 homes were affected

by the subsidence problem. As of this report, approximately 40 homes in the area are still occupied.

Recently, residents in the Feltonville neighborhood also complained of severe settlement of their foundations. Congressman Brady's office requested that the US Army Corps of Engineers investigate the following areas in Feltonville:

700 Raymond Street
600 and 700 Courtland Street
600 Luray Street
600 and 700 Annsbury Street
4400 and 4500 Reese Street
4400 North 7th Street
4400 and 4500 North 5th Streets.

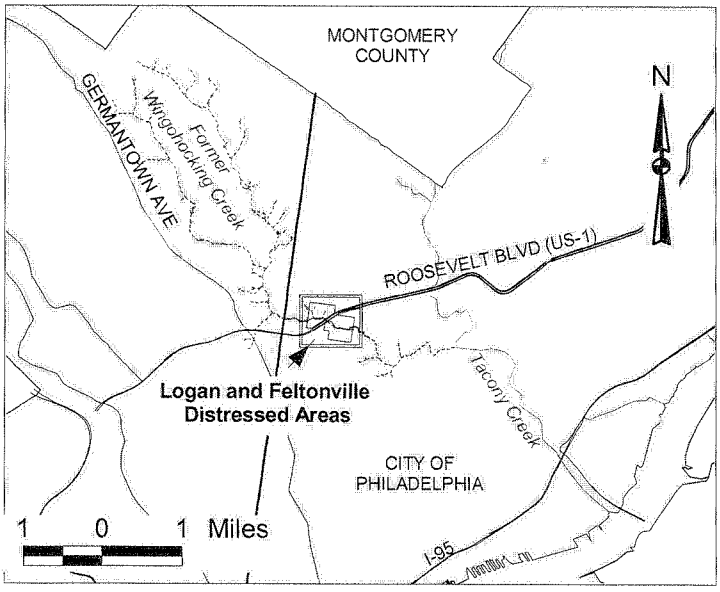
## 2.2 Scope of Study/Investigation

The City of Philadelphia, through Senators Specter and Santorum, and Representative Brady have requested the assistance of the US Army Corps of Engineers to gather and develop data as well as perform a preliminary analysis of the potential magnitude, extent, and scope of the problem and its possible causes. This investigation began by defining the horizontal and vertical extent of the original creek bed. Next, a topographic change map was prepared to show the distribution of fill by measuring topographical changes from a century ago. Limited geotechnical investigations were performed in the basin to verify the location of the fill, characterize the soil conditions, and help ascertain the accuracy of the topographic change map. Also, a cursory building exterior assessment was performed to identify any structures that were in imminent danger of failure, settlement and its correlation to the depth of fill, or if any structures had signs of continuing rapid settlement/movement. Sewer line lateral inspections have been performed on ten homes. Finally, drawings of water, gas, and sewer mains have been obtained from the City in various formats including hard copy and georeferenced digital images. Digital images of sewer lines have been incorporated into Geographic Information Systems (GIS) applications to support future investigations of these lines and their correlation to subsidence problems. This study presents findings and provides recommendations for more comprehensive studies required to design a remediation effort.

Senator Specter, in a letter dated November 23, 1999, requested that the Corps of Engineers investigate the sewer system infrastructure in the Logan Area (a.k.a. "Logan Triangle") of Philadelphia since it could be a contributing factor to the ground instability and, thus, the "sinking" home problem. In the seventeen-block area of the Logan Section, both the Philadelphia Water Department (PWD) and Lippincott Engineering Associates (LEA) have performed an investigation on the sewer infrastructure.

The USACE study was conducted in a portion of the Feltonville section of Philadelphia bounded by 4th Street on the east; Wyoming Street on the north; 8th Street and Roosevelt Boulevard on the west; and Cayuga Street on the south.

This is an environmental assistance project authorized by the Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the Water Resources Development Act of 1996. Funding in the amount of $150,000 has been authorized to complete this initial engineering study in an effort to augment the on-going work of the City of Philadelphia and its private engineering/consulting firms.


VICINITY MAP

Feltonville Area of Investigation

"Logan Triangle"

Approximate Location of Channel of Former Wingohocking Creek

**FIGURE**
**STUDY AREA**


**FIGURE 2-2**
**FELTONVILLE AND VICINITY**

# SECTION 3.0
# TOPOGRAPHICAL CHANGE MAP

## 3.1 US Army Corps of Engineers, Philadelphia District Map

### 3.1.1 Description of Work

For the Feltonville area of immediate concern, the US Army Corps of Engineers, Philadelphia District was able to obtain detailed pre-development topography on which to base a higher resolution investigation of surface elevation changes.

The City of Philadelphia Streets Department provided maps showing five-foot contour intervals dating back to the early twentieth century. The Corps scanned these maps and, using Arcview software, registered the resultant images to the City street grid. The contour lines were then digitized and appropriate elevation values assigned.

The five-foot contour lines were then overlaid on the City's current digital two-foot contour interval lines and a file created for all intersecting points of the two data sets. The original elevation was compared to the current elevation at each point, thus indicating the net changes in ground elevations. The Arcview extension Image Analyst was then used to create a grid and a set of contours indicating the changes in elevations.

It is assumed that areas with a net increase in ground elevation have been filled sometime during the last century. As expected, areas showing the greatest increase in elevation - or depth of fill - are closest to the original course of Wingohocking Creek.

# SECTION 4.0
# EXISTING SUBSURFACE SOIL CONDITIONS

## 4.1 Geologic Setting

The Feltonville area of Philadelphia, Pennsylvania lies along the edge of the Atlantic coastal plain geologic province. The coastal sediments in this area are diverse and related directly to fluvial systems draining to the sea. The Pennsauken and Cape May formations were deposited in the Feltonville area and subsequently eroded by local streams. Today, these sediments can be found at higher elevations between the former Wingohocking and Tacony Creeks. They consist of poorly sorted sand and gravels. The erosive action of the former streams caused the early Paleozoic Wissahickon Formation to be exposed in the creek valleys. The Wissahickon Formation is widespread in Philadelphia and is the metamorphic by-product of originally interlayered sedimentary shales and sandstones. These sedimentary rocks were changed to schists and quartzites through intense temperatures and pressures. Marked cleavage, fissility, and coarsely chrystalline texture are characteristic of the Wissahickon Formation. Locally, the Wissahickon schist is interlayered with quartzite and contains coarsely crystalline pegmatitic intrusions. The Wissahickon Formations slopes generally toward the southwest except where local erosion by streams has created valleys. The engineering characteristics of the formation include abundant, well-developed platy cleavage and open steeply dipping irregular joints that are widely spaced. The schist is often highly weathered to a moderate depth.

## 4.2 Previous Geotechnical Investigations

### 4.2.1 Lippincott Engineering Associates, Inc. Study of Soil Conditions

Lippincott Engineering Associates, Inc. (Lippincott) was retained by the City of Philadelphia Department of Licenses and Inspections in April 1986 to perform an in-depth geotechnical evaluation of the Logan Section of Philadelphia. The Logan Section is located directly across from the Feltonville Section, separated by U.S. Route 1 (Roosevelt Boulevard), and both are situated in the reclaimed valley of the old Wingohocking Creek. The purpose of the Lippincott investigation was to characterize the subsurface soil conditions and determine the cause of the settlement and distress in the area. Lippincott submitted the results of their findings in their report "Geotechnical Investigation, Study of Soil Conditions, Logan Area, Philadelphia, Pennsylvania," dated August 1986, a synopsis of which follows.

The study was conducted in a portion of the Logan Section of Philadelphia that encompassed 17 city blocks and a total of 957 residential properties. The scope of work for the subsurface investigation included surveying, drilling a total of 38 test borings and installing five (5) groundwater observation wells, conducting a literature review, performing a field reconnaissance, managing a field exploration program, field and laboratory testing, and developing recommendations for the proposed remedial actions.

The results of the investigation indicated that the Logan Section is a reclaimed valley of the old Wingohocking Creek. Records show that the creek ran through a valley that was approximately 40 feet deeper than the surrounding ground and was completely backfilled by 1913. Through a comparison between the original ground elevations and the as-built contour maps, it was determined that the area received ash and cinder fill, ranging in thickness from zero near Loudon and 11$^{th}$ Streets, upwards to forty (40) feet near portions of Roosevelt Boulevard.

A comprehensive laboratory testing program was developed by Lippincott to identify the index, mechanical and chemical properties, and characteristics of the ash and cinder fill. The program included typical geotechnical testing parameters such as grain-size distribution, Atterberg Limits and water content, moisture/density relations, shear strength, consolidation behavior, and permeability. Specially designed tests included the determination of the susceptibility of the material to piping and its dispersive characteristics, chemical composition, and its reactions (such as solubility) to water and acids. All soil and fill samples were identified through a combination of visual classification and laboratory testing. Based on the results of the borings, test pits, and laboratory testing techniques, it was Lippincott's opinion that five different strata exist at the site.

Because the Feltonville Section is also located in the reclaimed valley of the Wingohocking Creek and essentially developed at the same time as the Logan Section, it was assumed that the same stratums would be encountered during the District's investigation. Descriptions of these stratums are provided in Section 4.3, "Subsurface Conditions."

### 4.2.2 Lippincott Supplemental Study of Soil Conditions

In accordance with a meeting held in January 1987, Lippincott conducted a supplemental geotechnical investigation within and outside the target study areas to delineate the boundaries of the areas with five (5) feet of fill or more within the immediate vicinity of the target areas. The subsurface investigation included advancing 81 test borings to depths ranging from six (6) to eight (8) feet, or to a shallower depth if natural soil was encountered. The findings of this investigation can be found in the Lippincott report "Supplemental Geotechnical Investigation, Study of Soil Conditions, Logan Area, Philadelphia, Pennsylvania," dated April 1987.

## 4.3 US Army Corps of Engineers, Philadelphia District's Geotechnical Investigation

The Philadelphia District's geotechnical investigation is comprised of a total of thirteen (13) test borings in the Feltonville study area to determine the type, nature and state of the subsurface conditions. The study area is bordered by Roosevelt Boulevard and Wyoming Avenue to the north; 8$^{th}$ Street to the west; 4$^{th}$ Street to the east; and Wingohocking Street to the south. To the best of the District's knowledge, other than the Lippincott investigations conducted in the neighboring Logan Section, there have been no subsurface explorations in the Feltonville Section. The locations of the test borings are shown in Appendix B-1, "Boring Location and Cross Sectional Plans" and outlined in Appendix B-2, "Schedule of Drilling and Sampling." Contour maps that estimated fill thickness based on the former valley contours and the as-built street elevations were used for the selection of the boring locations.

The drilling contract was executed by Chesapeake Geosystems, Inc. of Baltimore, MD, under the full-time direction and supervision of the District's field representatives. Fieldwork commenced on 7 June 2000 and was completed on 14 June 2000. The borings were advanced with the use of hollow stem augers and soil samples were taken continuously with a 2-inch outer diameter split spoon sampler using the Standard Penetration Test. Blow counts for the borings were recorded in six-inch increments and represent the energy imparted upon the soil by a 140 pound hammer free-falling 30 inches. All disturbed split-spoon sampling was conducted in accordance with ASTM D 1586, "Penetration Test and Split-Barrel Sampling for Soils." No undisturbed samples or rock cores were taken during this particular investigation. Also, no chemical sampling or testing was conducted. The test borings extended to total depths ranging from 7 to 50 feet below the existing ground surface, at which point all but one boring had been advanced into native soil. In many cases the borings were terminated due to auger or split spoon refusal. The boring logs are presented in Appendix B.

### 4.3.1 Subsurface Conditions

During the subsurface investigation, all soil and fill samples were identified in the field by representatives from the District's Geotechnical Section in accordance with ASTM D2488, "Description and Identification of Soils (Visual-Manual Procedure)." Samples from each split spoon were collected and placed in jars and are presently kept in storage at the District's Soil Laboratory, Fort Mifflin Project Office. All field logs are retained on file in the District Office.

In the Lippincott report, "Geotechnical Investigation, Study of Soil Conditions, Logan Area, Philadelphia, Pennsylvania", dated August 1986, the material encountered was characterized into five different strata. During the District's investigation of the Feltonville Section, those same five strata were encountered. In order to be consistent, the designations used by Lippincott for the soil and fill in Logan are used by the Corps for the soil and fill in Feltonville. In order of increasing depth, the Feltonville strata are described as follows:

Stratum F – Loose-to-Medium Compact Grey-Black Miscellaneous Fill

This layer was encountered in most of the borings extending from the ground surface to depths as great as 41 feet. This stratum consists of ash and cinder mixed with varying amounts of building debris (decomposed brick, glass, and wood), coal, and soils (sand, silt, clay, and gravel). The fill material is generally characterized by low standard penetration resistance and the absence of a natural soil structure in the recovered samples. However, due to factors such as amount of soil and building debris content, and presence of groundwater, standard penetration resistance varied across the study area.

The fill thickness was found to range from 41 feet near the 600 block of Roosevelt Boulevard to zero along portions of 8$^{th}$ Street, Annsbury Street between 7$^{th}$ and 8$^{th}$ Streets, and Blavis Street. From information collected in previous investigations, this fill was placed in the valley during the early 1900's after the Wingohocking Creek was contained within a large diameter brick sewer. The fill material is loose and apparently was placed with little to no compaction. Based on the nature of the fill, it appears that the filling operation was uncontrolled and that the characteristics of the fill vary tremendously across the study area.

Stratum RS – Residual Soils

Directly beneath the fill in most of the borings, a residual soil layer was encountered. The residual soil was formed by the complete weathering of the decomposed mica schist bedrock that underlies the site. Generally, the stratum was found to be in a soft-to-medium state of consistency or a medium-to-compact state of density. The residual soils generally consist of a silty clay deposit or silty sand with variable amounts of gravel. This stratum, where present, was found to range in thickness from 2 to 12 feet over the study area.

Stratum S – Stream Deposit (Recent Alluvial)

This stratum was observed in only borings FBH-5, FBH-10, and FBH-14 that were located where low former ground surface elevations existed along the old stream alignment. This material consists of a mixture of soft silt, clay and organic material, encountered at an elevation of 58 to 60 feet (City of Philadelphia datum), overlying a deposit of rounded gravelly fine to coarse sand. The gravelly fine to coarse sand was not encountered at FBH-14. The thickness of this unit ranged from 1 foot (FBH-14) to 10 feet (FBH-5).

Stratum D – Decomposed Mica Schist

A decomposed rock layer was encountered across the entire study area directly beneath the miscellaneous fill or the residual soils in most of the borings, and under the stream deposit in FBH-5 and FBH-10. The deposit consists predominantly of hard yellow, white or grey micaceous clayey silt with varying amounts of sand. The materials exhibited the visual appearance of weathered rock, although they are essentially soil. The stratum was encountered at depths ranging from zero to forty-three (43) feet below the existing ground surface. Most of the borings were terminated within this stratum at practical refusal to advancement of the hollow stem augers or the split spoon sampler.

Stratum R – Bedrock

Based on drill rig observations and Standard Penetration Test blow counts, it appears that weathered bedrock was encountered at three locations – FBH-9 (near the intersection of Fairhill and Courtland Streets), FBH-10 (on Fairhill Street between Annsbury and Wingohocking Streets), and FBH-12 (on Courtland Street between 4$^{th}$ and 5$^{th}$ Streets). The depths at which weathered bedrock was encountered were 33, 38, and 20 feet below ground surface, respectively. No rock cores were taken during this investigation. However, Lippincott reported that the rock encountered in the Logan Section consists of partially weathered and moderately fractured mica schist with a Rock Quality Designation (RQD) ranging from 7 to 30 percent, which is indicative of a moderately hard rock.

Groundwater

Groundwater was encountered in only a few of the borings during the drilling operation. The depths to the groundwater table vary from 21 to 42 feet below the existing ground surface. No

monitoring wells were installed during the District's investigation. The location of the groundwater table was approximated by the change in moisture content of the soil samples collected. Ground water levels are expected to fluctuate with daily and seasonal climatic changes. Based on the limited amount of groundwater information available, it is impossible to discern whether or not the former creek is still flowing.

### 4.3.2 Geologic Cross Sections

Five (5) cross sections were developed by comparing the existing drawings that depict the contours of the former valley of the Wingohocking Creek with the as-built street elevations and correlating them with the boring logs obtained from the drilling program. The following cross sections, presented in Appendix B, were developed:

| | |
|---|---|
| Section A-A' | 7th Street (from Wingohocking Street to Roosevelt Boulevard) |
| Section B-B' | 6th Street (from Wingohocking Street to Roosevelt Boulevard) |
| Section C-C' | Fairhill Street (from Wingohocking Street to Wyoming Avenue) |
| Section D-D' | Courtland Street (from Roosevelt Boulevard to 4th Street) |
| Section E-E' | Annsbury Street (from 8th Street to 4th Street) |

The locations of the former ground surface indicated on the drawings were obtained from the as-built drawings of the streets which also depicted the original contours of the former Wingohocking Creek.

# SECTION 5.0
# BUILDING EXTERIOR ASSESSMENTS

## 5.1 General

A visual assessment of the exterior of the structures in the Feltonville area was conducted to determine the overall realm of the settlement problem, the seriousness of the problem, the potential for future catastrophic structural failure, and recommendations for future action. A visual exterior assessment provided valuable information on the extent of settlement and the condition of structures throughout the area. Only limited conclusions, however, could be drawn without interior inspections of the foundation walls of individual structures, sewer laterals, and main sewer lines in streets. The age of the structures, which also reflected the type of design of the row homes commonly used in the area at that time, influenced the amount of information that could be gleaned from a visual inspection. Many of the row homes, which are the predominant structures in the area, have frame porches that have been enclosed over the years and used as living areas. The homes have cantilevered frame dormers on the front and back face of the structures on the first and second floors. The frame portion of the structures has obscured many of the cracks in the masonry and other signs of settlement. In addition, as structures aged, owners used new, less expensive materials, such as various types of siding to cover up deteriorated or cracked masonry. Cracks in masonry are not necessarily caused by settlement, but they can also be attributed to the aging process itself, a poorly designed mortar mix, or inferior brick, stone or concrete units. Porches or sidewalks may also be affected by local settlement, and masonry or concrete steps may pull away from structures. This could occur even if the main structure does not have a settlement problem.

## 5.2 Limits of Assessment

The area included in the assessment extends between the Roosevelt Boulevard on the north to Cayuga Street on the south and from 8$^{th}$ St. on the west to 4$^{th}$ St. on the east. An additional area bounded by Courtland Street, Raymond Street and Annsbury Street between 4$^{th}$ Street and 3$^{rd}$ Street was also included in the assessment. The boundaries of the area were generally determined using City of Philadelphia topographic mapping that showed the original location of the Wingohocking Creek. Then, five-foot elevation contours, as shown on the City Plans dated back to the early twentieth century, were compared to recent two-foot elevation contours obtained from the City of Philadelphia Streets Department. The difference in the elevation of the contour lines showed the location of varying depths of fill along the creek. The depths of fill were plotted on a City of Philadelphia street map and the assessment proceeded from the areas of deeper fill to the areas of lesser fill. The location of the buildings that showed evidence of distress corresponded closely with the limits of the fill that were developed from the topographic change maps.

## 5.3 Description of the Structures

The majority of the structures in the area are two-story masonry row homes with flat built-up roofs and basements. The first and second stories are brick with the rubble masonry foundation walls that are constructed of native mica schist stone. It was noted during the assessment that the foundation walls, with few exceptions, have only a weak lime-sand mix between the stones with cement mortar pointing on the exterior of the wall. An end unit of row homes at 636 Roosevelt Boulevard collapsed recently due to water saturating the rear wall and foundation wall. An abandoned end unit of row homes at 630 Luray Street has a partially collapsed basement wall that may be attributed to continually flowing water from a broken service line that was never shut off.

Most of the homes have frame porches and cantilever frame dormers on the second and/or first floors. There are some twin homes located on the south side of Roosevelt Boulevard between Courtland Street and 8th Street. The rear of the homes have yards that face back to back to other row homes with a pedestrian walkway that provides access. The homes on the west side of Reese Street, between Annsbury Street and Wingohocking Street have an alley for vehicle access. Likewise, the homes on the south side of Raymond Street between 4th Street and 5th Street have a common alley with the homes on Annsbury Street.

Along 6th Street, on the east side, there are one story masonry industrial and commercial buildings with open area behind them used as a junk yard or equipment storage yard. None of these buildings showed any signs of distress. In an interview with one of the owners (Filograna Auto Body Shop), he stated that the footings of his structure were constructed on piles about 30 years ago. On the east side of Fairhill Street, there are one-story dilapidated masonry and frame garages used for auto repair. At the corner of Annsbury Street and 5th Street, there is an abandoned four-story masonry factory building that has no signs of any distress caused by settlement.

On 5th Street, between Courtland Street and Cayuga Street, there are row homes used as residences and commercial businesses. Some of the row homes have been replaced with single story masonry or frame buildings.

## 5.4 Assessment Criteria

Assessment of the building exteriors required walking along each street to observe the structures for signs of distress that would indicate previous or continuing settlement problems. The amount of settlement is influenced by the depth of fill, the components of the fill, the presence and movement of water, and the amount (or lack of) compaction when the material was placed. One of the major indicators of settlement is cracks that appear in masonry caused by differential settlement of a structure. Distress in masonry caused by settlement is characterized by cracking that occurs along a line that is, generally, about 45 degrees to the vertical on a concrete face or stepped along joints of masonry units at about 45 degrees. This is related to the shear strength characteristics of mortar and concrete. The settlement cracks in masonry can occur anywhere,

but usually originate from points of high stress concentration such as building corners or openings for windows and doors. Cracks that have been repaired and which continue to reopen are a good indicator that settlement is still occurring. Likewise, cracks that have been repaired in the past and now show signs of aging would indicate that settlement is not currently occurring. New crack repairs may also indicate settlement, but can also indicate replacement of old, weathered material.

Another major indicator of settlement is any part of a structure (i.e., doorframe, door lintel, or windowsill) that is visually out of plumb or level. Consequently, in many cases the exterior doors or storm windows are cracked or tilted and will not close. Many times property owners cut doors to make them fit, which is apparent when looking at a structure. Exterior masonry chimneys that are out of plumb or separated from the main structure can also indicate settlement of a structure. Likewise, walls that are bulging or out of plumb are indicators that settlement is also occurring. Corners of buildings may be out of plumb due to settlement or just poor construction. In the Feltonville area, many of the structures have windows and doors which are out of level or plumb from obvious settlement, but the masonry does not show the typical signs of cracking. For some reason that lacks a clear technical explanation, the masonry did not have any visible cracks or signs of stress caused by the differential settlement. The assessment was made more difficult because frame dormers, siding, or enclosed front porches covered much of the masonry. The number of abandoned homes made assessment more difficult, because it was hard to determine if settlement or a lack of maintenance or a combination of both reasons were the cause of structural distress. In any type of assessment, experience and engineering judgment have to be used carefully to evaluate the visual clues in determining if settlement is occurring and causing distress of a structure.

Other indicators of settlement include low spots in streets that hold storm water and curbs that are the same height of the pavement in localized areas. In areas of severe settlement, the difference in elevation between the edge of pavement and the centerline may be much greater than is normally acceptable.

## 5.5 Assessment Results

The assessment commenced from the area of the deepest fill (40 to 48 feet) and expanded to the perimeter of the study area where the fill ranged from 10 to 20 feet. Roosevelt Boulevard, 7$^{th}$ Street, Luray Street, and 6$^{th}$ Street bound the area of deepest fill. On Luray Street, between 6$^{th}$ Street and 7$^{th}$ Street, row homes are located on each side of the street. The end units on this street (601, 629 (Photo No. 1), and 630 Luray Street) show the most signs of distress, such as step cracks and bulging walls. This is a typical condition for row homes subject to settlement, because the end units buttress the remaining homes in the row. Differential settlement can occur more readily on three sides of the end unit. Also, there are numerous abandoned homes in the area with some located on each street. Abandoned structures always continue to deteriorate and can become so weak that they provide no support for the adjacent homes in the row. These structures become end units in themselves. An abandoned structure at 626 to 628 Luray St., which is an end unit, has a settled porch foundation wall on the front and step cracks on the rear

wall. The frame porch is rotting away and may collapse in the near future. Another end unit, 600 Roosevelt Boulevard, at the corner of 6th Street has a tilted back wall.

Along Courtland Street, between 6th and 8th Street, the homes are constructed on fill that ranges from 30 feet to 48 feet deep. Many of the homes show the typical symptoms of distress caused by settlement, such as walls out of plumb, windowsills not level, and step cracks extending from window openings (Photo No. 2). From 704 to 712 Courtland Street, the south edge of the street has settled two to three feet lower than the centerline of street. On Roosevelt Boulevard, between 7th Street and Courtland Street, the end units of the row homes (710 (Photo No. 3) and 734 Roosevelt Boulevard) have step cracks and windowsills that are not level. Likewise, at 4543 to 4545 7th Street (near Courtland Street), the windowsills and lintels are not level and the foundation walls for the porch columns are not plumb. The fill in this area ranges from 40 to 48 feet deep.

A large portion of the area, bounded by Fairhill Street and 6th Street from Roosevelt Boulevard and Blavis Street is open space, which is used as an automobile junkyard and storage area for construction equipment. Part of this area contains a former right-of-way for rail lines that have been abandoned. On the east side of Fairhill Street, between Annsbury Street and Wingohocking Street, there is a continuous one-story masonry building that has repaired step cracks on the front face, step cracks on the rear face, and a large open step crack on the rear face (at approximately the middle of the block).

The next area that was assessed was along Reese Street. None of the homes on Reese Street, between Blavis Street and Wingohocking Street, showed signs of distress from settlement, except for 4458 Reese Street. This structure is an end unit row home located on the west side of the street at the intersection with Wingohocking Street. The end wall has a repaired step crack from the first floor window to the ground floor entrance.

Many of the row homes on both sides of Reese Street, from Wingohocking Street to Annsbury Street, showed numerous signs of significant differential settlement. This included step cracks in the masonry, lintels and windowsills out of level, and settlement of the curbs and pavement of the street in front of 4506 (Photo No. 5) and 4507 Reese Street. In this area, the fill ranged from 30 feet to 40 feet deep. The distress was evident in both the front and rear of the homes. The homes showing the most significant settlement are located at 4500, 4506, 4508, 4510, 4514, 4516, 4518, 4520, and 4524 (end unit on the west side of Reese Street at Annsbury Street), 4501, 4503, 4505, 4507, 4509, 4519, and 4523 Reese Street. The home at 4523 Reese Street has severe settlement and may be structurally unsound. This home is currently the end unit, with the former adjoining end unit having been torn down a number of years ago (Photo No. 7).

An abandoned end unit row home (4500 Reese Street), which is also on the east side of Reese Street at Wingohocking Street, had step cracks from the second floor windows to the first floor windows. This structure appeared to be settling down toward Wingohocking Street. At the time of the visual assessment, this structure was in the process of being demolished and the adjoining home would now become the new end unit.

The homeowner at 4510 Reese Street granted access to the interior of the home to observe the settlement that has occurred. From the interior, the top of the front door lintel had settled down to the right toward Annsbury Street (Photo No. 5). The living room floor sloped down towards the front of the structure and the dining room floor sloped down toward Annsbury Street. In the basement, the floor joists (aligned parallel to Reese Street) also sloped down to the left toward Annsbury Street. Other property owners at 4505, 4506, 4507 and 4523 Reese Street requested that USACE make at least a cursory assessment of the interior of their homes. All of the homes showed similar signs of distress due to settlement. The homes had sloping floors and, in some of them, the floors had been leveled through the addition of "sister" joists to support the floors. Additional support for the floor joists had been provided using steel wide flange beams and circular steel columns. In many of the rooms, the doorframes were not level and the homeowners had difficulty closing doors and windows. Cracks in the walls continued to open after repairs had been made, and gaps continued to reappear between the staircases and walls. A large concern to residents located near the low point in Reese Street was the damage caused by water coming through the basement walls and floor slab. In all cases, this was attributed to ground water flowing in when the fire hydrant at Reese Street and Wingohocking Street remained open for extensive periods of time. In addition, residents had knowledge of broken and replaced sewer laterals.

Along 5th Street, between Annsbury Street and Wingohocking Street, there are some structures that had distress from settlement but there was no distress from Wingohocking Street to Blavis Street. The distress included repaired step cracks from second floor windows to first floor windows, cracks in chimneys, lintels out of level, and pavement settled on Wingohocking Street at 5th Street. At the northeast corner of 5th Street and Raymond Street, the end unit had a repaired step crack from a second floor window to a large plate glass store window on the first floor. In most cases, the end units that are located in areas that experience settlement show the most signs of distress.

On Annsbury Street, between 4th Street and 5th Street, many of the homes had signs of settlement including windowsills and lintels that were not level, but the steps cracks were minimal. The end unit at 400 Annsbury Street had a repaired step crack from the second floor window to the first floor window. On this block of Annsbury Street, the original alignment of the Wingohocking Creek was located along the street and the fill ranged from 30 to 40 feet deep.

The assessment continued on Raymond Street, from 5th Street to 3rd Street. From 5th Street to 4th Street, there were some window sills and lintels that were not level, but no noticeable cracks except for a step crack from the second floor window to the party wall at 413 Raymond Street. One property owner reported that a sinkhole in the street had been repaired within the last several years and water had run underground along the street from the hole.

On Raymond Street, between 4th Street and 3rd Street, there were extensive signs of serious distress on both front and the rear of the row homes. From the depth of fill maps, the front of the homes appear to be on top of 20 to 30 feet of fill while the rear of the homes appear to be on 30 to 40 feet of fill. There were numerous step cracks, both repaired and not repaired, from the second floor windows to the first floor windows and down to the foundation wall. At 319 to 321 Raymond Street, a party wall has settled, and at 325 to 327 Raymond Street, a masonry

foundation wall for a porch has settled (Photo No. 8). Overall, settlement cracks were observed at 301, 303, 305, 317, 319, 320, 321, 323, 325, 327, 328 and 330 Raymond Street. The rear of the homes had many repaired step cracks that were caused by settlement (Photo No. 9).

On Courtland Street, between 3rd Street and 5th Street, there were only a few signs of distress. The end unit at 3rd Street had repaired step cracks. Between 4th Street and 5th Street, the rear wall of the fifth and sixth home from the east end was bowed out.

The assessment included the row homes on the remaining streets beyond the location of the 10 to 20 foot fill depths, but within the overall boundaries of the assessment area that were established initially. There were no signs of distress from settlement, but many of the homes had faces that were almost entirely covered by frame dormers, siding or enclosed porches.

Large London Plane (Sycamore) trees were observed growing along streets in the Feltonville section. These trees continually drop leaves and bark which clog gutters and rain water conductors. In these instances, the rainwater no longer drains completely into the sewer system but infiltrates into the garden soil surrounding the foundation which contributes, over time, to the settlement of the homes. The Fairmount Park Commission informed residents that the trees cannot be removed unless they are dead. The Fairmount Park Commission has stated that the trees contribute to the aesthetics of the neighborhood. The Philadelphia Water Department has found that large trees minimize the opening of fire hydrants in the summer months as well as maintain a lower storm water temperature.

Residents also stated that they are financially responsible for the trimming of these trees. This requirement may pose a financial burden to some residents. These residents would prefer to have the trees replaced with a variety which requires less maintenance. In this instance, perhaps, the City of Philadelphia should weigh the advantages and alternatives that these trees pose when planted over buildings in areas of fill.

# SECTION 6.0
# INFRASTRUCTURE

## 6.1 Existing Infrastructure

### 6.1.1 General

The Feltonville area is a highly urbanized part of the City of Philadelphia and, as such, has a highly complex infrastructure that provides utility services to the residents. The underground utility lines are constructed in a grid pattern and form interconnected networks within the limits of the study area. Generally, the major underground utility lines are water, sewer, and gas. Maps and drawings of these lines have been obtained from the City of Philadelphia in various formats including hard copy and digital files that were transferred electronically to USACE Philadelphia District.

The sewer lines within the area are a combined system that carries both sanitary sewage and storm water. Prior to the filling of the Wingohocking Creek valley, the creek was directed and contained in a sewer system which was installed at or near its former location. Remnants of this former creek, diverted through the sewer system, ultimately discharge to the Delaware River. The location and condition of these lines may have a possible influence on the settlement problems of the area, particularly if the fill material is entering the pipes through breaks in the lines.

There are no underground electric lines except the lines that are located along Roosevelt Boulevard. At this time, there are no reported underground communication or cable television lines within the Feltonville area. Similar to most large cities, the utility lines range from the newest to the oldest, with replacements occurring on an as needed basis as lines break and or as capital funds become available. All of the lines within the study area are subject to the stresses caused by the lack of a firm bedding due to settlement or loss of material under the pipes.

### 6.1.2 Water Lines

Water lines within the study area belong to the City of Philadelphia Water Department and they range in size from 6 inches in diameter to 48 inches in diameter. Similar to most distribution systems, the smaller side streets that serve the row homes have the smaller diameter (6-inch to 8-inch diameter) lines, and the larger diameter lines are located on the major streets. In the Feltonville area, all of the lines are the smaller diameter distribution lines, except for a 48-inch diameter line that is located on 5$^{th}$ Street.

The lines are constructed of various materials, including steel, cast iron, or ductile iron pipe. The cover on the pipes is generally 4 feet or greater, but there are exceptions where the cover is as shallow as 2 feet.

### 6.1.3 Gas Lines

Gas lines within the study area belong wholly to the Philadelphia Gas Works, which is a city agency. The lines range from 6 inches in diameter to 20 inches in diameter, and are constructed of steel or ductile iron pipe. Generally, the 20-inch diameter lines are the high-pressure lines that feed the lower pressure 6-inch distribution lines. Service lines to individual structures are generally 4 inches in diameter or less. The cover is generally 3 feet but can vary to as little as 2 feet - 8 inches. The lines are located either in the paved area of the street or the area beyond the curb line, but within the legal right-of-way line of the street.

### 6.1.4 Sewer Lines

As stated in Paragraph 6.1.1, all of the sewer lines within the study area are part of a combined sanitary/storm sewer system. The pipes are a multitude of sizes that range from 8-inch diameter circular pipes to a 17'-6" diameter reinforced concrete pipe, and 12' x 21' and 15' x 17' rectangular reinforced concrete box culverts. Many of the older pipes, many of which were constructed of brick, were formed as egg or ellipsoid shaped structures, with the long axis in the vertical plane. Similar to the pipe sizes, there is a multitude of pipe types depending on their age and size. The lines are constructed of terra cotta clay pipe (unfired), vitrified clay pipe (fired), brick, reinforced concrete circular pipe, and reinforced concrete rectangular box culvert type sections. The largest reinforced concrete pipe (17'-6" diameter) generally follows the path of the original alignment of the Wingohocking Creek, along Courtland Street and Annsbury Street, and then joins an 18'x21' reinforced concrete box culvert that flows south to Hunting Park Avenue and northeast along Macalester Street. These lines were constructed during or prior to the fill placed in the stream valley. During periods of normal flow the combined sanitary/storm water flow can be can be treated as sanitary waste, but during periods of high flow separating structures in the system were constructed with weirs to allow the excess flow to flow directly into the Delaware River. The pipes have a large amount of cover because most of the lines are at the elevation of the existing stream valley and they flow by gravity to a lift station or treatment plant.

## 6.2 Infrastructure Observations

The sewer system in the City of Philadelphia is owned, operated, and maintained by the Philadelphia Water Department. Visual observations and interviews with residents attempted to focus the study on the obvious and most problematic portions of the infrastructure. This approach would yield a higher degree of discovering potential problems in the sampling that was to be performed. The 4500 block of Reese Street displayed a higher than usual number of distressed homes in a given area as well as depressions in the sidewalks and street.

Laterals are the connections from the house to the City sewer system and are privately owned and maintained by the individual homeowners. Based on the results of previous investigations, broken laterals provide the conduit whereby infiltrating rainwater transports ash and cinder in the "piping" and sewer system. Also, as the ash and cinder travels through the lateral to the main sewer, the volume of the supporting fill is reduced, leading to further settlement.

Ten lateral inspections were performed in the study area. Five homes were selected for lateral inspections on Reese Street and five additional inspections were done (one each on Courtland Street, Roosevelt Boulevard, Raymond Street, and two inspections on North 5th Street). Sidewalks on Courtland Street at the Roosevelt Boulevard showed evidence of sinking and attempts were made to contact those residents to obtain real estate agreements for lateral inspections. Since homes were either abandoned, owners could not be reached, or residents unwilling to cooperate, an attempt should be made by the City of Philadelphia to further investigate the sewer laterals on this block.

Photographs and reports of the lateral and sewer inspection are shown in Appendix D.

### 6.2.1 Laterals

Hired by the Corps of Engineers, a contractor performed lateral inspections on the ten properties. The laterals were inspected using a video camera made specifically for the interior of pipelines. The inspection was performed between the cleanout connection in the basement to the vent/trap located on the front sidewalk of each property.

At the rear of the building, storm water from the roof and (if applicable) driveway flow into an underground drain in the vicinity of the party wall. This drain extends beneath the basement floor for tie-in with the building plumbing drain, then extends to the front of the property where rain water from the front porch roof tie in prior to exiting to the municipal sewer on the street.

#### 6.2.1.1 4506 North Reese Street

Inspection of the lateral immediately downstream from the foundation wall revealed that this portion of the line was cracked and distorted (approximately 1 inch) at two locations. All remaining portions appeared normal.

#### 6.2.1.2 4510 North Reese Street

Inspection of the lateral immediately downstream from the foundation wall revealed that this portion of the line was slightly distorted at this location. Approximately 11 feet downstream of the foundation wall, the lateral bottom was completely broken. Water was observed pouring into a void beneath this opening. This home is located a few feet downhill from the depression in the street.

#### 6.2.1.3 4519 North Reese Street

Inspection of the lateral immediately downstream from the foundation wall revealed a minor crack at the top of the clay pipe bell. The cast iron pipe beneath the basement transitioned into this bell.

#### 6.2.1.4 4521 North Reese Street

Inspection of the lateral immediately downstream from the foundation wall revealed two slightly distorted sections and cracks at the top of the trap.

#### 6.2.1.5 4523 North Reese Street

Inspection of the lateral did not reveal any defects. This home is located on the corner and shows major signs of distress.

#### 6.2.1.6 4508 North 5th Street

Inspection of the lateral did not reveal any defects.

#### 6.2.1.7 4554 North 5th Street

Inspection of the lateral did not reveal any defects.

#### 6.2.1.8 606 West Roosevelt Boulevard

Roots were observed in the lateral. There was no damage to terra cotta pipe, however. A large sycamore tree was growing at the street.

#### 6.2.1.9 427 West Courtland Street

Inspection of the lateral did not reveal any defects.

#### 6.2.1.10 428 West Raymond Street

A 1-inch drop in the lateral was observed at the connection to the trap.

### 6.2.2 Sewers

#### 6.2.2.1 Feltonville Section

A depression or dip exists in the vicinity of 4506 to 4510 North Reese Street which extends across the street and into the sidewalks on either side. Also, complaints from residents concerning water entering their basement foundation at this location prompted an inspection of the sewer on the 4500 block of North Reese Street. A resident also reported that, approximately one year ago, a small spring of water emanated in the basement of one of the homes (4504 North Reese Street) for approximately a week or two. The water was not in the vicinity of any basement piping and disappeared on its own. A plumbing contractor could not determine its cause. Residents also noted that the depression in the street started/accelerated approximated two years ago.

The Philadelphia Water Department performed an examination of the 20-inch vitrified clay pipe sewer between Wingohocking Street and Annsbury Street. The inspection revealed that a depression in the sewer at the same location also existed. A pool of water formed inside the sewer at this location. Further uphill from this depression, however, at the intersection of Reese Street and Wingohocking Street, the inspection revealed that a base section of the sewer pipe was broken/missing. The robotic camera could not pass beyond this point because it became submerged in the hole. The section of sewer between the depression in the street and the intersection at Wingohocking Street, therefore, could not be inspected because the camera was unable to pass from either of these ends. The City of Philadelphia Risk Management Division was notified of the problem for corrective action.

A few feet upstream of the broken sewer, major cracks were noted throughout a section of the pipe which could potentially result in a collapse.

#### 6.2.2.2 Logan Section

Lippincott Engineering Associates, Inc. (LEA) was retained by the City of Philadelphia, Department of Licenses and Inspections in April 1986 to conduct an in-depth geotechnical investigation of the subsurface soil conditions in order to determine the cause of the settlement and structural distress occurring in the Logan Section of Philadelphia. The study area, which is sometimes referred to as the "Logan Triangle," is an area, about 48 acres in size, that encompasses 17 city blocks that once held 957 residential properties (to date, a majority of those properties have been razed). The "Logan Triangle" is bounded by Wingohocking Street and Roosevelt Boulevard on the south; Marshall Street on the east; Loudon Street on the north; and Eleventh Street on the west.

The investigation indicated that the study area was a portion of the reclaimed valley of the Wingohocking Creek that was filled around 1910 with as much as 40 feet of ash and cinder fill and then subsequently developed with rowhouses around 1920. Laboratory testing indicated that the ash and cinder are susceptible to substantial volume change by flowing water, due to solubility, densification and piping. It was concluded by LEA that the continuous movement in the Logan Section resulted primarily from ground loss and volume change in the foundation supporting materials. The US Army Corps of Engineers, Philadelphia District agrees with this assessment.

During their investigation, LEA determined that based on the mechanical properties of the fill, the settlement of the ash and cinder could not have resulted in all of the movement occurring in the Logan Section. However, movements monitored following heavy rainfalls tended to indicate that water, and its effect on the fill, was a more likely factor. Based on this information and the susceptibility of ash and cinder to "pipe," LEA expanded their field investigation to include house laterals and the City sewer lines.

Two (2) lines were selected by LEA for their investigation: Franklin Street and Hutchinson Street. Their selection was made because both of the lines were supported on the ash and cinder fill, running shallow in the middle of the street, and severely damaged homes existed on both sides of the streets.

The Franklin Street line is a 510-foot long, 20-inch terra-cotta pipe and is supported within the ash and cinder fill. Upon examination, the pipe was found almost half full with ash and cinder with nearly 22 cubic yards of ash and cinder. Once the fill was removed from the line, a TV survey was conducted and showed evidence of open joints, cracks, and a collapse in the crown in one of the sections. Several house laterals were dye tested along this street to verify the their soundness and continuity. In a few of the damaged houses tested, the dye water did not reach the main sewer, indicating a discontinuity in the lateral. This results in the wastewater draining directly under the house foundation, and with a lower pH than potable water it will adversely affect the ash and cinder.

The Hutchinson Street line is a 500-foot long, 20-inch terra-cotta pipe, also supported within the ash and cinder fill. A TV survey indicated that the condition of the Hutchinson Street line was worse than the line in Franklin Street. Severe undulation was discovered, as well as open joints, cracks, and evidence of ash and cinder entering the line through these joints. Test pits at lateral locations between the house and street indicated that extensive corrosion within the cast iron pipes has occurred. The TV survey of laterals indicated that joints are open, laterals are broken and filled with ash and cinder.

LEA attempted to inspect the Courtland Street sewer line; however, the flow presented a safety hazard to their inspection team and therefore was not conducted. It was reported by Mr. Robert Serpente of the Water Department, that the sewer line is intact and in good condition.

LEA indicated that the ground loss and migration of water could be reduced considerably by rehabilitating the underground utilities in the area. Therefore, LEA recommended that all house laterals be changed, all water and gas connections be checked, the structural integrity of the City sewer be evaluated, and that efforts should be made to improve the existing drainage system, to minimize flooding after severe storms.

# SECTION 7.0
# CONCLUSIONS

## 7.1 USACE Topographical Change Map

The topographic change map completed by the USACE, utilizing detailed pre-development topography, provided a high resolution investigation of surface elevation changes for a small, localized region. This map assisted in defining the depth and extent of the fill in the vicinity of the disaster and assisted in focusing the areas of investigation for further subsurface and building assessment investigations. The map is depicted in Appendix A.

The City of Philadelphia Streets Department maps, showing five-foot contour intervals dating back to the early twentieth century, will not reveal any fill or topography changes which may have been completed prior to that date. An examination of the depth of fill map reveals discontinuity at two locations – 5th Street and the abandoned rail line between Fairhill and 5th Streets. These locations were filled prior to completion/survey of the early 20th century five-foot contour interval maps for the installation of bridges over Wingohocking Creek. Evidence of the embankment and rail bridge trestle can still be seen on Annsbury Street. Fill depths shown along the railroad embankment and along 5th Street in the vicinity of Annsbury Street, therefore, will not reflect differences between "original," i.e. pre-railroad, pre-5th Street bridge, and current ground elevations.

Several houses along 5th Street showing structural distress are in areas mapped as having no or minimal fill. They may, in fact, be located on fill that predates the five-foot contour mapping used to estimate depth of fill.

## 7.2 Geotechnical Investigation

Based on the results of investigation conducted by the Philadelphia District, it has been determined that portions of the Feltonville section of Philadelphia are situated on the reclaimed valley of the former Wingohocking Creek that has been filled in with miscellaneous fill including ash and cinders. From information collected in previous investigations, this fill was placed in the valley during the early 1900's following the containment of the Wingohocking Creek within a large diameter brick sewer. The excessive settlement occurring in some of the residences in the Feltonville section are similar to those experienced in the Logan section that is located directly across from the Feltonville section, separated by US Route 1 (Roosevelt Boulevard). The Logan section is also situated in the reclaimed Wingohocking Creek valley and was studied in-depth by Lippincott Engineering Associates (1986, 1987) and later by the Philadelphia District (1998).

During the subsurface investigation, a layer of miscellaneous fill comprised mostly of ash and cinder mixed with varying amounts of building debris (decomposed brick, glass, and wood), coal, and soils (sand, silt, clay, and gravel) was encountered. This stratum ranges in thickness

from zero to depths as great as 41 feet depending on the location within the study area. This stratum is generally characterized by low standard penetration resistance and the absence of a natural soil structure. The fill material is loose and apparently was placed with little to no compactive effort.

The variation in thickness of the miscellaneous fill stratum determined during the drilling investigation correlated very well with contours shown on drawings provided by the City of Philadelphia. The drawings provided the contours of the former Wingohocking Creek and the as-built street elevations used to estimate the thickness and help establish boring locations for the drilling program. These drawings were also instrumental in determining which residences are located on suitable ground and not prone to the settlement that is occurring in the residences founded on the miscellaneous fill.

The investigations of the Logan Section of Philadelphia, conducted by Lippincott Engineering Associates (1986, 1987), have confirmed that loosely compacted ash and cinder fill is a poor foundation material, and its unique physical properties make it susceptible to excessive settlement with changes in conditions. The most prevalent is the presence of water. Some properties, and the effects of water include, but are not limited to, the following:

- The densification by ponding (e.g., the accumulation of water) or compaction could result in a volumetric change in the ash. This would result in the fill changing from a loosely compacted state to a more compacted state, and with the decrease in volume there would be an increase in settlement. If the settlement is not uniform over an area, this leads to differential settlement that may have significant impacts on the structural integrity of a building.

- The shear strength of the ash and cinder is typical to that of a loose granular material. Generally, the shear strength of saturated granular soils is about the same as the shear strength of dry granular soils (at a given state of compaction). However, tests run on similar materials obtained in the Logan Section, indicated a significant decrease in the shear strength of ash and cinder when saturated.

- The elastic settlement characteristics of the ash and cinder are typical of granular material. Elastic, or "immediate," settlement of a foundation takes place during or immediately after the construction of the structure. All structures undergo elastic settlement. The amount of elastic settlement that can occur is dependent upon several parameters including the stress increase at the foundation level, the thickness of the soil layer(s) and the modulus of elasticity of the soil(s). Since the material is not cohesive, it does not undergo consolidation (which is the dissipation of excess pore water pressure in silty and clayey deposits that result in settlement over time)

- Ash and cinder are highly susceptible to dispersion and piping. Piping is the condition where the finer-grained particles are carried away with the water through the larger pores in the soil matrix.

- Ash could be lost by either dissolving or by being carried away in migrating water with a higher amount when in an acidic environment. An example of this is when laterals crack or rupture and the flow of water and or wastewater flushes material away. The crack in the lateral also provided a conduit for the material to leave. This condition can be exasperated when the lower pH (more acidic) wastewater is introduced, since the ash may dissolve.

- The permeability of the material is similar to granular material of the same grain size.

Combined with the exterior structural investigation conducted, it appears that the majority of the settlement exhibited by the residences in the Feltonville section is due to the elastic settlement of the granular-like materials (ash and cinder) used to fill in the former valley of the Wingohocking Creek. While other strata were identified - residual soil, stream alluvial, and highly decomposed rock and bedrock - it is the layer of miscellaneous fill that is the major contributing factor to the settlement occurring in the area. The other soil strata are generally characterized by high penetration resistance and are found at depths that would be outside the zone of influence of increased stress due to foundation loads. As a result, significant amounts of settlement are not likely to occur in these layers. The portions of the Feltonville section that are not filled are founded on the native material, either the highly decomposed rock or bedrock itself, and are not subjected to any significant settlement.

By today's standards of suitable foundation materials and compactive efforts, the ash and cinder fill would be considered unacceptable. Current standards would require a quality structural fill, such as well-graded sand with little to no fines, with specifications for compacted density, moisture content and placement thickness.

The amount of elastic settlement that can occur is highly dependent on the modulus of elasticity of the soil, e.g., the lower the modulus, the higher the settlement. Empirical correlations have also been made comparing modulus with the number of blow obtained during the standard penetration tests and show that the values are directly proportional. Based on the low penetration resistance observed in the test borings, it can be concluded that the fill used in the area has a low modulus. This most likely resulted in amounts of elastic settlement which exceeded the tolerable amounts that are normally accepted today and have made some of the structures unsound and unsafe.

There are several buildings in the Feltonville section that are situated in areas that were filled with the miscellaneous fill that are not showing signs of excessive settlement. There are several reasons that may explain why this is not occurring. Most likely, the buildings have a pile foundation comprised of point bearing piles that bypass the unsuitable fill and rest on the bedrock. The piles transfer the building load to the bedrock so the building is not prone to any settlement. Another possible explanation is that the material used to fill in the area under these buildings may not be ash and cinder, but a more competent material such as sand or gravel. While this particular explanation cannot be proven in this case, conversations with one of the business owners do confirm that pile foundations have been used.

The presence of water in the loosely compacted fill material can lead to additional settlement beyond that which occurs immediately. The lowering of the groundwater table, which can

happen either naturally over time or by methods such as pumping (dewatering operations), increases the stress that is imposed on the soil structure and, therefore, the amount of settlement that can occur. The rising of the groundwater table can also affect loose, granular material by allowing the soil particles to rearrange into a denser orientation.

Subsurface erosion due to the flow of the groundwater and/or the introduction of water/wastewater from house laterals or street sewers could possibly occur. The groundwater elevations observed in the field during the drilling investigation were relatively deep and appear to be close to the elevation of the former creek. This was concluded based on the fact that, for the most part, the ash and cinder material was dry, but the stream alluvial and some of the residual soils were saturated at depth. There is no evidence indicating that the former creek is still flowing. A recent survey conducted in the sewer main on Reese Street between Wingohocking Street and Annsbury Street revealed that sewer was cracked in several places and was undulating in one location. The sewer main is located within the ash and cinder fill and the street shows signs of distress (dip/depression) immediately above the undulation in the pipe indicating that the settlement in the pipe is reflected in the settlement of the street.

## 7.3 Building Exterior Assessments

Many of the buildings in the Feltonville area that were assessed visually showed signs of distress caused by differential settlement. In general, the amount of distress coincided with the original location of the Wingohocking Creek and the fill depths that had been mapped. Some of the row homes experienced more distress than others even though the depths of fill may have been similar. This may be attributed to the type of fill, the degree of initial compaction, or the depth and flow characteristics of ground water. From the exterior, it appears that some of the structures are experiencing significant stress and are progressively becoming more unstable with time. This would have to be determined by a complete structural inspection of the row homes on an individual basis. Abandoned homes within a row, because of the lack of maintenance, deteriorate to a point that they are structurally unsafe and exacerbate the distress of the adjacent homes. The adjacent homes become end units and, as such, are subject to more stresses due to settlement as they provide buttressing for the remainder of the row. As a rule, the end units show more signs of distress than homes in between them. Removal of end units because of abandonment or settlement distress may start a domino effect and result in the gradual removal of an entire row of homes.

At several locations the settlement was severe enough to notice significant differences in the grade elevation of the curbs and pavement of the streets. This could be attributed to broken sewer laterals or the sanitary sewer lines themselves.

## 7.4 Infrastructure

The depth of fill map in Appendix A indicates the locations of sewer and lateral pipes which are located at a depth within the fill layer. If this infrastructure is not installed on the proper foundation, the fill compacts and the pipes settle, causing the joints to open further.

Water and sewer lines, if defective, provide a means for fill material to either wash away in the flow of a sewer or densify the fill by washing away the fine particles. The volume of the supporting fill is then reduced, leading to further settlement.

### 7.4.1 Laterals

Broken/cracked laterals were discovered on Reese Street. These homes were located adjacent to the depression in the street and, in addition to the broken sewer, were a contributing factor to the settlement which occurred in this vicinity.

Misaligned and separated pipes can also contribute to the settlement problem. The clay pipe used in the installations can separate since the end of one pipe is merely fitted into the bell mouth of an adjoining pipe.

Misalignment of the pipe could possibly be attributed to the roots from large trees which line the street. Otherwise, the misalignment can result from either undermining of the soil surrounding the pipe and/or poor construction practices. Rainwater, if allowed to collect and drain in only concentrated areas, also begins to densify/wash fine particles to form channels beneath the surface. When a rear drain/rain water conductor was clogged, water drains into cracks beneath the concrete driveway and the foundation, forming a channel. It also permeates the soil at the front gardens of some of these homes. This condition may attract roots from large trees to grow in the vicinity of a lateral, potentially exposing it to further damage from the roots as they grow.

### 7.4.2 Sewers

#### 7.4.2.1 Feltonville Section

The broken 20-inch sewer main at the intersection of Reese and Wingohocking Streets is a probable cause of the depression on the 4500 block of North Reese Street. A boring taken at this location revealed that the sewer is located on approximated 26 feet of fill material. A thorough inspection of the main along this street should be completed to determine the extent of damage which resulted from the broken sewer. Appropriate repair/replacement measures should then be implemented to prevent any further damage.

#### 7.4.2.2 Logan Section

LEA was retained by the City of Philadelphia, Department of Licenses and Inspections in April 1986 to conduct an in-depth geotechnical investigation of the subsurface soil conditions in order to determine the cause of the settlement and structural distress occurring in the Logan Section of Philadelphia. During their investigation, LEA determined that based on the mechanical properties of the fill, the settlement of the ash and cinder could not have resulted in all of the movement occurring in the Logan Section. However, movements monitored following heavy rainfalls tended to indicate that water, and its effect on the fill, was a more likely factor. Based on this information and ash/cinder material properties, LEA expanded their field investigation to include house laterals and the City sewer lines. Based on the results of this field investigation,

LEA concluded that it was apparent that broken laterals provide the conduit whereby infiltrating rainwater transports the ash and cinder. So as the ash and cinder travel through the lateral to the main sewer, the volume of the supporting fill is reduced, leading to further settlement. The PWD has indicated that the City's main sewers are below the fill level or otherwise supported on proper bearing material and thus have not settled. LEA indicated that the ground loss and migration of water could be reduced considerably by rehabilitating the underground utilities in the area. The final LEA report recommended that all house laterals be changed, all water and gas connections be checked, the structural integrity of the City sewer be evaluated, and that efforts should be made to improve the existing drainage system, to minimize flooding after severe storms.

The relocation of all utility lines, including existing storm and sanitary sewer lines are being considered in preparing the draft redevelopment report on the Logan section by the Philadelphia District of the Corps for the City of Philadelphia Planning Commission. The District, with the permission and encouragement of the Planning Commission, has interacted directly with the PWD and coordinated the preliminary plans and costs for the sewer lines. The PWD is aware of the problem of sub-surface material migrating into the sewer lines, which are combined sanitary and storm sewer lines. In a letter dated June 4, 1999 to the District, they summarized the results of their sewer examination, and provided recommendations to line the City sewer system in order to seal the abandoned homeowner lateral connections. This would prevent any further soil migration into the sewer from the deteriorated homeowners' laterals. Depending on the final redevelopment plan and soil stabilization methods employed, the City's sewer infrastructure may need to be replaced in part or entirely. Preliminary unit costs for this work, based on similar jobs, was included. All of this information was included in the draft report that was provided to the Planning Commission. The City accepts and desires to maintain control of their own system and the District was not previously tasked with investigation of the existing system. The District performed the required work that was necessary to provide a total estimated cost, including infrastructure, for development of the site at Logan.

In summary, the District does not believe that any further investigation is required at the "Logan Triangle" area. The City of Philadelphia/LEA has completed the necessary investigations for the sewer infrastructure.

# SECTION 8.0
# RECOMMENDATIONS

## 8.1 Topographical Change Map

- Utilizing Streets Department data, analyze and provide more detailed, localized depth of fill maps for the remainder of the former creek bed, downstream of the Feltonville study area, to include completion of data digitization for water, gas, and sewer lines. The area is depicted in Section 2, Figure 2-2.

## 8.2 Geotechnical Considerations

- Based on the information obtained during the geotechnical investigation, the Philadelphia District was able to adequately determine the depth, nature and condition of the fill placed in the Feltonville section. The study area is a portion of the reclaimed valley of the former Wingohocking Creek. The information obtained from the testing portion of the Lippincott study of the Logan section provided additional insight into the engineering properties of the soil and fill encountered. With the objective of determining the extent of the fill within the study area met, it is the District's opinion that there is no need to conduct any additional geotechnical investigations within the study area at this time.

- Utilizing the as-built street elevation and contour maps, the City of Philadelphia can determine which residences and buildings are situated in areas filled in with ash and cinder, and which are founded on competent ground (those areas which show that the current street elevation is equal to or less than the original contours). Those buildings founded on ash and cinder may be prone to excessive settlement due to the loose compaction of the fill. However, any "distress" observed in residences founded on native soils is more likely due to poor maintenance rather than excessive settlement. The highly decomposed rock and bedrock of the Wissahickon Formation would be considered "native" in the study area.

- The City of Philadelphia should consider conducting additional geotechnical investigations and structural assessments (outside of the current study area) in other neighborhoods that may be situated in the valley of the former Wingohocking Creek and other reclaimed creeks. As-built drawings, similar to those used in this study, as well as the topographical map that depicts changes in contours (both cut and fill) can be used to pinpoint areas of concern for potential future investigations.

- Any new buildings that may be constructed in the former valley of the Wingohocking Creek must be founded on suitable ground. Deep foundation systems and ground modification techniques, for instance, can be utilized to either bypass the problem soil or to improve it into a more suitable foundation material. The use of a deep foundation system, such as piles, could extend below the depth of the fill and be situated on native material, namely the decomposed bedrock of the Wissahickon Formation. Ground modification techniques, such

as grouting and vibrocompaction, where the existing soil is mixed with cementitious materials (grouting) or is densified (vibrocompaction) to improve the physical and engineering properties of the soil could be considered. Further subsurface investigations would be required in order to assess the most feasible and economical method, and a registered professional engineer certify the foundation design.

- Ideally, all of the utilities should be founded in competent material. During the replacement or repair of any utilities in the Feltonville neighborhood that may be founded on fill material, the City should ensure that the utilities are set and backfilled with compacted structural fill. During any utility work or repairs, proper shoring and bracing of residences and buildings that may be affected by the construction activities should occur. A registered professional engineer should perform the design of any bracing.

- While no chemical sampling or testing was conducted in the Feltonville section, past experience in the Logan section investigation has shown that the ash fill may contain elevated levels of lead, arsenic, and mercury. It is important to note that the District is not implying that such elevated levels occur in Feltonville and that background levels for the City of Philadelphia should be taken into consideration when comparing values. However, if any additional construction or future remedial actions are taken, the City should address the issues of potential contaminated soil, and at a minimum conduct chemical sampling and testing.

## 8.3 Building Exterior Assessments

- Perform an inventory of the structures that show signs of distress caused by settlement within the fill area. Establish a geographic information system (GIS) database which would be updated with inspection reports.

- Perform a semi-annual or annual inspection to update or supplement the inventory. Any structures showing signs of continuing or rapid change should be inspected more thoroughly, including interior foundation walls.

- Establish a telephone number or mailing address for residents to call or write if they notice changes in their particular structures.

- Establish a standard procedure for which a detailed structural inventory would be performed and damage prevention measures would be instituted at locations where construction activities (i.e. deep excavations, dewatering, pile driving, fill compaction etc.) are undertaken that might disturb the fill. This would include proper design of construction methods, certified by a registered professional engineer, which are to be utilized in the areas of fill. Damage prevention measures should include additional real time monitoring during such activities.

- Establish survey reference points on structures that show the most signs of settlement, particularly the structures at the end of rows, and monitor the movement annually by field

survey. The reference points would be benchmarks (such as pins installed in the walls) that would facilitate settlement measurement (if any) over time.

- Perform a detailed structural inspection of the homes at the following locations:

  Luray Street, between 6th Street and 7th Street,
  Courtland Street, north side between 6th and 7th Street,
  Courtland Street between 7th Street and 8th Street,
  Reese Street, between Wingohocking Street and Annsbury Street,
  Raymond Street, between 3rd Street and 5th Street, and
  Annsbury Street, between 4th Street and 5th Street.

- Develop a design, certified by a registered professional engineer, for providing structural support to row homes where a gap is created by removal of an abandoned home.

- Provide structural support, designed by a registered professional engineer, for any new end unit created by the removal of an abandoned end unit that has been demolished and removed.

- Inspect rainwater conductors to ensure integrity/proper drainage at the downspouts; repair and replace as necessary. Investigate impact of trees on downspouts and trim back. As an additional alternative, utilize gutter guards to minimize clogging from tree leaves and bark. This may be more cost effective than continually cleaning the gutters, especially for residents who may lack the financial means/ability to perform such work. Otherwise, remove/replace trees with a variety less conducive of damage.

- Establish a hotline for residents of the area so that priority can be given to shutting off open fire hydrants.

### 8.4 Infrastructure

- Philadelphia Water Department should thoroughly inspect sewer and water infrastructure in areas of fill to verify integrity; repair if necessary and monitor on a regular basis. Priority should be given to those streets requiring a detailed structural inspection (listed in Section 8.3).

- Inspect homeowner laterals in areas of fill to ensure integrity/proper drainage; repair and replace as necessary (possibly using alternate materials such as heavy duty PVC pipe or ductile iron pipe with joints that are able to sustain some deflection).

- Investigate impact of large trees along the sidewalks which could be causing damage to sewer laterals. Replace existing laterals if roots are found in the pipes and trim back roots to trench wall. If necessary, remove/replace trees with a variety less conducive of damage.

# SECTION 9.0
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# SECTION 10.0
# APPENDIX