Garage A Sinkhole Project Final Report

In late March 2018 Federal Parking noticed a hole that had developed between Garage A and the Hock Plaza Building. It was approximately 2 feet from the side of Garage A and approximately 4 to 5 feet deep and 4 feet in circumference. Federal Parking contacted a local geotechnical engineer, Falcon Engineers, for guidance and to ensure there was no immediate impact to the garage foundation or structure. The next step was to meet with several utility locating companies (PSNC, NC One Call, KCI) to identify utilities near the sinkhole, scan and mark the area.

Garage as-built files and underground and surface utility surveys were reviewed by the engineers. A foundation plan with annotations/comments was prepared to show the approximate location of the observed sinkhole in relation to the top of the old 54-inch reinforced concrete storm pipe (RCP), which traverses the entirety of the parking deck from east to west.

A highly-regarded HD robotic CCTV company (Vision NC) was engaged to do a detailed video inspection of the entire 54-inch RCP and other accessible tie-in lines so that the pipe conditions could be documented and assessed by the engineering team. Slab soundings/chain dragging (to seek out potential under-slab voids) were used and none were found. Federal Parking was prepared to use ground penetrating radar (GPR) surveys to look for deeper underground voids that might exist, and undertake soil test borings, etc. to evaluate what the soil conditions actually were at or near the observed sinkhole and/or near voids uncovered by GPR. However it was determined by the Federal Parking engineering team did not think this was required prior to the video inspection and excavation.

The team observed NC Vision setting up to enter a storm inlet near the center of the parking deck lower level (referenced as 0 feet, and CB-1 on the NC Vision report). NC Vision deployed a rover-type HD video camera, which traveled a total of 127 feet downstream within the 54-inch RCP (referenced as 127 feet, and CB-2 on the NC Vision report). The sinkhole was located above the 54-inch RCP at approximately 100-105 feet downstream from CB-1. A 360-degree HD video capture of the entire 127 feet of RCP was captured and reviewed on-site via TV monitors provided by NC Vision. An initial on-site review of the video did not indicate any damage, distress, or notable areas of soil infiltration within the sections of the 54-inch RCP explored. The pipe was in very good condition for its age (>30 years old), and very clean (i.e., no notable debris). Within the

pipe video, and at the approximate location of the sinkhole (~105 feet into the pipe), a much smaller diameter storm water pipe was noted to have been tied into the top third of the 54-inch RCP via cutting into a section of pipe, without utilizing a junction box (which would be standard construction). While this "blind drop" tie-in appeared to have been constructed in a non-standard, rough way, the video review indicates that this tie-in does not appear to be a major source of soil infiltration from above. This tie-in, which is located approximately beneath the observed sinkhole, did not appear to be the cause of the sinkhole. The underground video inside the large 54-inch RCP indicated that the RCP was appeared to be in excellent condition for its age, and therefore likely not the cause of the sinkhole. The repair solutions, however, could not be determined.

The next step undertaken was a limited geotechnical subsurface field investigation in the vicinity of the sinkhole. Prior to performing these field test-borings, the team contacted the North Carolina One Call Center (NCOCC) to request the location and marking of subscriber (public) utilities on site prior to drilling. However, because most utilities on-site are owned by the VA (or others) and not subject to NCOCC notification and response protocols, the subcontracting of private utility location and marking services for the area of the sinkhole and immediately surrounding areas where test borings may be performed was also required.

Due to constrained access to the sinkhole area, which is bordered by Garage A, Garage B and the Duke Medical tenanted Hock Plaza Building, it was determined that a gate was needed in the existing chain link fence that runs adjacent to Pratt Street in order to allow site access and parking for field crews and their vehicles/equipment. Due to the relatively unknown subsurface conditions at the sinkhole, and likelihood for difficult and sensitive boring excavations due to visually observed buried debris and the amount of underground utilities in the sinkhole vicinity, a variety of hand-tool test boring methods were utilized to investigate the area. These methods included hand-augers, a dynamic cone penetrometer, and steel sounding rods, each advanced to anticipated depths on the order of 5 to 15 feet deep or auger refusal, whichever occurred first. Boreholes were backfilled with soil cuttings, and excess cuttings were evenly dispersed around the ground surface surrounding the boreholes. Federal Parking worked with the testing contractors and utility contractor to ensure field activities caused minimal disturbance and removal of the existing ground surface, grassy areas, landscaped areas, and surface vegetation, including tire ruts and generation of excess soil spoils.

As a result of supplemental video monitoring in a cleanout and subsequent engineering analysis, it was determined that a broken 8-inch drain leader was the primary source of the sinkhole. In April, excessive rain made the depressed area widen, potentially causing the sinkhole area to expand west and to deepen. Federal Parking had an obligation under its insurance policy to mitigate further damage from occurring if possible. Accordingly, the engineering team recommended that an 8-inch temporary auxiliary storm drain pipe be installed to go around the broken 8-inch drain. Great American Insurance and its engineers concurred. Provisions were also made for the protection of the gas line and 54-inch RCP. Both of these utilities were appropriately marked by KCI and marked again prior to commencement of temporary repair work.

Early during this process, Federal Parking filed a claim with its insurance carrier, Great American Insurance Company. As a result, Great American engaged an engineer from Raleigh and appointed an insurance adjuster to assess the condition on site of the sinkhole, and attempt to identify its cause in order to determine if Great American would provide insurance coverage. During the initial meeting, both Federal Parking and Great American's engineers discussed findings to date, reports issued, and the chronology of investigative events that occurred over the initial month after the sinkhole was first observed. The engineers walked the sinkhole area and inside the garage at the roof level and at the lower level near the sinkhole. The Great American team seemed to agree with the assessment and findings of the Federal Parking team. The Great American team seemed to agree that the break in the roof leader pipe was the cause of the sinkhole, and needed to know the cause of the break in order to assess insurability for the claim. The Federal Parking team discussed multiple possible causes but there was no evidence to point to a specific reason that caused the pipe to break/separate. The adjuster requested that the engineer prepare a report that addressed all possible causes for the pipe failure. Federal Parking shared select images/pipe videos that were collected, hard copy construction drawings, etc.

Based on investigative work undertaken through the end of April, the sinkhole appeared to have been partially caused by a break in the roof leader pipe that was allowing storm water pipe flow to uncontrollably erode/wash subsurface soils away into an unknown location, instead of keeping the storm water pipe flow contained within the designed storm water pipe system. The sinkhole deepened by approximately three feet during the 60 day period of observation, and the sinkhole also became wider by about two feet during that time.

The break in the roof leader pipe could have been caused/initiated by many different things, including but not limited to:

1. Poor quality backfill soils placed below, around and/or above the roof leader pipe at time of original construction.
2. Poor quality construction of the roof leader pipe joints / tie-in at time of original construction.
3. Material defects in the roof leader pipe and/or pipe joints used during original construction.
4. Excessive loading applied over top of installed roof leader pipe prior to adequate soil cover (backfill) being in-place at time of original construction.
5. Installation, construction, repair and/or maintenance activities performed on site utilities, site facilities, etc. in the vicinity of the underground roof leader during the service life of the roof leader.
6. Degradation of roof leader pipe materials and/or pipe joint materials over its service life (~30 years).
7. Degradation of organic materials contained within poor quality backfill soils in vicinity of roof leader over its service life (~30 years).
8. Tree roots penetrating roof leader pipe joints and/or the soils that support/surround the roof leader pipe during the service life of the roof leader.
9. Earthquake(s) that may have occurred and caused earth motion at the location of the roof leader during the service life of the roof leader.
10. Excessive vibrations caused by other activities in the vicinity of the roof leader during the service life of the roof leader.

Caution tape was put in place in an expanded area to keep people out of the affected area. Only authorized employees were allowed in the sinkhole area, which excluded landscaping/ground crew and anyone else not working on the sinkhole problem.

From the initial observation in March through the end of April, due to the expanding sinkhole and inclement weather, Federal Parking undertook the necessary work to temporarily bypass the roof leader drain that was broken and compromised until permanent repairs could be made. Performing the bypass was determined to be prudent in order to minimize the potential for the sinkhole to enlarge and to protect the 54-inch RCP storm drain pipe and gas line in the sinkhole area. This interim construction repair prevented further collapse of the sinkhole, allowing a definitive repair plan to fix

the broken pipe. It also helped protect the 54-inch RCP and gas line in the sinkhole area. As a result, the widening of the sinkhole area stopped.

On site staff continued to monitor the sinkhole area regularly to determine daily changes or conditions. All the engineers that frequented the site in May continued to verify that Garage A foundation and structural integrity was not being compromised by the sinkhole.

Federal Parking continued to prepare additional claim materials based on its insurance policy with Great American to justify coverage of the costs for the investigation, engineering, temporary repair, excavation, final repair and re-filling, stabilization and grading work that was underway and to be completed.

Numerous meetings and discussions were held among all stakeholders to ensure the protection of the nearby gas line and 54-inch RCP storm drain pipe and other utilities that were previously marked by NC One Call, PSNC and KCI. Federal Parking also scheduled re-markings by PSNC and NC One Call before final repair work began.

The expedited bidding process commenced in May for excavation of the sinkhole, final repair and re-filling of the excavated area. On-site inspections were held with contractor candidates. Scopes of work were created. Proposals were secured. Contracts were negotiated and executed. Federal Parking, along with project managers from affiliated companies, undertook pre-planning and project management efforts in order to save what could have been up to $15,000 in additional costs.

During contractor negotiations with RBS, the selected excavation/utility contractor, the Federal Parking project management team made it clear that excavation methods and excavation safety, including protection of underground utilities in the vicinity of the sinkhole, was 100% the responsibility of RBS. Exclusions were kept to a minimum but change orders were allowed based on actual site conditions, including repair and replacement of the pipework.

The KCI potholing report secured by Federal Parking indicated the amount of soil cover on top of the gas pipe at two known exact locations, as well as the gas pipe size and material type. The size, weight and proposed setup(s) of the excavation equipment that RBS planned to use, as well as the quality of soils below and above the gas pipe were factored in when planning mobilization and impact of equipment on top of underground and unknown utilities. The need for additional soil cover or steel plating over the gas

pipe and other excavation safety methods to protect the gas pipe and any other nearby underground utility lines, and to protect nearby structures and their workers, was thoroughly discussed with RBS during construction agreement negotiations and meetings.

During the contracting process, investigation procedures employed by Falcon Engineering were reviewed by the contracting team. This included review of original construction documents, review of robotic pipe video capture inside of the 54-inch RCP, performance of rod soundings, pipe snake video of two small-diameter roof leader drains, and various other site observations and measurements.

As a result, an "unknown" utility was located in the sinkhole area that was initially marked by KCI. However the sweeping did not report a "significant" finding at first. However, in subsequent project meetings with engineers and contractor staff, it was determined that the "unknown" utility could cause issues based on excavation activities and movement of equipment.

It was believed that this "unknown" utility could be a live or abandoned gas line, storm water drain, sanitary sewer line, or water line. The utility was not marked anywhere on VA, PSNC or Federal Parking's utility drawings prepared in prior years.

Accordingly, to err on the side of caution, the affected area was swept twice by two different locating services and subsequently swept twice again by KCI and the City of Durham. Because of concerns regarding the impact on the VA Medical Center in the event an active gas line was damaged or destroyed, Federal Parking approved and authorized additional vacuum excavating "potholing" to further identify this utility line.

Additionally, a 30-page safety plan was created for this project and distributed to the Durham VA, covering all required actions in the event of any gasoline explosion or disruption. The scope of work covered:

- Egress in/out for site repairs at the gate on the south side of Pratt Street and the west side of Garage A.
- Removal of existing 4-inch to 6-inch trees at sinkhole, load, and export off site.
- Bench grading of slope at sinkhole to the west to create a landing for exposing the existing 8-inch roof drain.
- Installation of shoring as required during excavation
- Repair of 8-inch roof drain and backfill to existing grade

In preparation of work commencement, Federal Parking closed off part of the lower level of Garage A for extra safety precaution.

Commencing the week of May 22, 2018, Federal Parking on-site, corporate and project management staff oversaw the repair, replacement and rebuilding stages of the sinkhole. In addition, a Falcon Senior Geotechnical Engineer was on-site to observe, along with the adjuster for Great American Insurance (Engle Martin & Associates), the Raleigh-based engineer engaged by Great American Insurance (Rimkus Consulting Group), and the owner and workers from Durham-based RBS Grading & Excavation. The excavation of, and subsequent repairs made to the observed surface collapse lasted four days, from mobilization and site preparation to final grading after completion of sinkhole re-filling. During this process, NC One Call inspected the uncovered gas lines to designate which gas lines were still active, ensuring that no damage, intrusion or removal occurred by the construction team. The photos below illustrate the initial sinkhole observed, the site during excavation, and the re-graded site.

RBS performed the excavation and pipe repair services. Excavation at and below the location of the observed sinkhole confirmed that the partial cause of the sinkhole was in fact a break in the 8-inch roof leader drain pipe, in the general vicinity of its original construction tie-in to the 54-inch reinforced concrete pipe (RPC). This was previously suspected and reported in an April engineering investigation report, and included in the photo below taken during excavations.

A break in the roof drain pipe was observed within the 8-inch diameter ductile iron pipe (DIP) section just inches before the hard connection to small diameter reinforced concrete pipes (RCP) that had settled multiple inches in two separate, short RCP pipe sections prior to tying into the underlying 54-inch RCP. The two sections of excavated broken and settled pipe sections are shown in the following photo.

The broken section of DIP was cut, cleaned and prepared for a new DIP-to-HDPE connection. A section of 8-inch diameter semi-flexible HDPE storm water pipe was installed and utilized to connect the 8-inch DIP to the 54-inch RCP, completing repairs to the broken roof leader, as shown in the photo below. Once repair of the broken roof drain was made and a new tie-in to the 54-inch RCP was established, the area was backfilled to re-establish surrounding site grades. The final grading was done with straw, and grass seed was put down as well. The temporary storm drain pipe was removed during the final repair process.

After Falcon Engineering's initial investigation of the sinkhole was complete, concluding that the sinkhole was caused by a break in the 8-inch ductile iron pipe (DIP) roof leader drain line below and in the vicinity of the observed sinkhole, Federal Parking engaged Falcon and RBS to provide opinions on the likely cause(s) of the pipe break. Federal Parking re-engaged Falcon Engineering and RBS to update the assessment of causes of the sinkhole after excavation and repair activities were concluded. The following conclusions were provided based on on-site observations of subsurface conditions resulting from excavation up to twenty feet below the surface.

The sinkhole was caused by a break in the roof leader pipe that allowed storm water pipe flow to uncontrollably erode/wash subsurface soils away into an unknown location, instead of keeping the storm water pipe flow contained within the designed storm water pipe system. The break in the roof leader pipe could have been initiated and caused by many different things, including but not limited to:

1. Poor quality backfill soils placed below, around and/or above the roof leader pipe at time of original construction.
2. Poor quality construction of the roof leader pipe joints/tie-in at time of original construction.
3. Material defects in the roof leader pipe and/or pipe joints used during original construction.
4. Excessive loading applied over top of installed roof leader pipe prior to adequate soil cover (backfill) being in place at time of original construction.
5. Installation, construction, repair and/or maintenance activities performed on site utilities, site facilities, etc. in the vicinity of the underground roof leader during the service life of the roof leader.
6. Degradation of roof leader pipe materials and/or pipe joint materials over its service life (~30 years).
7. Degradation of organic materials contained within poor quality backfill soils in vicinity of roof leader over its service life (~30 years).
8. Earthquake(s) that may have occurred and caused earth motion at the location of the roof leader during the service life of the roof leader.
9. Excessive vibrations caused by other activities in the vicinity of the roof leader during the service life of the roof leader.

After on-site observations of site excavations, observations of the exposed broken DIP, and observations of the non-typical as-built tie-in details of the 8-inch DIP, to three

short sections of small diameter RCP, to 54-inch RCP over a distance of only 10 feet (approx.), Falcon Engineering could not state with 100% confidence what single action caused the DIP to break or when it was actually broken during its service life. It was the opinion of Falcon Engineering that items 1, 2, 3, 6, and 7 as listed above likely contributed to causing the pipe break, along with the observed differing pipe grades (i.e., installed pipe slope inclinations) of the DIP and three sections of small diameter RCP. Falcon also believed that the initial break in the 8-inch DIP was likely caused by the non-typical dissimilar pipe materials rigid (grouted) connection observed between the DIP and the three short sections of small diameter RCP, coupled with settlement/movement of those small RCP pipes due to lack of pipe bedding stone and/or inadequate pipe subgrade support (i.e., poor underlying subgrade soils). Once the DIP pipe was broken, allowing storm water to infiltrate and further weaken the supporting and surrounding subgrade soils and create voids, the three very short sections of small diameter RCP likely continued to settle and move excessively and differentially, to the positions observed in the field during repairs. The ensuing subsidence of surface soil materials and overlying soil materials into the underlying voids also likely contributed to the further movement/settlement of the three very short sections of small diameter RCP. In essence, once the break in the DIP occurred, other failure modes that ensued over an undetermined period of time may have ultimately caused the observed sinkhole. However based on initial investigations and observations during site excavations and repairs, neither Falcon Engineering, RBS nor Federal Parking can conclusively rule out other possible causes (or contributing causes) of the pipe break, including items 4, 5, 8 and 9 as listed above.

In summary, had the ground depression area not been immediately addressed, the sinkhole would have expanded even greater, and the situation could have become much worse, possibly causing damage to Garage A's foundation, wall and other structural components. Had this occurred, the expense to repair would have been substantial, and the shutdown of the garage during any repair work would likely have created a significant (and costly) impact on the operation of the hospital, its patrons and employees. Left unrepaired, over time the damage could also have had an impact on the adjacent Hock Plaza Building (owned by Duke University Medical).