Today many Public Works and Utility Departments are struggling with impacts of rapid growth and rising cost to expand or replace aging infrastructure. A part of the southwest, the City of Phoenix has experienced tremendous growth in recent years. This growth along with new Arizona Department of Environmental Quality requirements has revealed that portions of the Phoenix wastewater collection system are at capacity or are near capacity. The potential deficiencies in capacity could impact upstream new development which is an important stimulus to the Phoenix economy. Thus Phoenix developed the Sanitary Sewer Relief and Replacement Program to address the capacity issues. Solutions to mitigate the potential capacity issues included upsizing the pipeline with full replacement, relief sewers, sewer diversion and trenchless techniques.

Project Engineering Consultants (PEC) was selected as one of eight engineering firms to provide design and construction management services for the program. Construction Manager at Risk (CM@R) was the chosen delivery method and Kiewit Western Co. was selected as the CM@R contractor. The team of PEC and Kiewit Western was assigned a sewer relief project in the vicinity of 35th Avenue and Peoria Avenue in Phoenix. The team developed an innovative approach to increase the sewer system capacity and reduce negative impacts that are inherent to open cut pipeline construction. 35th Avenue and Peoria Avenue are major arterial streets that route large volumes of traffic to and from major business centers, a regional shopping mall and Interstate 17. In addition a large number of retail shopping and commercial businesses are located adjacent to the busy streets. The goal was to minimize disruption to the surrounding community while upsizing and renewing the existing sewer lines at the lowest possible cost.

The traditional method of open cut pipeline construction was designed and evaluated using construction plans developed to the 90% complete level. At this point the CM@R and PEC provided the City detailed construction estimates in excess of $8 million. After a few modifications the initial GMP of $7.9 million for open trench excavation was presented to the City. The cost far exceeded the City's programmed budget of $5.3 million. PEC has been recognized by Trenchless Technologies Magazine as one of the Top 50 Trenchless Design Firms in the Nation since 2004 and was originally selected for their expertise and involvement in Trenchless Technologies. Trenchless construction opportunities had been discussed during the design phase but had not been pursued. Therefore, PEC proposed a Trenchless Technology known as pipe bursting.

Pipe bursting is an alternative installation method to open cut/trenching and is used to upgrade or replace existing sewer pipelines. Selecting this method of construction reduces the amount of trench required, allows for upsizing the pipe (e.g., 12-inch to 15-inch), decreases traffic control during construction and minimizes social impacts spawned from lengthy disruptions to local business and residential customers. Pipe bursting can minimize construction disruption and most inconveniences to the City's customers. The old pipe is not removed but, is fragmented into the surrounding soil. The pipe bursting construction method usually results in substantial cost savings over open cut construction. Pipe bursting installs a new pipe in the same location of the existing pipeline and generally eliminates the need for new right-of-way. The new pipe is pulled into place behind a bursting head or expander fragmenting the old existing pipe into the surrounding soil. Pipe bursting also allows the City to upsize the existing pipeline size to increase capacity. After discussions with the City staff and contractor plans and specifications were developed by PEC. The installation method was to be static pipe burst using No-Dig Vitrified Clay Pipe (VCP). The No-Dig clay pipe is an excellent material for sanitary sewer systems. The product is inert and not subject to corrosive sewer gases known as hydrogen sulfide gas (H_2SO_4). The vitrified clay product is not subject to the hydrogen sulfide gases and has sustainable benefits offering a long life of over 100 years.

Preliminary cost estimates for pipe bursting indicated that the construction cost could be reduced to less than $6 million. Final plans and specifications were then prepared. The final plans and specification using static pipe bursting resulted in a final GMP of $5.3 million and decreased the construction schedule from twelve (12) months to nine (9) months. The initial cost saving to the City was $2.6 million and Three (3) month shorter construction schedule.

Another advantage of pipe bursting is a reduction in carbon emissions. The pipe bursting process requires much less trenching resulting in a reduction of construction activities such as less saw cutting, less removal, hauling and disposal of asphalt materials. Construction trucks are not constantly waiting while backhoes load them with excavated materials to be hauled to a dump or storage site. There is also much less hauling of engineered backfill from the materials mining operation to the project to fill the excavated trenches. There is less pavement replacement, less trucking and less equipment normally associated with the repaving operation. Utilities are researched and shown on construction plans. However, because there is less open trench most utilities do not require bracing, support or relocation. Another plus is the reduced impact to traffic throughout the project site. The reduction of these construction activities has a huge impact towards the reduction of green house gasses. In fact the reduction can actually be calculated. The reduced carbon foot print for this project was over 85% less than a typical open excavation sewer installation.

The project consisted of an unprecedented upsizing of nearly 7,400 feet of existing 12 inch and 15 inch pipe, which are 10 feet to 20 feet deep and within major streets that house the usual multitude of existing utilities. The sewer layout consisted of two perpendicular main sewer lines that intersected at Peoria Avenue and 35th Avenue. The 2,500 feet along Peoria Avenue was an existing 15 inch VCP pipeline that needed to be upsized to an 18 inch diameter pipeline. The 4,700 feet sewer main along 35th Avenue was an existing 12 inch to 15 inch VCP pipe that needed to be double upsized for most of its length to an 18 inch diameter sewer line. The method of pipe bursting selected was static pull with "cartridge" loading using segmented No-Dig jacking pipe.

The static pipe bursting method of installation kept the jobsite footprint relatively small and compact. Utilizing the segmented pipe and cartridge loading technique eliminated the need for long lay-down areas that are typically required for welded pipe. "Cartridge loading" is the process for launching one section of pipe at a time. Cartridge loading is highly beneficial in high-traffic urban settings where long strings of welded pipe would interfere with vehicular access to adjacent businesses during the bursting operation. Consequently, traffic control was not a major issue for this project.

Launch and receiving pits were constructed at existing manhole locations at approximately 400 foot intervals. Trench boxes were used to stabilize the walls of the launch pits and receiving pits to provide a safe working environment while allowing ample room for equipment, crew and pipe. The bursting equipment could easily be rotated 180-degrees in the launching pit to begin bursting pipe from the opposite direction.

Communication between all parties of the project team was significant. The City's Traffic Operations worked with the contractor allowing some freedom during non-peak times for better and faster movement. PEC had full time inspectors dedicated to the project. In addition, the team met weekly to review the construction schedule, appraise work completed and prepare for future tasks. During design it was recognized that the conventional open cut construction method for the sewer in Peoria Avenue would have severely impacted the east-west movement of traffic. The existing soil conditions and probability of a 20 foot deep trench to install a new sewer would only accommodate a single lane of traffic which was not acceptable to Traffic Operations. Using the pipe bursting method of construction allowed for two (2) lanes east bound, one west bound lane and left turns at most intersections. Limited left turns were also permitted after construction hours into the local shopping centers.

Pipe bursting requires the sewer flow in the existing pipe to be bypassed or diverted out of the pipe.

The existing pipe was cleaned and closed-circuit television (CCTV) inspected to insure there were no severe alignment problems, sags, and to locate all service laterals prior to installation of new pipe. Existing service laterals were intercepted, monitored during the operation and connected into the sewer bypass system which ran alongside of the pipe bursting operation. The bypass piping was conveniently tied to the sewer system far downstream from all the operations. When a driveway was encountered, the bypass piping was trenched under and paved to allow property owners' full access at all times.

The project also included a 200 foot jack-and-bore portion through the high traffic volume intersection of 35th Avenue and Peoria Avenue. The CM@R used a local subcontractor to perform the jack-and-bore operation. The jack-and-bore installed a 36 inch outside diameter (OD) 3/8 inch thick steel casing diagonally across the intersection from the traffic island in Peoria Avenue northeasterly to the east side of 35th Avenue. 180 feet of 18 inch bell-and-spigot VCP was slipped through casing. The jack-and-bore took approximately 3.5 weeks to complete.

A number of utilities existed within both 35th Avenue and Peoria Avenue. Each utility was identified on the construction plans and marked in the field by the respective Arizona Call Center "Blue Stake". The utilities included fiber optics conduits and electric duct banks which were potholed and surveyed, waterlines, telephone conduits, natural gas lines, storm drain and connector pipes, and sewer lines. A few utilities were in conflict with a few launch/ receiving pit areas, those utilities were supported and maintained at all times.

An obstacle was encountered with an existing 40-year old 6 inch asbestos cement pipe (ACP) waterline that meandered adjacent to the 35th Avenue sewer alignment. The ACP water main began breaking at a few locations. This breakage was apparently caused by soil displacement during the pipe bursting operation. The City decided to relocate the entire portion of the ACP waterline which was within six (6) feet horizontally of the existing sewer pipe. However, the decision to relocate this existing water line would have been the same if an open-cut construction method was elected over pipe bursting. There were no other major conflicts with utilities and there were no service disruptions during construction.

Potholing of electrical utilities was performed during design. In addition to potholing, soil borings were collected every 150 feet to 200 feet along the project for a total of 19 soil borings. Soil boring data is very important for pipe bursting and bore-and-jack projects to determine feasibility. Soil classification, size, density and existing trench conditions are of particular importance when pipe bursting.

The pipe bursting operations went smoothly. However, the Peoria Avenue section did produce a few challenges and additional pits where excavated to free the bursting head at three locations. The bursting head had stopped due to conditions created during the original pipe installation and existing trench configurations. So, the contractor elected to open cut and install a short section of the new pipeline. The contractor soon discovered that it was more economical to continue pipe bursting and avoid having to open cut because production rates were considerably higher when pipe bursting could be used. One obstruction proved to be a non-compressible backfill (cementitious cap) or an existing point repair. The cementitious cap was thought to be a low strength material because the bursting operation pulled through most of it. It was mutually decided to open-cut segments where difficult ground conditions caused hydraulic pressures to increase towards the working limits of the machine. At those locations the bursting head was excavated and a short distance of pipe was hand laid. When the ground conditions improved the pipe bursting operations resumed.

In isolated cases, the original pipe was laid too close to one side of the original trench wall and not the centerline of the trench. The original trench wall was hard soil and more unyielding than the bedding and backfill materials. This condition, unlike the backfill material would not accept compaction required by the pipe bursting process. The hard material increased pulling tensions beyond the equipment's safe working limits. In these situations, the bursting head was excavated and pipe was hand laid until conditions improved. The contractor's second pull in 35th Avenue exceeded all expectations. After the first pull of approximately 98 feet, the machine was relocated downstream and the longest burst of 448

feet was accomplished. Minor cracks occurred in a paved access road but the area was to be repaved anyway. A portion of sidewalk rose around a bus bay and was easily repaired. A portion of the upstream pipe rose a few inches during the initial pull back and the contractor adjusted those few pipe sections before reinstalling a new manhole in the launching pit. The pull back was completed in only a few hours. Other than these few locations heave was not observed.

The project schedule was delayed when at the beginning of the project a record summer "Monsoon" rainfall caused excavated launch and receiving pits to flood. Rain also delayed the project for two to three days during the winter rainy season in December. Rain delays were a result of excavated pits flooding.

Static pipe bursting equipment has been around the industry for many years. Over time the equipment has evolved from a cable pulled bursting head to a more sophisticated system that uses a system of interlocked rods to pull the bursting head.

The equipment, provided by TT Technologies Inc., included a Grundoburst® 2500G static bursting machine and the accompanying tooling. This machine is capable of providing up to 315 tons of pulling force. It would prove necessary to use virtually all of the machine's capability in the difficult soil conditions encountered on the project. The Grundoburst® 2500G machine utilizes Quicklock rods between the machine and the expander that weigh approximately 400 lbs each. These rods were connected to a special 24 inch outside diameter (OD) expander sized for the 18 inch VCP. The expander had a special internal socket arrangement for the lead piece of VCP to butt against. The crew added new sections of pipe as the pull progressed and additional rods were added followed by the pipe sections which were slipped over the rods. The Cylinder Pack with three pressure plates was then employed and pinned to the rods. Next, the plate was hydraulically energized to serve two functions; (1) push the newly added pipe joint fully "home" and (2) hold the entire jacking pipe train in compression as the pipe bursting expander was pulled forward by the bursting machine.

The bursting equipment for this project was designed and assembled for the specific purpose of bursting the existing VCP and towing in the new non-restrained joint jacking VCP. Because the pipe sections are compression fit joints, a bursting system was built to push each pipe joint "home" as well as keep the column of assembled pipe sections in compression during bursting. A ride along hydrostatic machine (Cylinder Pack) attached to bursting rods inside the new pipe sections kept the column of assembled pipe segments in compression as the bursting progressed. The pipe sections were lowered into the pit and the pipe joints were pushed "home" with the Cylinder Pack via pressure plate. The Cylinder Pack provided 40 tons of force to keep the assembled pipe segments in compression (and rods in tension) as the bursting head was pulled toward the static pipe bursting machine. The Cylinder Pack was sized according to the pipe manufacturers' specification for weight of each 18 inch diameter pipe section. The rear cylinder pack pressure plate kept the assembled pipe sections in compression while the bursting head was pulled forward.

The contractor's team kept in constant telephone/radio communication and the hydrostatic pressures were observed and recorded real-time during the bursting operation. Cycle times for each section of pipe to be assembled and pulled forward during bursting began at an average rate of ½ ft per minute. As the project progressed, the crew became much more efficient resulting in average rate of 1 ft per minute. Thus, a typical 350 ft reach was completed in 5½ to 6 hours.

The static pipe bursting installation was a huge success and was the first project in the United States to accomplish a maximum drive of 448 feet using VCP and first to perform a double up size pipe burst with VCP. Most of all this installation method saved the City $2 million over open cut construction. The process shortened the construction schedule, reduced negative socio-economic impacts to the community and businesses. Carbon emissions were reduced in excess of 85% over open cut methods. In addition to these benefits the City increased sewer capacity with a new sustainable sewer line.