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NON-CIRCULAR SEWER LINER INSTALLATION AND FUTURE PROJECTS IN LOS ANGELES

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ABSTRACT: The City of Los Angeles (City) operates and maintains more than 6,500 miles of sewers ranging in size from 6-inch to 150-inch in diameter. Many of the larger diameter sewers constructed in the early 1900's were constructed of un-reinforced concrete with clay tile liners or of brick. Approximately 64 miles of sewers were constructed using non-circular pipes. A number of these sewers are not in the public right-of-way and cross under homes, businesses and other urban development. These sewers are approaching the end of their service life and need to be rehabilitated while minimizing the impacts to the community.

The City has traditionally rehabilitated larger diameter sewers using a sliplining methodology. For circular pipe rehabilitation, this method is a relatively straight forward procedure. Choose a pipe with a dimension smaller than the existing sewer and install by pushing the new pipe into the old sewer and grout the annular space. For non-circular sewers the process is more of a challenge.

A majority of the non-circular sewers were constructed by hand or cast-in-place. The inside dimensions of these sewers may vary complicating rehabilitation by sliplining by requiring a larger annular space or verification of shape and size prior to liner pipe fabrication. The City recently completed a short installation of non-circular sliplining into a 100 year old sewer using a glass fiber reinforced polymer mortar pipe that required verification of the shape and size of the existing sewer as well as addressing concerns about pipe rotation during the sliplining operation and annular space requirements.

This paper will discuss the short installation of non-circular lining into a 57-inch by 72-inch oval brick sewer and the lessons learned during this installation that will be used on future projects. This paper will also discuss upcoming projects that will rehabilitate several miles of the City's non-circular sewers utilizing both sliplining and man-entry methods.

INTRODUCTION

The City of Los Angeles owns and operates one of the largest wastewater collection and treatment systems in the world. The City operates and maintains over 6,500 miles of sewers and 4 wastewater treatment facilities with a combined treatment capacity of 550 million gallons per day (mgd). Sewer construction in Los Angeles began in the 1870's and had major construction periods in the 1920's and 1950's. Many of these older sewers are approaching the end of their useful service life and need to be replaced or repaired to continue serving the citizens of Los Angeles. Several projects have been successfully constructed that rehabilitated larger diameter circular sewers. The City has now begun to implement a rehabilitation program for non-circular sewers which included the short repair of the Central Outfall Sewer (COS), one of the oldest sewers in Los Angeles.

BACKGROUND

Sewers in Los Angeles began to be constructed in the late 1870's. These sewers would convey the sewage to the outskirts of the City where the sewage would then be used for irrigation. As this practice was abandoned, the City began constructing sewers that conveyed the sewage to the ocean. One of the first sewers constructed in 1904 was the Central Outfall Sewer (COS), an oval brick sewer consisting of 2 or 3 layers of bricks. This sewer remained in operation for approximately 20 years before the effects of corrosion and capacity limitations required the replacement of this sewer by the North Outfall Sewer (NOS). Major construction of sewers occurred in the 1920's that provided the backbone of the City's collection system. The larger diameter outfall sewers were typically constructed of un-reinforced concrete and incorporated clay tile liners above the springline to protect the concrete from the attack of sulfuric acid. As the City continued to grow and required additional sewer capacity, the COS was subsequently repaired in the 1940's returned to service. Figure 1 shows the major sewers in the City. As the sewers in Los Angeles continue to age, the City has moved forward on rehabilitating the collection system.

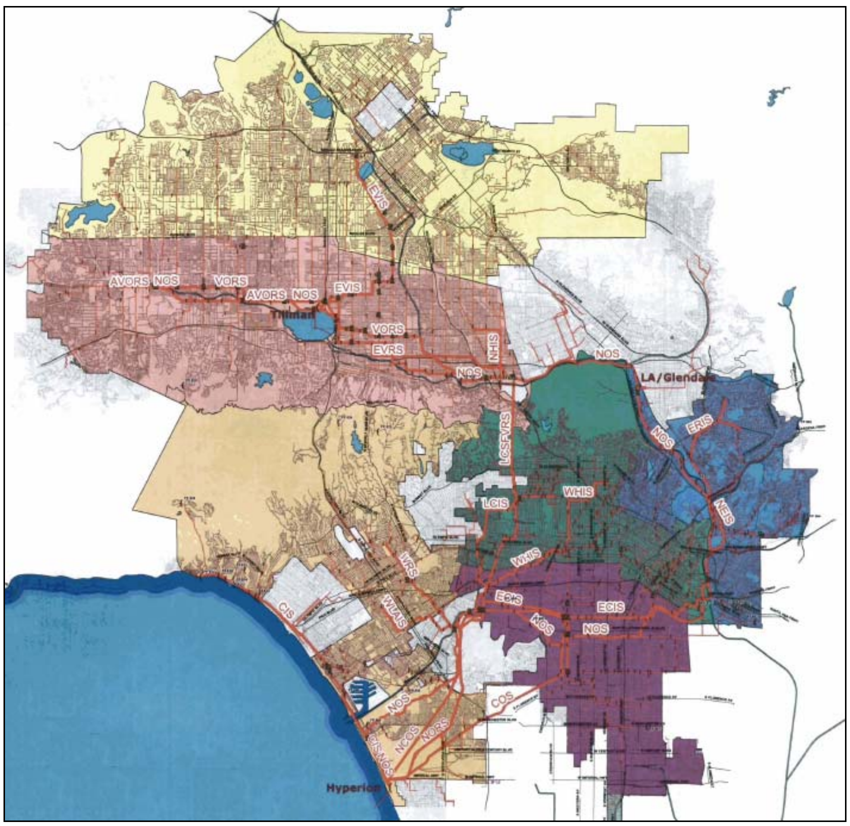

Figure 1. Collection System – City of Los Angeles

SEWER REHABILITATION

The City has successfully rehabilitated a number of larger diameter sewers. These projects include the 60-inch semi-elliptical West Los Angeles Interceptor Sewer (WLAIS), portions of the 60-inch by 73-inch oval COS, and 63-inch to 102-inch circular portions of the NOS. Rehabilitation methods using sliplining and man-entry have both been used on these projects.

The COS and the NOS projects were rehabilitated using a sliplining process. This work included excavation and construction of access pits, cleaning and removal of debris, installation of a circular sewer typically 9-inches smaller than the diameter of the existing sewer, and grouting of the annular space. This reduction in size allows sufficient annular space for the slipliner pipe to be successfully installed into the old sewer. During one of the earlier sliplining projects on the 102-inch-diameter NOS, the annular space was reduced to approximately 3 inches between the old sewer and the new slipliner pipe. Due to debris in the sewer and irregularities in the interior surface, the sliplining operation was challenging and required removal of the clay tile liners before the slipliner pipe could be installed. Allowing additional annular space on the following projects has eliminated this problem. Approximately 40,200 feet of circular pipe ranging in diameter from 57-inch to 102-inch have been rehabilitated by sliplining to date.

The WLAIS was rehabilitated using a man-entry cast-in-place PVC liner. This method was chosen to maintain the shape of the sewer in lieu of installing a circular slipliner and losing 40-50% of the hydraulic capacity. This rehabilitation work required a major bypass of approximately 35 cfs to allow the workers to be inside the sewer. Approximately 3,750 feet of sewer was rehabilitated. Challenges in the project consisted of working in a small confined space area, controlling the heat of hydration during the grouting process and installing a dependable bypass system during construction.

The City has rehabilitated a majority of the larger diameter circular un-lined concrete sewers and is now pursuing rehabilitating non-circular sewers that are in need of repair. Until recently repair of these sewers were limited to man-entry or cured-in-place-liners which require full bypasses of the existing sewer, which may not be always feasible, especially in a highly developed urban environment of Los Angeles. The City has recently approved new lining materials and methods that will allow these non-circular sewers to be repaired while maintaining the sewers in operation or minimizing the bypass requirements.

NON-CIRCULAR SEWERS

The City has about 54 miles of semi-elliptical sewers ranging in size from 24-inch to 126-inch in height. The City sewers also include about 8 miles of 57-inch by 72-inch and 60-inch by 73-inch brick oval sewers. Figure 2 shows the non-circular sewers in Los Angeles. Figure 3 shows the typical cross sections of the semi-elliptical pipe and the oval pipe used by the City.

Figure 2. Non-Circular Sewers in the City of Los Angeles

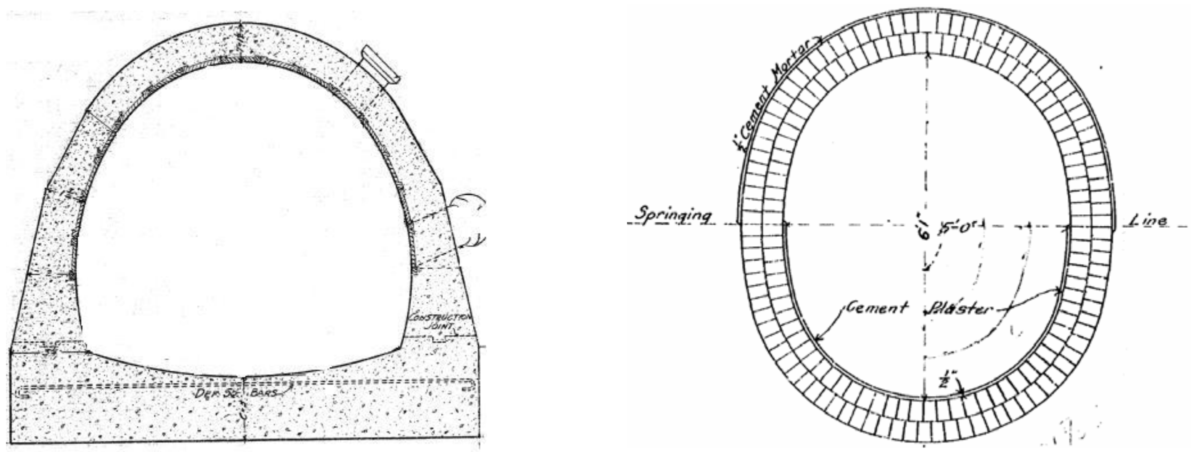

Figure 3. Semi-elliptical and Oval Sewer Cross Sections

These semi-elliptical and oval sewers were constructed between the early 1900's and the 1920's. In the early 1950's some larger semi-elliptical sewers were constructed however these were lined using a PVC liner. The City has implemented a design standard that all larger diameter concrete sewers be lined using PVC. However, the older un-lined concrete sewers have reached the end of their useful service life and these sewers need to be rehabilitated.

The Slauson/V an Ness/Central Outfall Sewer (COS) External Bypass and COS Diversion to North Outfall Sewer (NOS) from Van Ness to Slauson Project (Slauson/Van Ness Project)

The Slauson/Van Ness Project constructed two diversion structures at the intersection of two major sewer lines, the 75-inch-diameter North Outfall Sewer (NOS) and the 57-inch x 72-inch oval shaped Central Outfall Sewer (COS). The structures would facilitate flow diversion for future repair projects planned for both aging sewer lines and balance the sewage flows in the collection system. Figure 4 shows a diagram of the Project.

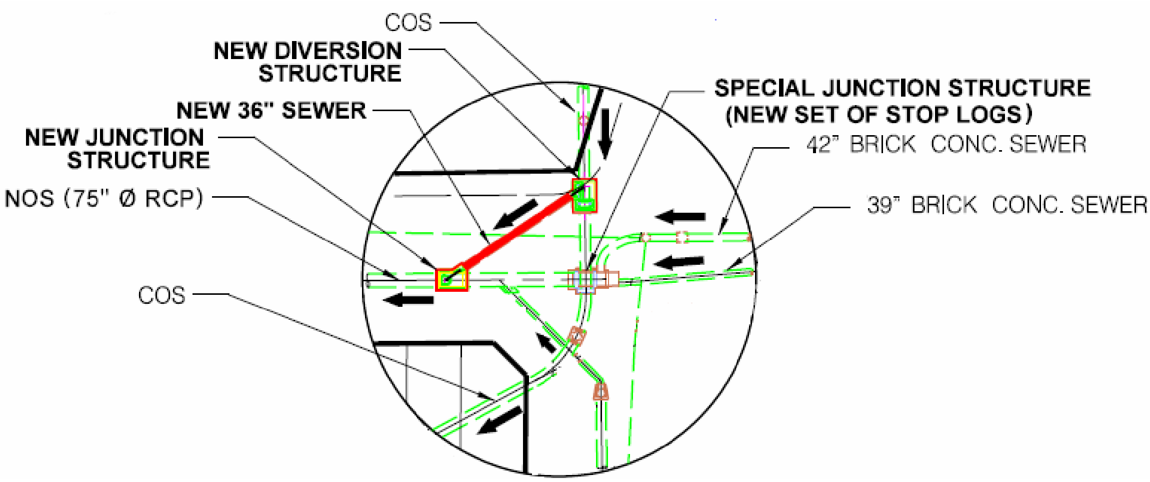

Figure 4. Diagram of the Slauson/Van Ness Project

The first phase of the project modified the special junction structure at the COS/NOS intersection as well as constructed a new junction structure along the NOS. Stop-log installation modified the existing special junction structure where two existing brick sewers, 39-inch and 42-inch in diameter, join together and flow into the NOS at its intersection with the COS. With the flow diversion of the 39-inch and 42-inch sewers into the COS, the south branch of the NOS was hydraulically relieved thus reducing the possibility of spills. The new junction structure installed along the NOS was designed to accept flow from the COS sewer through a 36-inch sewer that was installed during the second phase of the project. These structures would allow for the COS to be taken out of service during future repairs, rehabilitation, or maintenance work.

The second phase of the project constructed a new 36-inch diameter sewer between the COS and NOS and built a diversion structure at the COS that would allow flow to be diverted to the new junction structure installed during the first phase of the project. When the contractor excavated the pit to construct the diversion structure, it was found that the existing COS pipe, made of brick and mortar, had a number of longitudinal cracks. It was not known how far these cracks traveled along the pipe. Further inspection showed that some of the original bricks were gone and this section of pipe was in very poor condition and falling apart. The Contractor did not want to continue with the construction of the diversion structure, fearing that the additional load of the new structure and vibration from construction activities may collapse the existing pipe and cause sewage spillage, construction safety issues, and possibly even a sink hole right in the middle of this busy intersection.

After a number of meetings with all of the City of Los Angeles (City) agencies involved with the project and further investigations, it was concluded that due to the safety concerns and questionable structural integrity of the pipe, it was not advisable to have any man entry repair/rehabilitation performed inside the pipe. It was also agreed that a slip liner inserted in the existing COS sewer line (host pipe) was the only method of repair that would satisfy the construction safety needs.

Because the existing pipe was of an irregular shape (oval) and constructed of brick and mortar, it was not known if the pipe's internal dimensions would be uniform throughout. Although inserting the largest possible circular liner and grouting the void was considered because of availability and proven effectiveness in previous City projects, it was not a viable option because it would have reduced the hydraulic capacity (flow) of the existing sewer by about half. It would also create a bottle neck in this part of the COS line once the upstream side became due for rehabilitation. Maintaining the existing capacity was the greatest concern for the project, an alternative method had to be found. This presented a unique challenge for the City. Not only had the City never utilized non-circular lining for its large repair projects, the project was under a tight schedule as the sewer had already been excavated and additional delay would cause additional cost and even further impact to the surrounding community. The City utilized the services of Ameron International to expedite the design and fabrication of an oval (non-circular) liner. This material was in the final stages of City approval at the time of this project.

It was determined that a non-round fiberglass reinforced polymer mortar pipe (RPMP Non-round) lining that fit as closely as possible to the existing pipe shape would be the best option for retaining as much flow capacity as possible and providing a structural repair to the existing sewer. However, this had to be custom made! In order to determine the proper dimensions for the new liner, a plywood template was constructed. The template was physically inserted through the 41 feet of pipe to be lined to ensure that the liner would fit through the entire repair length. The plywood template then became the template for the custom-made liner. Figure 5 shows the dimensions and configuration of the pipe.

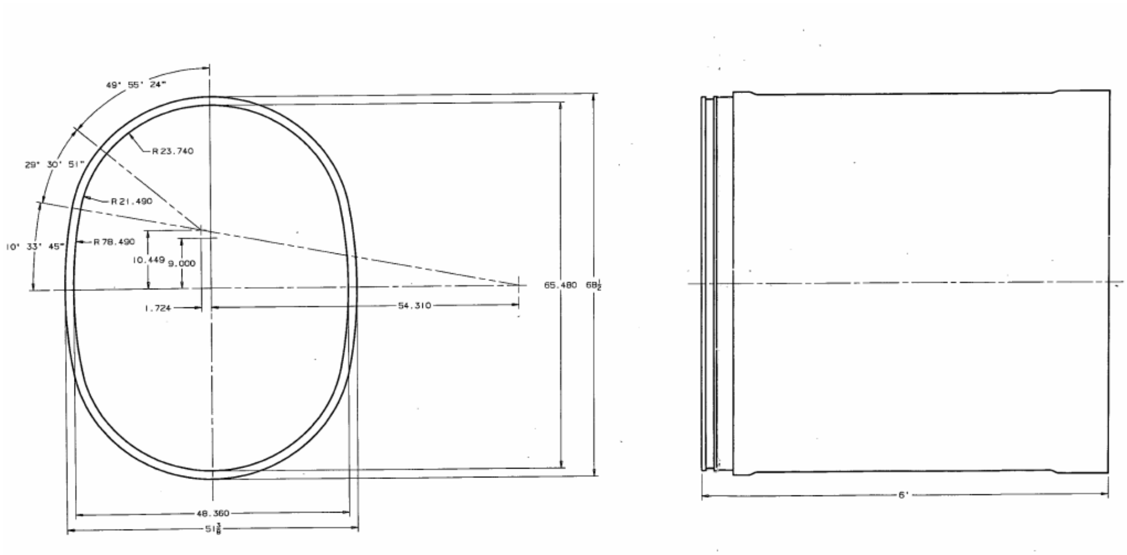

Figure 5. Configuration of the oval slipliner for the COS

The City provided Ameron International with a sketch of the outline of the plywood template. With this custom made template, Ameron was able to design and manufacture an oval pipe that fit within ½ inch of the template dimensions. The liner pipe was fabricated into 6 foot segments and was inserted into the sewer through the existing pit of the diversion structure. A bell and spigot joint was used in lieu of the typical flush joint used on previous sliplining projects. The City had requested that anti-rotational devices be used on the slipliner to prevent the pipe from rotating or tipping during the installation process. During the actual installation these were not used because the Contractor opined that they were not necessary. Field observation verified that on this particular installation these devices were not needed. The 2-inch annular space that remained between the outer dimensions of the liner and the brick sewer was then grouted to City standard specifications. By utilizing this method, the city was able to retain the original cross section and minimize the loss of hydraulic capacity while effectively rehabilitating the line to prevent future failure.

This installation of non-round liner for the Slauson/Van Ness repair will prove advantageous in the upcoming rehabilitation of the eight miles of the COS and other future projects that call for rehabilitation of irregular shaped sewer lines. The City will benefit from the innovation used to rehabilitate the oval-shaped Slauson/Van Ness sewer.

NEAR TERM NON-CIRCULAR SEWER PROJECTS

The City has several upcoming sewer rehabilitation projects that are in design and will be constructed over the next few years. These projects include rehabilitation of the North Outfall Sewer, the La Cienega Interceptor Sewer and the Central Outfall Sewer.

North Outfall Sewer Maze Phase 5

When the North Outfall Sewer was constructed the system was diverted into two branches in the south central part of the City and then subsequently joins together further downstream. This area has become known as the ‘Maze’. A majority of the maze was constructed using circular sewers and has been rehabilitated. The last portion of this system to be rehabilitated is the Maze Phase 5 (Maze 5) project.

The Maze 5 project will rehabilitate 8,471 feet of sewers that includes 60-inch semi-elliptical, 42-inch semi-elliptical, 63-inch circular and a short section of 75-inch circular pipe. The project will also include the rehabilitation of two junction structures. The rehabilitation of this sewer is being designed by either sliplining or by man-entry installation of a PVC liner with 4-inches of high strength concrete. The concrete will provide the structural strength while the PVC provides the corrosion barrier. The slipliner pipe will be a glass fiber reinforced polymer mortar pipe. The contractor will have the choice of using either method.

Access pits are one of the major issues being addressed during the design phase. Should this sewer be installed by man-entry or by sliplining, the contractor will need access pits for cleaning the sewer or for gaining access to the sewer for construction purposes. The Maze 5 project has multiple curves with a small 50-foot radius that typically prevents sliplining around the curve. For this project construction will allow the curves to be open trenched to allow the pipe to be installed around the curves by removing the top of the existing sewer pipe or by man-entry methods. The design of this project typically provides access pits on either ends of the curve or at a transition in pipe sizes. These access sites will impact not only the local residents but overall traffic through the project area.

Traffic control is a major issue with this construction project. As access pits will be required for construction, this will have impacts to the traffic lanes. The sewer is typically in small residential streets and will require a full closure of the local street during construction while the pit is being used. The contractor will be required to maintain access for local residents and access to all private property. The rehabilitation of one of the junction structures will require a full closure of a major street. An aggressive and comprehensive community outreach program is being used to inform the residents of these impacts as well as providing mitigating traffic measures such as traffic signal modifications and planned detour routes.

Sliplining of this sewer will be one of the first installations of a non-circular liner in Los Angeles. This has required the modification of the semi-elliptical shape for the new slipliner pipe. Figure 6 shows the revised shape compared to the existing cross section. This modified cross section was designed to balance the structural requirements and minimize the reduction of capacity. One of the concerns discussed during the design is the rotation of the slipliner during installation. The contractor or manufacturer of the pipe will be required to provide skids along the bottom of the slipliner to prevent this from occurring. This cross section also allows a 3-inch annular space on the sides and top of the sewer. The contractor will be required to verify that the new slipliner can be installed by pulling a mandrel through the sewer prior to the actual sliplining. This mandrel will be the same dimensions as the slipliner pipe to be installed.

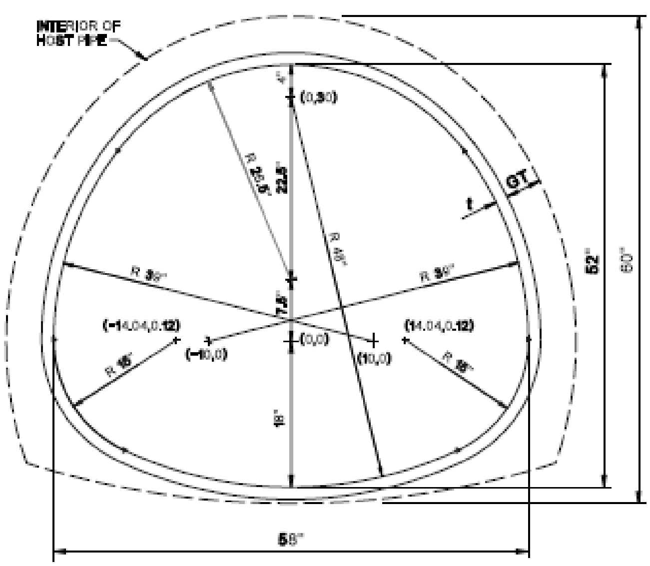

Figure 6. Modified Semi-elliptical slipliner for Los Angeles Sewers

This project is currently scheduled to start construction in winter 2008. The project has an estimated construction cost of 20 million dollars and will take 2 years to complete construction.

Central Outfall Sewer
The rehabilitation of the COS has been divided into three projects or phases. The first phase of the COS rehabilitation was completed in 2000 which traversed under the Los Angeles World Airport. The upcoming rehabilitation phase will be the COS Rehabilitation NORS Diversion 4 to Market Street project which will rehabilitate nearly three miles of the 60-inch by 73-inch oval brick sewer. When this sewer was constructed in 1904 this area of Los Angeles was undeveloped and mainly farmland. As the City grew, development occurred around and above the existing sewer and this sewer is typically not in the public right-of-way but in a 15-foot wide easement. The sewer is now in a highly urbanized area consisting of commercial, industrial, single and multiple unit residential neighborhoods. In some cases buildings have been constructed over the sewer limiting surface access to the pipeline requiring a trenchless rehabilitation method to be used.

The rehabilitation design of this project has centered on two basic rehabilitation technologies to be used, sliplining using a non-circular slipliner similar to the Slauson/Van Ness sewer repair and installation of a PVC liner by man-entry methods. Figure 7 shows the lining options for the COS pipeline rehabilitation. The contractor will be allowed to select the method during the bidding process.

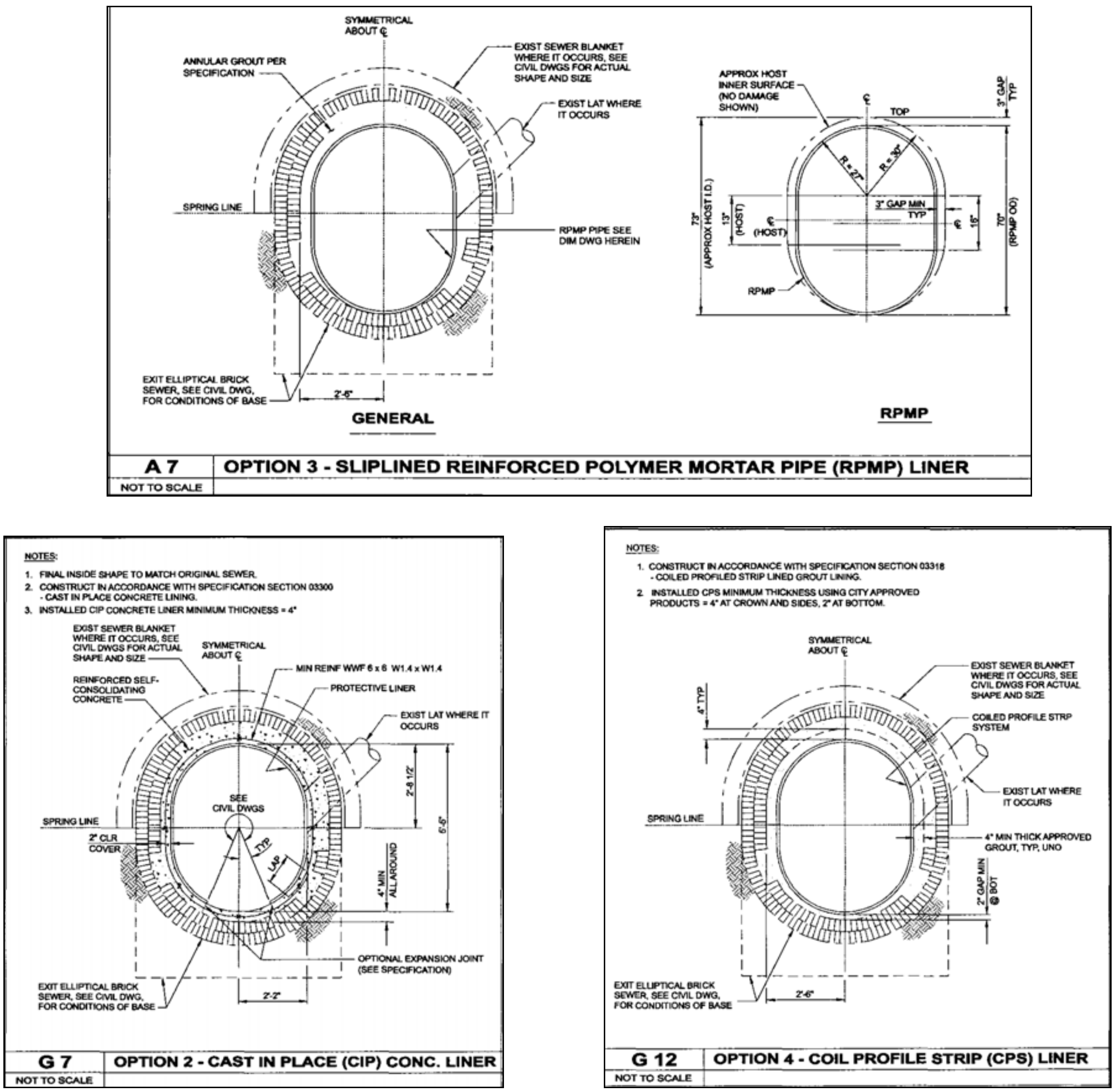

Figure 7. Rehabilitation sections for the COS

Access sites are one of the key elements being addressed in the design phase. For this project, primary access sites are being provided every 1,500 feet to 2,600 feet depending on surface restrictions and availability of land for a work site. Secondary work sites are also being provided for maintenance hole abandonment, lateral reconnections, grouting operations and other ancillary work involved with this rehabilitation project. The sliplining or man-entry installations will have to be installed within these access site parameters as additional access sites are not available.

This sewer has experienced substantial corrosion and loss of bricks requiring a fully structural repair to be implemented. The COS in some cases has lost one layer of bricks from springline to springline. CCTV and laser inspections have also revealed areas of loose bricks which will likely be removed during the cleaning and rehabilitation operations. In the case of the cast-in-place liners and the coil profile strip liner, the concrete placed behind the PVC liner will be 5,000 psi. The RPMP liner will be designed for the full load condition for this sewer.

This project is currently scheduled to start construction in winter 2008. The project has an estimated construction cost of 30 million dollars and will take 2 years to complete construction.

La Cienega Interceptor Sewer

The La Cienega Interceptor Sewer Rehabilitation will repair 2,200 feet of 63-inch semi-elliptical pipe. This sewer was originally constructed in the mid 1920's and has experienced severe corrosion. The downstream section of the LCIS collapsed in 2006 causing substantial damage to a building that was directly over the sewer. The portion to be rehabilitated is in better condition but requires near-term attention to avoid additional emergencies.

This portion of the LCIS is predominantly within a sewer easement and access will be significantly limited. The upstream end of this project is located in a highly traveled road where any construction will create significant traffic delays. In addition, this sewer contains a number of curves where surface access is not feasible due to commercial and industrial developments that have occurred over the sewer alignment. This sewer will need to be rehabilitated within these access site limitations and utilizing a trenchless methodology.

This project is being designed to be rehabilitated by either sliplining, where feasible, and by man-entry techniques. At this time it is anticipated that the straight portions of this project, approximately 1,000 feet will be rehabilitated by sliplining and the remaining sections installed by man-entry. The contractor will be required to comply with Cal OSHA tunnel safety orders for the man-entry portion of the project as opposed to confined space requirements. Ventilation and odor control will also be a key issue during the construction of this project. The contractor will be required to provide required ventilation for the workers and to provide an odor control system that will scrub the ventilated air so that the hydrogen sulfide discharge is less than 10 parts per billion from the construction site.

This project is currently scheduled to start construction in spring 2009. The project has an estimated construction cost of 4 million dollars and will take 1 year to complete construction.

North Outfall Sewer

The North Outfall Sewer was constructed in the 1920's and extends from the Hyperion Treatment Plant near Los Angeles World Airport to the San Fernando Valley, nearly 44 miles in length. The lower NOS is currently being rehabilitated after being out of service for about 10 years. With the portions previously repaired, about 30 miles of this system remains to be rehabilitated in the future.

This sewer is currently scheduled for rehabilitation following the completion of the Maze 5 project. Due to the large estimated construction cost for the rehabilitation of the North Outfall Sewer, the City currently plans to rehabilitate approximately 1 mile per year with an estimated construction cost of 10 million per year. This project will be able to incorporate the lessons learned from the COS, LCIS and Maze 5 construction projects relating to access site requirements, sliplining of non-circular pipes and overall construction procedures.

CONCLUSION

The City of Los Angeles is moving forward in the rehabilitation of non-circular sewers. Lessons learned on prior projects and using newly developed materials will allow these sewers to be repaired and provide service to the citizens of Los Angeles for decades to come.