FLOOD TUNNEL –A SOLUTION TO HOUSTON'S STORMWATER CONVEYANCE PROBLEM.

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Abstract

Hurricane Harvey caused catastrophic flooding across the Houston, but this was not a once in a lifetime event. Tax Day 2016, Memorial Day 2015, and other storms have also resulted in severe flooding conditions across the Houston metro. As the city has grown, the ability to detain and convey stormwater at the surface has become more challenging. Tunneling is a solution for stormwater conveyance that has not been considered before in Houston but should be evaluated.

1. Introduction

Hurricane Harvey was an unprecedented storm, resulting in $125 billion in damages, flooding 300,000 structures in southeast Texas (1). Although unprecedented, flooding from torrential rain is not new to the Houston area. Following Hurricane Harvey many started to wonder what could be done differently to reduce the impact of future storms. The "flood tunnel" concept was born from this outside-the-box brainstorming. Although still a chalkboard idea it holds significant promise for reducing flood risk across Houston.

2. The Flood Tunnel

The flood tunnel, also known at the "Super Tunnel" by some in the Houston area is not a new concept, in fact it builds on previous plans while utilizing different construction methods. Recognizing the need for floodwater conveyance, the U.S. Army Corps of Engineers (USACE) in the 1940s planned a North and South Canal across the growing city. Since then, generations of Houstonians have recognized the need to move stormwater. As Houston's population has grown more than 10 times over the last 80 years, once-feasible routes for the surface diversion canals the USACE envisioned are no longer possible. In the mid-1990s when Interstate 10 was being expanded, another concept to move stormwater across the city was investigated, but the high cost sunk the project and the opportunity faded.

Since the mid-1990s San Antonio, Austin and now Dallas have chosen to address urban stormwater challenges by building large diameter inverted siphon stormwater tunnels. The San Antonio River Tunnel was completed in 1997 for $111 million and a year later prevented significant flooding in the Riverwalk and Downtown. The 24-foot diameter tunnel 150 feet below downtown San Antonio has continued to protect the Riverwalk from other events in 2002, 2013 and 2015, allowing the area to flourish (2). The Waller Creek Tunnel in Austin, completed in 2017 for $161 million has removed 28 acres of land from the floodplain on the east side of

Downtown Austin, encouraging reinvestment and growth (3). Not to be outdone, the City of Dallas is currently building a 35-foot diameter tunnel to provide much needed drainage relief for east Dallas and the Baylor Medical Center (4).

Until recently the soft clay and sandy soils, high groundwater and flat terrain had deterred aspirations for a large diameter tunnel in Houston. Although close by, the other Texan tunneling examples have distinct differences from Houston. The tunnels in San Antonio, Austin and Dallas were all excavated in rock, which is generally less complicated to mine and support than Houston's clay and sand. Also, Houston is much flatter, with only 2 to 3 feet of fall per mile (5). San Antonio for example has 35 feet of differential elevation over 3 miles, providing significant driving head allowing the tunnel to move more stormwater.

Fortunately, over the last 30 years significant advances have been made in soft ground tunneling below the groundwater table, resulting in cost effective solutions that can now be applied in Houston. Additionally, the diameter range for tunneling has grown substantially. In the 1980s the largest machine capable of mining in geology like Houston was approximately 20 feet in diameter. Today the largest machine in the world has a diameter exceeding 57 feet. This large diameter helps counteract Houston's flat terrain by providing a larger flow cross section.

3. How it Works

Although tunneling is a potential solution for multiple watersheds in the Houston region, this paper focuses on a future tunnel connecting Barker & Addicks Reservoirs to the Houston Ship Channel. The area surrounding the reservoirs and Buffalo Bayou experienced significant flooding and was at the center of controversy around the flood water release from the reservoirs. Houston is flat, but there is nearly 100 feet of differential elevation between the maximum water surface elevation (WSEL) in Barker Reservoir and the normal WSEL in the Houston Ship Channel. This differential elevation acts as driving head when the reservoir is connected to the Ship Channel with a large diameter inverted siphon storm water tunnel. An inverted siphon works entirely by gravity, no pumping required. All the large diameter Texan tunnels mentioned are inverted siphons.

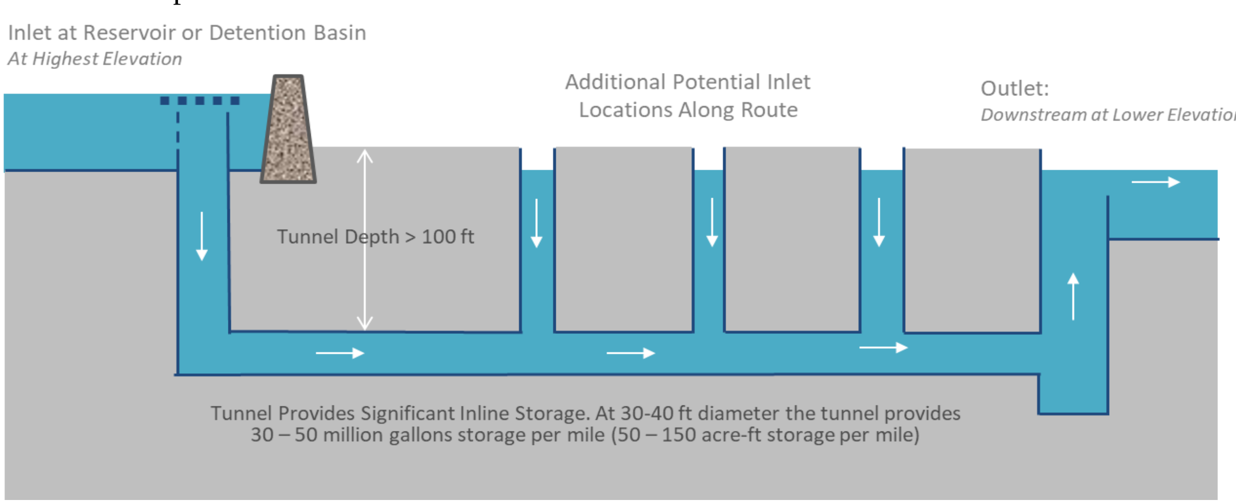

Figure 1 – Flood Tunnel Typical Profile

A large diameter inverted siphon tunnel exceeding 30 feet in diameter can convey 10,000 cubic feet per second (cfs) or more. The tunnel flow rate is calculated based on the differential elevation (driving head), tunnel diameter, tunnel length and roughness of the tunnel lining.

Had the tunnel existed during Hurricane Harvey, the operational flexibility provided by the tunnel would have substantially improved reservoir reliability and reduced flood damages both upstream and downstream of the reservoirs. Instead of being forced to hold water during the storm, the reservoirs could have potentially discharged up to 10,000 cfs to the Ship Channel through an underground tunnel. This release would have substantially reduced the amount of floodwater stored in the reservoirs, thereby reducing the water surface elevation and upstream flooding. The tunnel's ability to discharge water during the storm, and after the storm without the water touching Buffalo Bayou would have also reduced flood damages downstream of the reservoirs.

4. Why Tunnel?

Tunneling is inherently low-impact and can move and store storm water with very little effect on the surface, benefiting communities while addressing or even avoiding environmental concerns. Tunnels of this size are excavated deep below the ground surface, resulting in an imperceptible construction operation away from the shaft sites. Shaft site spacing can be as far as three to five miles, allowing considerable flexibility to identify shaft sites that are low-impact.

Tunneling can also extensively utilize existing public right of way, minimizing property acquisition and avoid displacing homes and businesses. If the tunnel must cross private property, access is provided with a subterranean easement. Because of the depth of the tunnel it is unlikely that this easement will affect future development of the property – unlike surface easements or utility easements. Since subterranean easements have limited impact, the cost to acquire them is reduced and there are fewer concerns from property owners about granting them.

5. What Does it Cost?

Based on similar large diameter soft ground tunnels built or under construction in the United States, $100 million per mile for a 30 to 40-foot diameter tunnel has been used as an early cost estimate. Therefore, a tunnel from the reservoirs to the Ship Channel exceeding 20 miles in length represents a significant investment in excess of $2 billion.

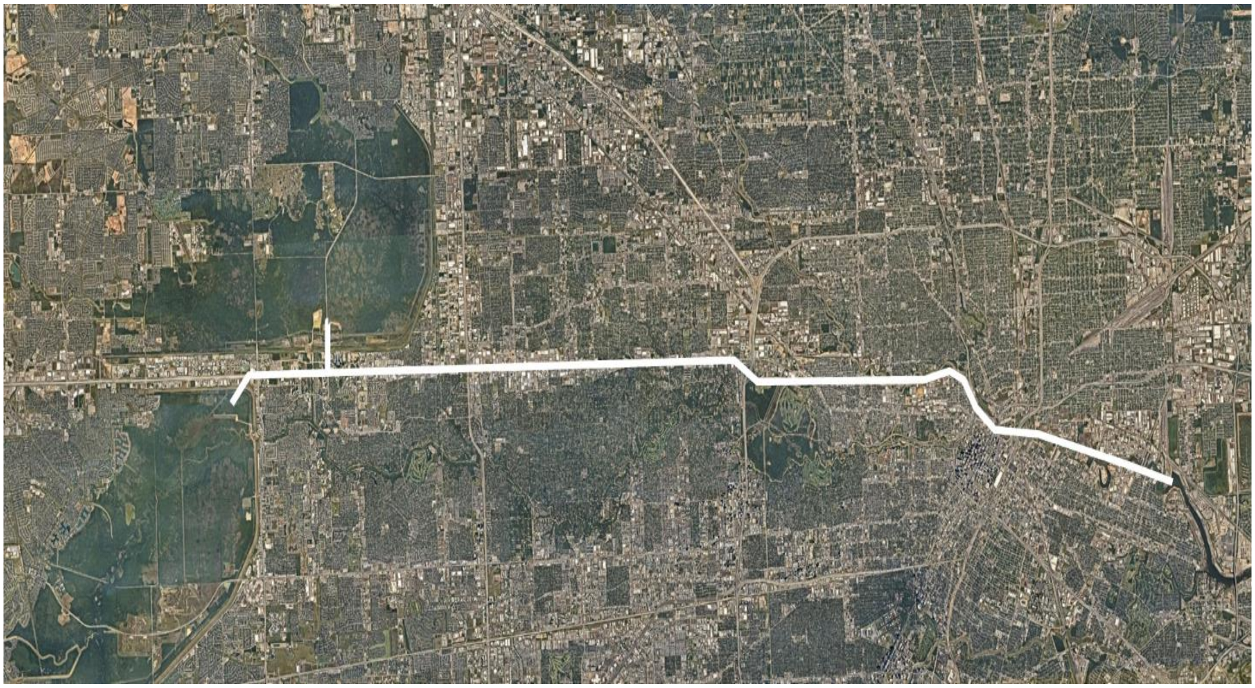

Figure 2 – Potential Flood Tunnel Alignment

Although significant, the cost of the project must be taken in context. First, what is the magnitude of the flood damage reduction provided by the tunnel? Although this has yet to be analyzed in depth, as discussed previously regional damage assessments have been reported to range between $3 billion and $6 billion along Buffalo Bayou, not including property devaluation due to flood risk concerns (8). Properties upstream of Barker and Addicks Reservoir experienced significant damage as well. Upstream of Barker Reservoir in Willow Fork Drainage District alone an estimated 5,000 properties (half of all properties in the District) were flooded. Estimated damages in this neighborhood alone are nearly $2 billion (9).

Secondly what would it cost to improve Buffalo Bayou to convey the necessary 10,000 – 15,000 cfs? Early estimates prepared by the West Houston Association following Hurricane Harvey have estimated a channel width exceeding 500 feet would be required for 100-year capacity. Such a channel would require significant property acquisition, estimated at over $4.1 billion (10), not including costs of improving the channel. Even if the funds existed to acquire the property, community and environmental concerns would likely derail a plan to significantly improve Buffalo Bayou.

Finally tunnel costs have continued to become more competitive as the industry has matured and risk is better managed on projects. The Dallas Mill Creek Tunnel project bid in 2018 for $206 million inclusive of 5 miles of 35-foot diameter tunnel, 6 shafts and a dewatering pump station. At $40 million per mile, the Dallas Mill Creek Tunnel project indicates that total project cost assumptions may be conservative.

6. Conclusion

Although tunneling is not a magic bullet it can provide significant flood protection benefits while navigating challenges that have derailed previous projects. Tunneling should be considered for all future flood conveyance projects large and small in Houston, particularly where urban, environmental and community constraints are challenging.

7. References

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