The tunnel construction and UFT maintenance are two most costly elements in implementing UFT system between the Port of Houston and the City of Dallas. Cash flow analysis of the UFT system cost components for the life cycle of 100 years, revealed that the total cost of the system would be $21.5 billion in present time.

Benefit-cost analysis results show that the NPV of the system for this route is about $59.7 billion for the 100-year life cycle. The benefit-cost ratio and internal rate of return of the system are about 3.77 and 12.44%, respectively. The calculated benefit-costs ratio shows the benefits of the system outweigh the costs by three times, during its service lifetime. Likewise, comparing the obtained internal rate of return and the market discount rate indicates the economic feasibility of this project.

Table 3. Present Value of the Costs for a Container Size UFT from the Port of Houston to Dallas (Najafi et al. 2016)

Costs	Present (2016) Value of Costs ($Million)
Fuel Tax Revenue Loss	$1,520.26
Tire Tax Revenue Loss	$99.15
Maintenance of Tunnel	$6,105.35
LIM Power Consumption	$881.70
LIM Maintenance	$32.75
Tunnel Construction	$11,651.64
Handlers	$8.80
Administrative Cost	$181.08
Freight Vehicles	$1,014.13
LIM	$12.50
Terminal Land	$1.43
Terminal Development	$10.05
Total	**$21,518.84**

DISCUSSION OF RESULTS

Although the results of benefit-costs analysis presented in this study along with technological advancements illustrated in the literature (Zandi and Kim 1974; Howgego and Roe 1998; Liu 2004; Egbunike and Potter 2011; Najafi et al. 2016) show the feasibility of implementing freight pipelines, there are still several risks associated with construction of large underground tunnels that affect the success of these projects. Ghosh and Jintanapakanont (2004) identified 54 risk factors related to tunneling (and pipelines) projects such as subsurface conditions of groundwater, permit and regulation, and defective design. Further study is required to assess how these risks impact feasibility of UFT projects.

Financial challenges such as high capital cost is one of the major challenges and barriers that would dissuade investors and decision makers from investing in the UFT projects. Although, present study shows that implementing a UFT system between The Port of Houston and the City of Dallas would be highly beneficial, substantial capital cost of this system is the biggest challenge in front of decision makers. Therefore, further study on innovative financial instruments and policies to attract capital for these projects is recommended.

CONCLUSIONS

Building new innovative intermodal freight transportation systems, such as UFT not only increases the capacity of freight movement but also alleviates the deterioration of existing transportation infrastructures and boost the economy. Being able to use a part of the underground space of the existing highways, will greatly facilitate the construction of such systems and reduce their construction costs. Using modern and efficient propulsion systems such as linear induction motors makes the UFT systems more promising these days.

The benefit-cost analysis showed that the benefits of implementing an UFT system between the Port of Houston and the City of Dallas would be rigorously outweigh the costs associated to that system in its 100-year life cycle. The net present value of the system and the benefit-cost ratio calculated from BCA showed this system would be economically beneficial. Comparing the internal rate of return of the system with the discount rate clearly confirms the economic viability of the system as well.

LIST OF ABBREVIATIONS AND ACRONYMS

B_t	Benefits at time *t*
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
C_t	Costs at time *t*
CUIRE	Center for Underground Infrastructure Research and Education
FHWA	Federal Highway Association
I-45	Interstate Highway 45
IRR	Internal Rate of Return
LIM	Linear Induction Motors
NPV	Net Present Value
TRB	Transportation Research Board
TxDOT	Texas Department of Transportation
UFT	Underground Freight Transportation
USOMB	U.S. Office of Management and Budget
UTA	The University of Texas at Arlington

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Kings River Pipeline

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Introduction

The City of Fresno was facing a dire water supply future before maneuvering the political climate to pass a necessary water rate increase that allowed the City to move forward with the design and construction of a new 80 mgd Southeast Surface Water Treatment Facility (SESWTF). The water rate increase, and the capital budgets assumed that raw water to the plant would be delivered the way it has traditionally, through existing irrigation canals. However, the existing irrigation canal identified to convey water to the site was historically a riparian corridor where the furthest reaches upstream and downstream were channelized by the Fresno Irrigation District. The thickly vegetated, winding riparian corridor, created concerns with water quality permitting agencies, and the extensive amount of tree removal required to provide access roads for water quality monitoring created a situation where it was increasingly apparent that the irrigation canal was going to create significant cost, environmental, and permitting constraints. The design team needed to develop a pipeline alternative quickly to keep the treatment plant project on schedule. Carollo conducted an alternatives evaluation to determine the cost comparison for pipeline alternatives relative to the costs of the required improvements for environmental mitigation, quality control improvements, and the unknown of permitting.

The work performed included the following elements:

- Canal and pipeline conveyance routing alternatives
- Development of diversion facility criteria
- Diversion facility design
- Operational and hydraulic analysis
    - System hydraulic analysis
    - Sediment load evaluation
    - Transient surge analysis
- Development of pipeline design criteria
    - AWWA C200 Steel Pipe Design Criteria
- Permitting agency coordination
- Geotechnical investigation

- Corrosion investigation
- Development of construction documents

Each of these elements is described in the following sections.

Alternative Analysis

Carollo worked closely with the City to develop multiple preliminary alternatives for proposed canal routing as well as pipeline routing. Figure 1 shows the proposed canal conveyance alternatives, and Figure 2, shows the pipeline conveyance alternatives that were evaluated. Ultimately, through a rigorous process the canal conveyance alternatives were determined to be fatally flawed due to the lack of acceptance by regulators, as well as the unknown impacts to the project schedule that could occur due to environmental factors, and permitting. The selected alternative included what is now the Kings River Pipeline (KRP), a 13-mile long 72-inch diameter raw water conveyance pipeline that included a new check structure and diversion upstream of the riparian habitat. The check structure is located just west of Trimmer Springs Road, and is identified as Alternative 2.A in Figure 2. Working closely with the City's program team, Carollo coordinated the pipeline design with the treatment plant design to deliver the project on schedule and under budget, to ensure that the raw water was available when the treatment plant construction was compete. Construction of the SESWTF began late 2015 with commissioning expected around mid-2018.Pipeline Alignment Routing Analysis

A preferred alignment was established by Carollo and the Program Management Team (PMT) along Armstrong, Belmont, and Trimmer Springs Road and is presented in Figure 2. Generally, the Right-of-way (ROW) in Belmont varies from 60-feet to 80-feet and is bounded on the north by overhead electric and on the south by overhead telecom lines. The corridor is relatively uncongested, with a 12-inch City potable water line located along Belmont between Armstrong and Temperance and an 8-inch County potable waterline between Leonard and Fancher. There are also overhead and buried communication lines owned by AT&T and Verizon that parallel the south ROW boundary in Belmont. Alternative alignments were considered, but ultimately, the preferred alignment was selected.

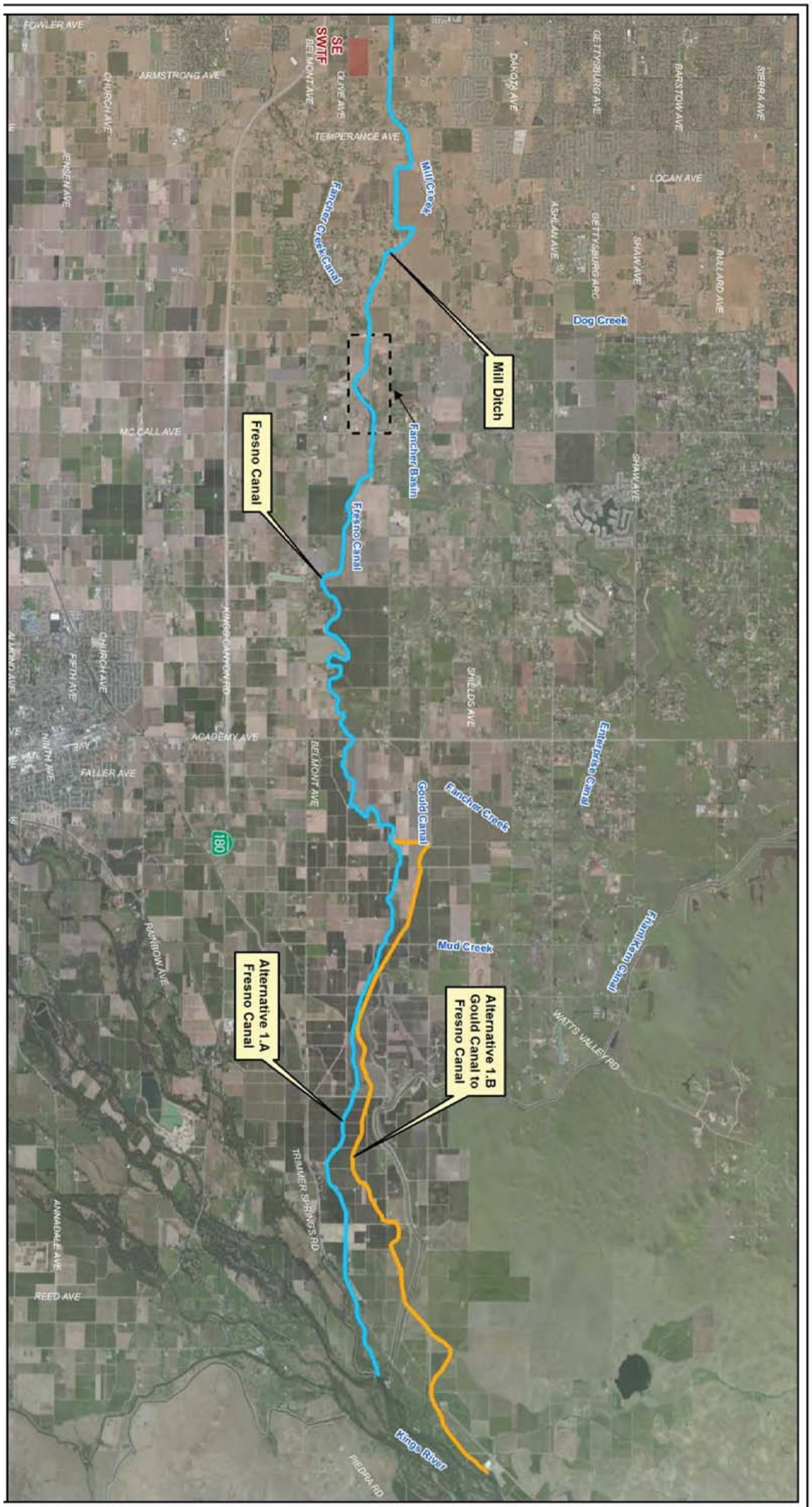
Based on the expected sequence of construction and trench zone operations, an evaluation of trenching and support zone operations was conducted to determine the ideal location of the alignment in the various ROW widths. The goal was to maximize production rates and minimize roadway removal and replacement. The construction zones are based on County approval to allow traffic detouring with local resident access only.

Potholing was performed at various locations to identify wet and dry utilities. These buried lines govern the location of the KRP to gain sufficient clearance for utility protection. Ten irrigation canal crossings were also identified. The location of these canal crossings was obtained from various irrigation District's base mapping and from record drawings. The majority of these crossings are relatively small reinforced concrete pipe (RCP) pipes or box culverts, the crossing method will be open trench. It is expected that with a 12-foot trench width, the RCP pipe will likely need to be removed and replaced. Concrete collars will be placed at the transitions from new to old RCP.

Diversion Facility Design and Operating Criteria

The diversion facility site will include a weir structure to maintain relatively constant upstream water levels, a new turnout structure with trash and debris handling equipment, flow meter vault, and facility control panels. Operational and design criteria are discussed herein.

The weir structure's purpose is to create a sufficient water depth in the Canal at low flows to adequately submerge the pipeline intake while still allowing the Canal's maximum design flow to pass through without a significant increase in water depth from the existing conditions. Depending on the flow rate, the water surface elevation in the Canal at the Turnout will vary between 425 feet and 429.5 feet.



Legend

Canal Conveyance Alternatives

Alternative 1.A- Fresno Canal

Alternative 1.B- Gould Canal

Fancher Basin

SESWTF

0 3,500 7,000 Feet

Figure 1
Canal Conveyance Alternatives

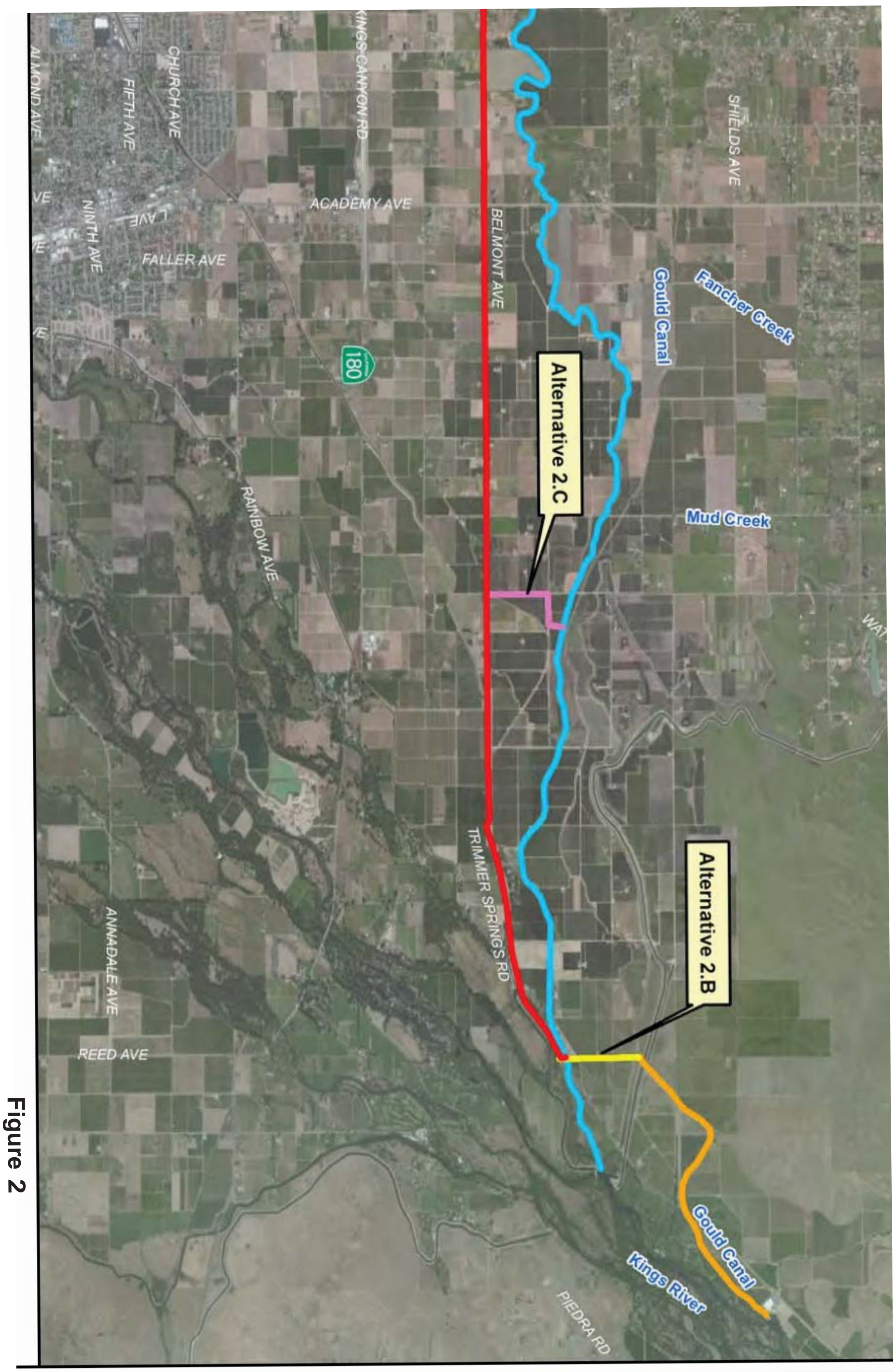


Figure 2
Pipeline Conveyance Alternatives

The turnout was designed to accommodate a maximum flow of 80 mgd. The turnout will be equipped with a traveling water screen that will remove trash and debris automatically based on differential pressure across the screen. There is also a separate flow metering vault with a 72 inch magmeter and a turbidimeter. The flow meter will have a ±1.65 percent at 10-mgd flow and ±0.38 percent at 80-mgd. Flow diverted into the Turnout will be regulated at the SESWTF downstream with two, 40-inch diameter plunger valves that will modulate to maintain the desired flow rate into the treatment facility.

Operational and Hydraulic Analysis

Various hydraulic models were created for the KRP in order to analyze various hydraulic conditions from the headgates to the SESWTF. Evaluations discussed herein include pipeline hydraulics, sediment transport and deposition analysis, transient analysis, and open channel hydraulics of the canal between the check structure and the headgates.

System Hydraulic Evaluation

The hydraulic analysis of the KRP was conducted using InfoSWMM version 12, by Innovyze INC. InfoSWMM is a fully dynamic hydraulic modeling tool that runs the complete one dimensional Saint Venant Equation of fluid flow. The hydraulic model combines information on the physical and operational characteristics of the conveyance system, and performs calculations to solve a series of mathematical equations to simulate flows in pipes. This data was collected from the survey and the preliminary alignment for the KRP to develop the model. Using the tools that allow for integration between AutoCAD 3D and Arc GIS, the pipeline information was input to the model using the geographic coordinate system.

The main goal of the hydraulic analysis was to simulate the expected hydraulic grade in the pipeline during multiple operational scenarios to understand the hydraulic constraints of the pipeline. In addition, the analysis was used to confirm proper sediment transport for the variations of flow within the pipeline, as well as to conduct the transient pressure analysis.

Based on references, and Carollo's experience, the recommended roughness factor for cement mortar lines steel pipe is a C-Factor of 140. However, given the length of the pipeline and the head requirements at the treatment plant, the design team conducted a sensitivity analysis to determine the expected hydraulic grade at the SESWTF using a C-Factor of 120 to determine impact the hydraulic grade at the plant. The results for average velocity are summarized in Table 1. The stated velocities show that proper flushing of the pipeline can be accomplished during normal operation and at low flow operation. Both C-factors evaluated provide proper flushing velocities and head at the SESWTF for proper treatment operation.