Tarrant Regional Water District/ City of Dallas

Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Draft Report No. 3

December 2010

CDM In Association with: Freese Nichols

Geo-Marine, Inc.

Tarrant Regional Water District/
City of Dallas

Amendments 3 and 4 of Phase 1 of the
Raw Water Transmission System Integration Study
Draft Report No. 3

December 2010

CDM In Association with: Freese and Nichols

Geo-Marine, Inc.

Tarrant Regional Water District/ City of Dallas

Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 3

December 2010

STATE OF TEXAS
GARY L. DREIGHTON
92545
LICENSED
PROFESSIONAL ENGINEER
12/27/10

CDM
TBPE Firm Registration No. F-3043

STATE OF TEXAS
ALAN C. HUTSON
90179
LICENSED
PROFESSIONAL ENGINEER
12/27/10

Freese and Nichols, Inc.
TBPE Firm Registration No. F-2144

CDM

In Association with:

FREESE AND NICHOLS

Geo-Marine, Inc.

TARRANT REGIONAL WATER DISTRICT

800 East North Side Drive
Fort Worth, Texas 76102-1097

P.O. Box 4508
Fort Worth, Texas 76164-0508
Telephone 817-335-2491
FAX 817-877-5137

James M. Oliver
General Manager

Statement of Work
Tarrant Regional Water District and City of Dallas
Raw Water Transmission System Integration Study
Scope Addition --
Pipeline Corridor Analysis, Route Selection, and Facility Siting

March 10, 2009

INTRODUCTION

The Tarrant Regional Water District (TRWD) and the City of Dallas Water Utilities (DWU) own or hold water rights or contracts for a combined 14 surface water reservoirs and provide raw water transmission facilities for many cities and water agencies across North Central Texas, ultimately providing drinking water to 4.4 million people, a population that is expected to double in the next 50 years. TRWD and DWU have a long history of cooperation in planning water supply. Current population projections and water demand trends, as developed in the Region C Water Plan and the 2005 Update of the Dallas Long Range Water Supply, have resulted in a comprehensive list of new water management strategies and recommendations. These strategies include the development of three independent projects: connecting Lake Palestine to the DWU water system; completion of the TRWD constructed wetlands; and construction of TRWD's Third East Texas Pipeline from Cedar Creek and Richland-Chambers Reservoirs in approximately 2015.

PHASE I CURRENT SUMMARY

During on-going water supply planning discussions between TRWD and DWU, the geographic proximity and similarity between the three proposed independent raw water delivery strategies (slated for completion between 2015 and 2018 with a combined capital cost of more than $1 billion) prompted both agencies to undertake a **Phase I Project Viability Assessment and Business Case Evaluation** of an integrated approach identifying the potential economic, operational, and non-economic advantages and disadvantages of integrating the three strategies.

The purposes of Phase I of this planning and conceptual design process are:

- Develop the institutional, legal, and financing framework and agreements needed to develop an integrated raw water transmission system and mitigate project cost and schedule variance;

- Compare the separate, independently adopted water strategies of both TRWD and DWU with integrated raw water delivery system alternatives in terms of their life-cycle cost implications, water quality and treatment implications, and permitting and environmental issues; and

- Identify any "fatal flaws" to developing an integrated raw water transmission system;

- Ensure that the principles of the National Environmental Policy Act (NEPA) are considered early in the planning process to expedite all regulatory decisions, permitting and land acquisition.

- Advance conceptual design of the raw water transmission system in anticipation of a 2018 delivery date.

Thus far Phase I results have concluded that interconnecting Lake Palestine through the TRWD system is viable (no fatal flaws were detected) and that the business case is sufficiently strong to recommend developing the concept further.

Statement of Work
Tarrant Regional Water District and City of Dallas
Raw Water Transmission System Integration Study
Pipeline Corridor Analysis, Route Selection, and Facility Siting

INTRODUCTION

The Tarrant Regional Water District (TRWD) and the City of Dallas Water Utilities (DWU) own or hold water rights or contracts for a combined 14 surface water reservoirs and provide raw water transmission facilities for many cities and water agencies across North Central Texas, ultimately providing drinking water to 4.4 million people, a population that is expected to double in the next 50 years. TRWD and DWU have a long history of cooperation in planning water supply. Current population projections and water demand trends, as developed in the 2006 Region C Water Plan and the 2005 Update of the Dallas Long Range Water Supply, have resulted in a comprehensive list of new water management strategies and recommendations. These strategies include the development of three independent projects: connecting Lake Palestine to the DWU water system; completion of the TRWD constructed wetlands; and construction of TRWD's Third East Texas Pipeline from Cedar Creek and Richland-Chambers Reservoirs by approximately 2015.

PROJECT STATUS

During on-going water supply planning discussions between TRWD and DWU, the geographic proximity and similarity between the three proposed independent raw water delivery strategies (slated for completion between 2015 and 2018, each with a capital cost of $1 billion) prompted both agencies to undertake a **Project Viability Assessment and Business Case Evaluation** of an integrated approach identifying the potential economic, operational, and non-economic advantages and disadvantages of integrating the three strategies.

The purposes of this planning and conceptual design process are:

- Develop the institutional, legal, and financing framework and agreements needed to develop an integrated raw water transmission system and mitigate project cost and schedule variance;
- Compare the separate, independently adopted water strategies of both TRWD and DWU with integrated raw water delivery system alternatives in terms of their life-cycle cost implications, water quality and treatment implications, and permitting and environmental issues; and
- Identify any "fatal flaws" to developing an integrated raw water transmission system;
- Ensure that the principles of the National Environmental Policy Act (NEPA) are considered early in the planning process to expedite all regulatory decisions, permitting and land acquisition.
- Advance conceptual design of the raw water transmission system in anticipation of a 2018 delivery date.

Work to date has concluded that interconnecting Lake Palestine through the TRWD system is viable (no fatal flaws were detected) and that the business case is sufficiently strong to recommend developing the concept.

SCOPE OF WORK

1.1 Pipeline Corridor and Facility Site Screening

The purpose of the Pipeline Corridor and Facility Site Screening Study is to determine the most likely corridor for the pipelines and the locations for the pump stations from siting, hydraulic feasibility, delivery points, and storage facilities considerations.

Project Facilities: The Project will include corridor/route studies and siting of the following facilities:

1. Pipeline from Lake Palestine to the Cedar Creek Junction
2. Pipeline from Richland-Chambers Reservoir to the Cedar Creek Reservoir Junction or other location on the Cedar Creek to Lake Benbrook pipeline.
3. Pipeline from the Cedar Creek Junction to approximately Lake Waxahachie
4. Pipeline from Lake Waxahachie to the take-off near Joe Pool Lake
5. Pipeline from the take-off near Joe Pool Lake to a connection to the Benbrook Pipeline near Lake Benbrook
6. Pipeline from the take-off near Joe Pool Lake to the Bachman WTP
7. Delivery points associated with these pipeline routes may include Bachman WTP, Benbrook Pipeline, Cedar Creek Reservoir, Richland-Chambers Reservoir, Waxahachie/Rocket SUD, Lake Bardwell, Lake Waxahachie, Midlothian, proposed Fort Worth Southside WTP, and other delivery points as are identified.
8. Pump Station sites at Lakes Palestine, Cedar Creek, Richland-Chambers, and booster pump stations near Waxahachie and other locations as need is determined based on hydraulic analysis and input from TRWD and DWU.
9. Sites for terminal storage and balancing reservoirs as determined based on hydraulic analysis and input from TRWD and DWU.

Obtain Data:

1. Property ownership maps from local appraisal districts
2. Database/list of utility crossings and their owners
3. Subdivision Plats from Cities and Counties
4. Master Thoroughfare Plans and Regional Mobility Plans
5. Temporary and permanent land acquisition costs to be provided by Owners

Initial Alternate Corridor Selection: Select alternate corridors and facility locations alternatives to be studied. The number of alternate corridors and facility sites to be studied for each facility/pipeline is as defined below:

Pipelines (total of up to 12 corridors, i.e. the number of combinations of corridors is up to 12):

1. Pipeline from Lake Palestine to the Cedar Creek Junction: Up to two (2) alternate corridors.

2. Pipeline from Richland-Chambers Reservoir to the Cedar Creek Reservoir Junction or other location on the Cedar Creek to Lake Benbrook pipeline: Up to two (2) alternate corridors.

3. Pipeline from the Cedar Creek Junction to approximately Lake Waxahachie: Up to two (2) alternate corridors.

4. Pipeline from Lake Waxahachie to a connection to the Benbrook Pipeline near Lake Benbrook: Up to four (4) alternate corridors with up to an additional two (2) combinations of these alternatives.

5. Pipeline from the Southern Pipeline to Bachman WTP: Up to four (4) alternate corridors.

6. Up to four (4) facility alternatives will be considered, where appropriate, including tunnel options or deep open cut options for reducing power costs.

Pump Station sites (total of up to 14 sites):

1. Lakes Palestine intake location: previous City of Dallas engineering studies siting this intake will be reviewed and up to two (2) intake sites will be selected.

2. Cedar Creek Reservoir – new intake/booster: Up to four (4) sites.

3. Booster pump stations near Waxahachie and other locations as are determined: Up to four (4) sites for each booster pump station.

Up to four (4) sites for terminal storage and balancing reservoirs as determined.

Kick-Off Meeting: Conduct a kick-off meeting to establish preliminary corridor alternatives and selection criteria and relative importance of criteria. Criteria will include the following:

1. Requirements for pump stations, outlet structures, storage facilities, and other hydraulic facilities

2. Estimated Construction capital cost

3. Estimated Operations and maintenance cost

4. Estimated land cost (permanent and temporary land acquisition costs to be provided by Owner)

5. Environmental issues

6. Geotechnical considerations
7. Requirement for power service
8. Total Life Cycle Costs
9. Conflicts during construction (traffic, noise, business interruptions, public land use)
10. Conflicts with future land uses (platted developments, planned roadways)
11. Coordination issues with the USACE Real Estate Property
12. Schedule ramifications due to permitting and construction
13. Reliability ramifications such as the following:
    a. Operational redundancies
    b. Water source redundancy
    c. Use of storage
    d. Risk of total system shut-down due to tornadoes, pipeline ruptures, or other events
    e. Event recovery (temporary and permanent)
    f. Electric power reliability to pump stations

Evaluate Alternate Corridors and Facility Sites: Conduct a detailed study of the alternate corridors and facility (pump stations, delivery structures, storage facilities) sites, including the following tasks:

1. Meet with USACE to discuss real estate issues on their property
2. Attend meetings with road and railroad owners to determine crossing permit requirements and to discuss future roadway projects. This step is needed to avoid conflicts and see if opportunities exist to combine pipeline routes with road routes.
3. Determine relative differences in corridor alternatives for conflicts during construction, conflicts with future land use, schedule ramifications, and reliability issues.
4. Combine analysis of other corridor selection criteria (land costs, environmental issues, geotechnical, power service cost, and total life cycle cost) into a preliminary corridor selection matrix.
5. Meeting: Present preliminary results of the corridor selection analysis. Provide one presentation on the corridor and facility siting analysis. Make recommendation of one corridor to be analyzed in Task 1.2.

Deliverables: An interim report with an executive summary and appendix with Technical Memoranda documenting the pipeline corridor and facility siting analysis. This deliverable will include the following elements:

1. *Mapping: Electronic GIS data, mapping and schematics of corridor alternatives. Provide 6 hard copies of corridor alternatives at 1" = 1000' scale. Expanded views of highly congested areas will be provided. Mapping will be provided in 22" by 34" prints, which can be reduced to 11" x 17" copies.*

2. *Update to the power source planning*

3. *Cost analysis for two baseline conveyance alternatives (DWU and TRWD independent transmission options) and the integrated conveyance alternative corridors and facilities*

4. *Project Permitting Inventory update*

5. *Hydraulic and Supply-Demand Scenario Tool results in support of pipeline corridor analysis*

1.2 <u>Pipeline Route and Facility Site Selection</u>

Route Study within Preferred Corridor: This task will include a refinement of the selected corridor to a proposed route, so that subsequent phases of access permission, surveying, field route selection, and field environmental surveys may proceed. The **Route Selection Study** includes the following tasks:

1. Meetings: Attend coordination meetings to establish procedures for fieldwork and mapping.

2. Obtain Data: Obtain the following data:

    a. Construction plans or other record data for critical utilities, drainage facilities, roadways, and other improvements that affect the final route selection.

    b. Estimated land cost (permanent and temporary land acquisition costs to be provided by Owners)

3. Route and Facility Siting Refinement: Using the preferred corridor from Task 4.1 and additional data obtained in Task 4.2, evaluate the corridor and recommend one preferred route within the corridor. Evaluation criteria will be as indicated in Task 4.1. In addition to the Task 4.1 criteria, the following is included in this evaluation:

    a. field observations (where public access allows)

    b. detailed analysis of physical and utility conflicts, property lines and related impacts

    c. proposed land use

    d. other selection criteria as identified in Task 1.1.

Deliverables: A Draft and Final report documenting the pipeline route and facility siting. These reports will include the same elements as the interim report deliverable but at the pipeline route selection level of detail.

1. *Mapping: Provide GIS data and draft GIS aerial mapping of the proposed route, showing the recommended route and easements, location of pump stations, storage facilities, and delivery points. GIS mapping will be at 1" = 1000' scale, with expanded views in congested areas.*

2. *Video Presentation: A video presentation of the recommended route for each line segment will be prepared. The presentation will be based on a helicopter flyover and will have basic audio commentary. In areas where security will not allow a flyover (such as near airports), a flyover presentation will not be provided.*

3. *Land Ownership Data: Provide a database of land owners whose property will be affected by the project, so that the survey access permission can begin in subsequent phases. Land ownership will be based upon appraisal district information. In addition, a preliminary database of all municipal and privately owned utility crossings will be provided.*

4. *Report: Provide a Draft and Final report showing the recommended route alignment, mapping, updated capital cost estimates, geotechnical review, environmental review, hydraulics and supply-demand scenario tool support of the route selection, the security and load flow study (power supply), the final project permitting inventory, and a narrative description of final route selection observations. The Draft and Final reports will include an executive summary, introduction, findings, conclusions, and recommendations.*

1.3 Preliminary Environmental Review and Preliminary NEPA coordination

In support of the Pipeline Route Selection task (1.2), this task is to conduct environmental review and preliminary NEPA coordination to identify and detail environmental, cultural, and natural resources and conditions in the pipeline corridor selected for analysis in the route selection task. Review existing and potential environmental and cultural issues within a 1-mile buffer around the selected pipeline corridor centerline for the proposed water pipeline and a less detailed review of affected environmental pieces in each of up to 12 potential pipeline corridors to support selection of the preferred pipeline route and pump station sites. The following facilities will be assessed:

1. Up to 12 pipeline corridors in a comparative analysis using data provided in Task 1.1

2. One pipeline corridor for the following reaches.

    a. Pipeline from Lake Palestine to the Cedar Creek Junction

    b. Pipeline from Richland-Chambers Reservoir to the Cedar Creek Reservoir Junction or other location on the Cedar Creek to Lake Benbrook pipeline

    c. Pipeline from the Cedar Creek Junction to approximately Lake Waxahachie

    d. Pipeline from Lake Waxahachie to a connection to the Benbrook Pipeline near Lake Benbrook

e. Pipeline from the Southern Pipeline to Bachman WTP: Up to four (4) alternate corridors.

3. Pump Station sites (total of up to 5 sites):

   a. Lakes Palestine intake location

   b. Cedar Creek Reservoir – new intake/booster

   c. Booster pump stations near Waxahachie and other locations as are determined

4. Up to four (4) sites for terminal storage and balancing reservoirs as determined.

An interdisciplinary team of environmental scientists, geologists, archeologists, historians, biologists, graphics technicians, and other specialists will document the existing social, cultural, and natural environmental conditions in the project vicinity through:

1. Site reconnaissance

2. Agency coordination

3. Assessment of maps, historical information, aerial photographs and site plans

4. Review of regulatory data

The existing social and natural environment issues within the project vicinity may include some or all of the following elements:

1. Geological elements (topography, geology, faults, soils, caves).

2. Hydrological elements (surface water bodies, ground water resources, aquifer recharge zones).

3. Floodplains and wetlands.

4. Climatic elements (precipitation, prevailing winds, air quality).

5. Biological elements (major plant and animal communities, protected species, critical habitats, natural areas, parks, forests, wildlife refuges).

6. Hazardous materials and waste.

Hydrological elements will be determined by utilizing National Wetland Inventory maps in conjunction with U.S. Department of Agriculture/Soil Conservation Service soil surveys, 100 year floodplain maps, and U.S Geological Survey topographic maps to document the potential presence of wetlands and hydric soils in the project area. These documents, together with aerial photographs will be used to delineate approximate boundaries of jurisdictional wetlands and Waters of the U.S. Biological elements will be determined through coordination with the U.S. Fish and Wildlife Service, Texas Parks and Wildlife, and Texas GAP data to determine listed species, critical habitats, and habitat designations within the proposed corridor. Lastly, a hazardous materials database for the proposed corridor will be purchased and analyzed to determine locations of landfills, underground storage tanks, and other potentially contaminated sites and the history of those sites that may influence the alignment of the proposed pipeline. A windshield survey will also be conducted, where possible within the corridor, to confirm the location of the sites and assess their current state, as well as confirm vegetation information and ability to support listed species.

The cultural investigation to be conducted at this phase consists of a detailed review of the known literature of archeological and historic sites (including cemeteries), geology, and potential for archeological sites within the project area. Reviews will include:

1. Texas Historical Commission's Texas Archeological Sites Atlas and Historic Sites Atlas.

2. Site files from Texas Archeological Research Laboratory.

3. Historic maps and aerial images of the area.

4. Previous archeological studies in the immediate vicinity.

A project archeologist and historian will also conduct a windshield survey, where possible, to locate unmarked features such as cemeteries and potentially historic structures. All findings will be noted on GIS maps.

Deliverable: The information obtained from the intensive desktop analysis will be compiled into a technical memorandum, which will contain a discussion on the known resources within the project corridor, a prehistoric context and historic context, GIS maps detailing the data collected, and recommendations for survey strategies along the pipeline alignment that will minimize environmental and cultural impacts and subsequent permitting.

1.4 Geotechnical Engineering Support

In support of the Pipeline Route Selection task, this task shall review geology maps within the selected pipeline corridor to characterize geologic conditions to be encountered during construction. This information will include the following:

1. Identify soil/rock interface (depth to rock) to the extent possible from existing available data.

2. Identify type of rock to be encountered in each formation

3. Develop a preliminary database of index properties of the rock, including strength, slaking properties, hardness, etc.

4. Make a preliminary evaluation of secondary features of formation such as faulting, inclusions of mineral deposits, organics, faulting, etc.

5. Identify groundwater conditions, including known aquifers

6. Perform a preliminary site reconnaissance to verify alignment geology and secondary features

Alignment Topography – Describe topographic features within the corridor including the overall terrain, creek, river and stream features, and lakes. The topographic features will be compared to the geology to correlate rock type and erosion characteristics to this topography.

Soil Survey Information – Review available resources that document soil conditions within the corridor, divide into segments of similar soil composition, and index properties for each segment. These properties will include the following:

1. Soil type and gradation, including Unified soil classification for each segment/soil type
2. The expected range of plasticity for cohesive soils and gradation for cohesionless materials
3. Permeability of each soil type, and expected groundwater conditions as they relate to the soil profile

Preferred Pipeline Route Constructability Evaluation – Based on the information gathered regarding geology, topography, and surficial soil conditions, discuss which conditions are more-favorable to cut-and-cover and tunnel construction. Constructability considerations associated with cut and cover and tunnel construction will be evaluated based on the available data. Available previous tunnel geotechnical investigation will be included in this review and general discussion provided on tunneling methods and techniques.

Review major infrastructure crossings (railroads, highways, channels, streams, etc.) by the preferred pipeline route relative to tunnel construction applications. Evaluate impact of corridor geology, soils and groundwater on tunnel construction methodology and cost opinions.

Assess impact of geologic, soil and groundwater conditions on proposed pump station/intake structure sites foundation requirements and cost opinions.

***Deliverable:** Prepare Technical Memorandum summarizing corridor geologic, soils and groundwater conditions, and pipeline, tunnel, pump station and intake construction considerations.*

1.5 Power Supply Planning for Pump Station Sites

As greenhouse gas regulations and issues are increasingly in the focus of state and federal government, it is important to identify at an early stage in the project key challenges and opportunities. The carbon footprint of the proposed project will be assessed; this will include calculations of greenhouse gas emissions for annual operations (not including construction-related emissions) of the transmission project. An evaluation of potential opportunities for carbon offsets and renewable energy credits will be investigated, and how their pricing may become more favorable in future years.

Preliminary Power Source Planning – Corridor Screening Phase

Determine the transmission or distribution power source locations, and levels of redundancy to serve the respective pump station (up to 14 sites) loads from:

1. Transmission line segments
2. Distribution lines
3. Substations

This will be accomplished by reviewing the Transmission and Distribution Service Providers (TDSP) infrastructure in the geographic vicinity of the pump stations. Based on preliminary evaluations of the ERCOT grid and Service Provider Area Plans the following meetings will be held with the following entities:

1. Transmission Level Service
    a. Oncor (Transmission Group)
    b. RCEC
    c. Brazos Electric Cooperative
2. Distribution Level Service
    a. Oncor (distribution Group)
    b. Trinity Valley Electric Cooperative
    c. Johnson County Electric Cooperative

Deliverable: *Memorandum with conceptual routing plans for alternative transmission or distribution routing where one or both options are available, and where one or more routes are available. Reliability and redundancy will be discussed for each of these options.*

Preliminary Power Source Planning – Route Selection

After selection of a preferred corridor, determine the transmission or distribution power source locations, and levels of redundancy to serve the respective pump station (4 sites) loads from:

1. Transmission line segments
2. Distribution lines
3. Substations

This will be accomplished by reviewing the Transmission and Distribution Service Providers (TDSP) infrastructure in the geographic vicinity of the pump stations. Based on preliminary evaluations of the ERCOT grid and Service Provider Area Plans the service providers will again be contacted.

Deliverable: *Memorandum with preliminary routing plans for alternative transmission or distribution routing where one or both options are available, and where one or more routes are available. Reliability and redundancy will be discussed for each of these options.*

Security and Load Flow Study

Submit information to the TDSP's so that they can perform security and load flow studies for the selected pump station sites. These studies will determine if distribution or transmission capacity is available for the transmission line segments, distribution lines, and substations selected as possible power source locations without compromising the security or capacity of the grid and distribution lines respectively. Information submitted to perform these studies will include:

1. Preliminary Loads
2. Preliminary One-Line Diagrams
3. Preliminary Site Plan showing Substation Location to Determine Line Approach
4. Schedule of Load Additions
5. Type of Load (Induction Motor, VFD's, Voltage, Power Factor etc)
6. Ownership of Pump Station Substation

Deliverable: *Memorandum identifying which of the options outlined in Task 4.5 are viable and the reliability and limitations associated with each of them.*

1.6 Capital and Lifecycle Cost Analysis

Update capital and operating costs for up to the following number of alternatives (based on results from Task 1.1 and 1.2):

Pipelines (total of up to 12 corridors, i.e. the number of combinations of corridors is up to 12):

1. Pipeline from Lake Palestine to the Cedar Creek Junction: Up to two (2) alternate corridors.
2. Pipeline from Richland-Chambers Reservoir to the Cedar Creek Reservoir Junction or other location on the Cedar Creek to Lake Benbrook pipeline: Up to two (2) alternate corridors.
3. Pipeline from the Cedar Creek Junction to approximately Lake Waxahachie: Up to two (2) alternate corridors.
4. Pipeline from Lake Waxahachie to a connection to the Benbrook Pipeline near Lake Benbrook: Up to four (4) alternate corridors with up to an additional two (2) combinations of these alternatives.
5. Pipeline from the Southern Pipeline to Bachman WTP: Up to four (4) alternate corridors.
6. Up to four (4) facility alternatives will be considered, where appropriate, including tunnel options or deep open cut options for reducing power costs.

Pump Station sites (total of up to 14 sites):

1. Lakes Palestine intake location: previous City of Dallas engineering studies siting this intake will be reviewed and up to two (2) intake sites will be selected.

2. Cedar Creek Reservoir – new intake/booster: Up to four (4) sites.

3. Booster pump stations near Waxahachie and other locations as are determined: Up to four (4) sites for each booster pump station.

Up to four (4) sites for terminal storage and balancing reservoirs as determined.

Two baseline conveyance alternative alternatives: one City of Dallas alternative and one TRWD alternative. These alternatives include one pipeline route each and sites for required intake/booster pump stations.

Cost opinions are to be prepared using spreadsheet models for pipeline and appurtenances and pump stations. The Consultant shall prepare an opinion of probable cost (cost estimate); the expected accuracy range, degree of preparation effort, typical estimating method and level of project definition will be typical of a conceptual level Class 4 estimate (using AACE International Recommended Practice No. 17R-97 - Cost Estimate Classification System) based on primarily stochastic methods.

Capital costs include construction costs plus allowances for land/right-of-way acquisition (per TWRD and DWU data); permits; utility relocation; power supply to pump stations; contingencies; and engineering, administration and legal costs. Construction cost opinions are to be based on pipeline quantities and unit costs developed for lump sum costs derived from owner and engineer's experience; published data and bids for recent similar projects. Capital costs will be based on current costs (2009-2010).

Unit costs for pipelines (in terms of cost per mile) are to be estimated for rural, low urban, medium urban, heavy urban and tunneled installations. Allowances are to be included for protection, valves, surge control, easement acquisition and contingencies. Surficial soil, rock and groundwater conditions are to be reflected in pipeline unit cost opinions where construction productivity may be impacted. Detailed routing that allows for more refined costs will be developed in subsequent scopes of services when developing ROW easements. Meetings will be conducted with the TDSP's to determine the portion paid for by them under a Standard Facilities agreement

Pump Station and Intake capital cost opinions will be prepared based on design concepts for existing TRWD pumping stations and intakes with adjustments for capacity, site conditions, level of redundancy, power supply and other factors. Consultant will meet with TRWD and DWU staff to collect data and preferences on pump station design concepts. Costs will be based on equipment vendor and materials quotes, allowances for installation, general conditions, contractor overhead and profit, and contingencies. Pump station costs will also include consideration of ground storage, surge control and disinfection facilities needs.

Operating costs will be developed for up to fourteen (14) delivery scenarios and are to include power (consumption and demand charges) and chemicals plus allowances for labor, materials, equipment renewal and replacement and maintenance based on owner/engineer experience. Delivery scenarios include:

1. Independent operation of TRWD transmission system with Third Pipeline (TRWD Baseline Alternative)
2. Independent operation of DWU transmission system with pipeline from Lake Palestine to the Lake Joe Pool vicinity and then on to Bachman WTP (DWU Baseline Alternative)
3. Twelve (12) delivery scenarios in the joint transmission system concept.

Phasing Cost Opinions: Prepare capital cost opinions for up to three (3) potential phasing options of the preferred pipeline route and pump station and intake sites.

Life-cycle cost opinions will be prepared using updated discount rates, debt service schedules, inflation rate, and infrastructure renewal and replacement time frames based on TRWD and DWU experience. Analyses will assess the sensitivity to life cycle cost opinions to variation in the discount rate and rate of inflation.

Research public data to forecast future energy generation costs (cost of generation at the energy plant). Develop estimate of generation costs by decade over the next 50 years.

Deliverables: *Cost Opinion Technical Memorandum*

1.7 Project Permitting Inventory

In preparation for the extensive permitting effort, a Project Permitting Inventory will be developed. This task will include compilation of an inventory of potential regulatory, agency and utility permits and license agreements including local, state and federal agencies and private entities; identification of agencies, necessary permits, estimated processing time, and the same for next subtask (below) for development of a NEPA-based Environmental Information Document (EID). Contact federal and state agencies to determine lead agency for NEPA consultation.

In addition, a summary of the water rights, water quality, pipeline routing, and regulatory considerations for the various facilities considered in the initial feasibility of the Raw Water Transmission System Integration project. In the next phase of work, approvals will be pursued for a broad range of state, county, municipal, and private permits that are necessary to construct the proposed raw water pipeline that will originate and convey water from Lake Palestine to state-approved north-central Texas destinations. Permit applications and agency coordination will need to be conducted through each agency's specific permit application process and will involve agency coordination and response until a permit determination is secured.

This scope of services includes development of a Project Permitting Inventory with consideration of the following regulatory entities:

1. Texas Commission on Environmental Quality (TCEQ) - Water Rights Permit Amendments, Stormwater Pollution Prevention Plan permits, potential Air Permit

requirements during construction, potential soil and groundwater remediation requirements, and Section 401 Water Quality certifications.

2. Texas Department of Transportation (TXDOT) highway crossing permits.

3. County Roads (Anderson, Dallas, Ellis, Henderson, Johnson, Kaufman, Navarro, and Tarrant) crossing permits.

4. Railroad (i.e. Union Pacific, Burlington Northern Santa Fe, etc.) crossing permits.

5. City or Municipal entity - Utility Coordination or Permits for pipeline crossings.

6. Private Entity Utility Crossing permits (i.e. Electrical, Communications, O&G, etc.)

7. Texas Railroad Commission – Pipeline Integrity Evaluations for Oil and Gas (O&G) pipeline crossings.

Federal and State-equivalent permitting requirements will be handled under Subtask 1.7.b as part of the likely National Environmental Policy Act (NEPA) program administration for projects that seek federal funding. This subtask will also incorporate preliminary findings from earlier studies. Such projects must satisfy the NEPA environmental and cultural rules prior to certification by US Environmental Protection Agency (EPA) that the project with mitigation is approved with a Finding of No Significant Impacts certification. Below is a summary of the jurisdictional federal and state regulatory considerations mandated by the NEPA program and that will be considered in the Project Permitting Inventory:

1. US Army Corps of Engineers (USACE) – Coordination with the Fort Worth District to determine potential jurisdictional determinations under Section 10 and Section 404 that may apply to the project.

2. Coordination with other Key Reviewing Agencies (US Fish & Wildlife Service, Federal Emergency Management Agency, Texas Historical Commission, Texas Parks & Wildlife Department, TCEQ, North Central Texas COG.

3. Public Participation - proper public notice procedures for required Public Hearing and Public Comment periods that are filed during the project's environmental evaluation; documentation of comments and transcripts from public hearings.

Prepare and compile the summary findings from Subtasks 4.7 to produce an inventory of potential regulatory, agency and utility permits and license agreements including local, state and federal agencies and private entities; identification of agencies, necessary permits, and estimated processing times for securing identified necessary permits and also for the development of a NEPA-based Environmental Information Document (EID).

***Deliverable:** Project Permitting Inventory-Summary Table*

1.8 Fully Integrated Supply-Demand Scenario Tool Additional Support

In support of additional route alternatives, the application of the models will support Corridor Analysis and Route Selection. This includes: 1) Model Development; 2) Lake Palestine Timing and Phasing Analysis; and 3) Screening Operating Rules. Therefore, additional support from the fully integrated supply-demand scenario tool (e.g. STELLA) is required. The model built in will be used to support this scope in the following form:

A STELLA model has been developed and will be applied to help screen 12 alternative pipeline corridor/route configurations. Energy costs and tariff structures will be applied to help distinguish the alternative corridors/routes using a platform of long-term continuous simulation. Additionally, the model will be reconfigured to examine a single 4-point interconnection between the Southern Pipeline, Cedar Creek Reservoir, and Richland Chambers Reservoir (in lieu of separate connections between the Southern Pipeline and the two reservoirs).

Deliverable: This task will support life cycle cost analysis and Tasks 1.1 and 1.2.

1.9 Hydraulic Modeling Additional Support

In support of additional route alternatives, the application of the models will support the Corridor Analysis and Route Selection defined in this scope. The model will be used to support this scope in the following form:

Steady-state hydraulic analysis: Conduct steady state hydraulic analyses to determine pipe size, pressure class/wall thickness (steel), pump station locations, capacity, total horsepower, optimization of pump curves and configurations, and energy and power supply requirements based on maximum operating pressure and range of reservoir water surface operating elevations in support of selecting up to twelve pipeline corridors, 14 pump station sites, and 4 storage facility sites. Coordinate modeling with system simulation/decision support modeling.

Surge modeling will be limited to the preferred corridor with a limited number of operating scenarios which focus primarily on power interruptions at different levels of operating capacity.

Deliverable: This task will support cost analysis and Tasks 1.1 and 1.2.

Administration

Project administration includes project-related travel, communications (mailings, phone conferences, video conferences, etc.), printing of draft and final reports and maps, the purchase of expendable supplies, and other activities related to project-specific administration and management.

A Draft report will be prepared and submitted to TWDB for review and comments. After TWDB has reviewed the Draft report and provided comments, the Final report will be prepared and will incorporate TWDB comments as appropriate. The Draft and Final reports will present all findings, maps, and technical analysis of the tasks noted above. Seven double-sided copies and an electronic copy in Portable Document Format (PDF) of the Draft and Final reports will be submitted to TWDB.

The study participants and other interested parties will participate in a minimum of three public meetings as required by the TWDB. These will include: 1) a project kick-off meeting 2) a mid-point meeting and 3) a final meeting after the Draft report is issued but before the

Final report is prepared. Other meetings, such as study participant workshops, may be scheduled as necessary.

TWDB will be iuvited to and notified of all three public meetings at least one week prior to each meeting. The contractor will prepare a meeting agenda in advance of each public meeting and will provide meeting minutes following the public meetings. The meeting minutes will be included in the final report.

Total Not-To-Exceed cost for Task I -- $2,123,945.

The Tarrant Regional Water District aud City of Dallas Raw Water Transmission System Integration Study Contract Not-To-Exceed Total is amended to -- $5,717,256.

Accepted by:
This statement of work accurately describes the project and will be used as the basis for implementing the work described herein. Any changes to the scope during implementation will require review and possible revision to budget and schedule.

CDM:		**TRWD:**	
Signed:	[signature]	Signed:	[signature]
Name:	Douglas Varner	Name:	James M. Oliver
Title:	Client Service Manager	Title:	General Manager
Date:	03/26/09	Date:	03/25/09

Contents

Figures

Tables

Executive Summary

ES 1 Background and Purpose

The Tarrant Regional Water District (TRWD) and the City of Dallas have partnered to explore the feasibility of an integrated approach to bring additional water into the Dallas and Tarrant Regional Water District service areas. This project's planning level phase, the "Raw Water Transmission System Integration Study: Phase 1", is completed with this report. It has been a business case evaluation and project viability assessment, meaning that it is focused on identifying fatal flaws (if present) and comparing independent projects to system integration. Because the project has been found viable and the business case sufficiently strong to recommend system integration, Dallas and TRWD intend to enter into an agreement to share conveyance infrastructure and water and begin the design and construction process.

Part of the Integrated Pipeline (IPL) Project planning phase is selection of a pipeline route (a pipeline centerline with a roughly 450' buffer based primarily on desktop analysis methods). Pipeline alignment planning is based on an engineering assessment typically broken down into (3) phases: Corridor Selection, Route Selection, and Alignment Selection. Each phase of study is progressively more detailed as one moves from the corridor selection phase to the alignment selection phase. This process helps identify the pipeline alignment that best meets performance criteria established by the Owner and design team, meets requirements of the NEPA (National Environmental Policy Act) process, and refines project definition on a path parallel to other project planning. This study represents the Route Selection phase of that process.

The purpose of this report is to present the final recommended pipeline route and preliminary facility sites (pending full operations study) for the Integrated Pipeline project (IPL). The selected pipeline route will be refined to a final alignment in the next phase of work, which will also include a full Operations Study that will finalize selection of facility sites.

Because Dallas is reviewing multiple alternatives to bring water into their system from the IPL (see *Dallas Delivery Location Analysis* Technical Memoranda), this report does not analyze, cost, or recommend a pipeline route for Segment H, the connection between the IPL and Dallas' delivery point. However, project cost including Segment H is included in Appendix M only for reference purposes and is not included elsewhere in the report.

The overall Integrated Pipeline has been subdivided into reaches, designated A through I; the recommended pipeline route is shown in **Figure ES-1** and **Table ES-1** provides segment descriptions and design flow rates. Segments were defined based on the proposed design flow rate of the pipe and based on cost allocation methodologies described in the October 2009 *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 1*.

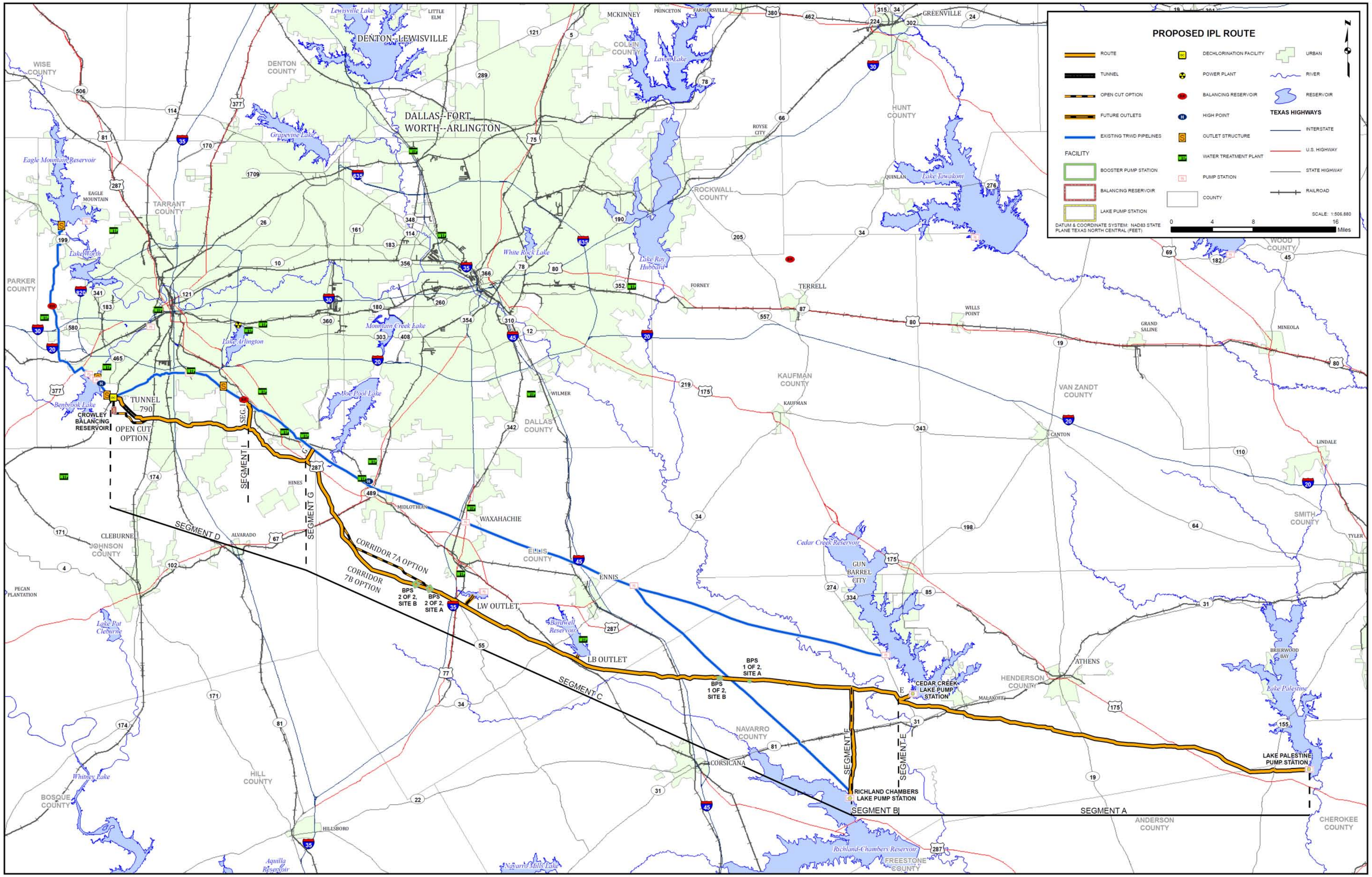

Figure ES-1. Integrated Pipeline Route

Pumping facilities selected for the Integrated Pipeline consist of three new intake pump stations (Lake Palestine Intake, Cedar Creek Intake, and Richland-Chambers Intake) and two booster pump stations as shown in Figure ES-1 above.

Table ES-1 Segment Descriptions

Segment	From	To	Design Flow Rate (MGD)	Potential Cost Allocation
A	Lake Palestine	Cedar Creek Connection	150	100% Dallas[1]
B	Cedar Creek Connection	Richland-Chambers Connection	277	Joint
C	Richland-Chambers Connection	Bachman Take-off Point	347	Joint
D	Bachman Take-off Point	Connection to Benbrook Pipeline	197	100% TRWD
E	Cedar Creek Reservoir	Connection to the Main Pipeline	127	100% TRWD
F	Richland Chambers	Connection to the Main Pipeline	70	100% TRWD
G	Main Pipeline	Existing TRWD Lines	347	Joint
I	Connection to Main Pipeline	Kennedale Balancing Reservoir	197	100% TRWD

In order to keep the main report body more concise, many of the analyses supporting pipeline route selection are contained in the appendices. The main report is structured as follows:

- Section 1 – Introduction
- Section 2 – Route Selections and Descriptions
- Section 3 – Facility Site Selection (lake pump stations and booster pump stations)
- Section 4 – Hydraulic Evaluation
- Section 5 – Costs
- Section 6 – Recommendations
- Section 7 – References

Appendices contain results of the following studies that support the evaluation of corridors:

- Integrated vs. Independent Project Costs
- Conflict Analysis
- Route Maps
- Phasing Analysis (in draft outline form as of the date of this draft report submittal)

Several workshops, technical memoranda and reports were used to help develop the recommendations noted in this report. Some of these documents are listed below:

- Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 1.
- Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 2.

[1] Under the existing form of the Team Charter, TRWD will share only in the cost for purchase of additional right of way in this segment.

- Corridor Selection Criteria Technical Memorandum
- Hydraulic Design Criteria Technical Memorandum
- Infrastructure Sizing Technical Memorandum
- Southern Re-route (Corridor 7) Comparison Technical Memorandum

ES 2 Recommendations and Conclusions

- Using primarily desktop analysis methods, this analysis recommends the pipeline route and facility sites as shown in Figure ES-1
- It is recommended that a 2 Booster Pump Station configuration be selected at this time for refinement and verification during the Conceptual Design and Operations Study phase.
- This report recommends that a deep tunnel be constructed through the Benbrook high point (near Crowley) for reasons of life-cycle cost reduction through pumping energy savings. This recommendation will also be refined and verified during the Conceptual Design and Operations Study phase.
- The following pipe sizes are recommended based on current system operations modeling:

Segment	*Design Flow*	*Nominal Pipe Size*
	(MGD)	*(Inch)*
A	150	84
B	277	108
C	347	108
D	197	84
E	127	72
F	70	66
G	347	108
H	150	84
I	197	84

- Current cost analyses conclude that significant cost savings will be realized by developing an integrated raw water transmission system as compared to developing independent systems, savings in the range of $375 to $443 million in capital cost and roughly $1 to $1.5 billion in present worth 50-year life-cycle cost.
- Total project (without Segment H) capital costs using the recommended pipeline route and current configuration is approximately $1.47 billion (in 2009 dollars). 100-year life-cycle present worth is approximately $3 billion.
- The detailed cost spreadsheets and tables noted in this report have been validated by the 0% Value Engineering (VE) team. Most of the recommendations and cost estimating methodology suggestions were adopted and incorporated into this final report subsequent to the VE workshops held during the week of May 17, 2010. However, because some analyses were completed prior to the VE, many comparative cost estimates rely on older

methodology. This is most evident in the appendices, which contain results from analyses completed prior to the VE.

To minimize environmental and cultural resources impacts associated with development of the proposed IPL, it is recommended that the following actions be undertaken:

- Qualified environmental and cultural resources professionals should be retained to conduct pedestrian surveys within a 450-foot corridor along the proposed right-of-way (i.e., the “study corridor” which is 225 feet either side of the proposed pipeline centerline) to verify resources identified from desktop analyses and to identify other resources that might not have been detected through such analyses. The objective of these pedestrian surveys would be to provide field-verified information to designers that would allow the pipeline to be realigned or otherwise designed to avoid and minimize impacts to significant environmental and cultural resources. Such avoidance and minimization measures are expected to reduce the effort required to obtain permits and minimize the compensatory mitigation burden.

- Qualified wetland scientists should be deployed to conduct preliminary jurisdictional determinations within the study corridor to locate, classify and map streams, wetlands, and other water bodies and identify whether or not they would be considered waters of the U.S. in accordance with Clean Water Act Section 404 or Rivers and Harbors Act Section 10 regulatory definitions.

- Qualified biologists should be deployed to conduct reconnaissance-level field surveys to identify potential habitat and to document observations with federally-listed threatened or endangered species within the study corridor. The results of such surveys should be documented to address compliance with Endangered Species Act requirements.

- Qualified archeologists and historians should be engaged and deployed to prepare approvable research designs, conduct pedestrian surveys, verify the presence of known archeological or historical sites, identify previously unknown sites, map the horizontal and vertical extent of sites, and make recommendations regarding whether further treatment of sites is necessary in order to comply with requirements of the Antiquities Code of Texas and Section 106 of the National Historic Preservation Act.

- Qualified environmental scientists should be deployed to conduct pedestrian surveys to verify the presence of previously documented contaminated sites within the study corridor, identify previously unknown contaminated sites, and make recommendations regarding whether further treatment of sites is necessary.

- Qualified environmental scientists should be employed to compile water quality data and prepare applications for National and Texas Pollutant Discharge Elimination System Permits (NPDES/TPDES Permits) to authorize the transfer of water between reservoirs that will be connected via the proposed pipeline.

- Qualified environmental scientists should be retained to prepare an environmental information document (EID) to assess the potential environmental effects of the proposed pipeline project on the natural and human environment in accordance with National Environmental Policy Act procedures.

ES 3 Next Steps

This report concludes the planning phase of the Raw Water Transmission System Integration Study and leads into the conceptual design phase of the Integrated Pipeline Project. The following next steps are recommended.

With the conclusion of this route selection, the pipeline analysis will transition from a desktop route study to a final surveyed alignment which will be used in the final design of all segments. To date, the corridor and route studies have been primarily “desktop” studies using aerial photography, available records and databases, and readily available property data. In order to refine the route to the final alignment, significant field work, survey, landowner research, engineering, environmental, and archeological research, will be required.

A full Operations Study will accompany pipeline routing and facility site selection in the conceptual design phase. This study will define system operations, hydraulics, and component operations under a variety of operating conditions, such as seasonal variations in water demand, maintenance and contingency operations, and etc. This operations study and accompanying cost analysis will refine and either verify or modify recommendations made in this report, which were based on one set of baseline operating conditions.

Project design standards are currently under development and will also be finalized in the subsequent project phase. These standards will be the basis for final design.

Section 1
Introduction and Purpose

1.1 Project Background

The Tarrant Regional Water District (TRWD) and the City of Dallas have partnered to explore the feasibility of an integrated approach to bring additional water into the Dallas and Tarrant Regional Water District service areas. This project's planning level phase, the "Raw Water Transmission System Integration Study: Phase 1", is completed with this report. It has been a business case evaluation and project viability assessment, meaning that it is focused on identifying fatal flaws (if present) and comparing independent projects to system integration. Because the project has been found viable and the business case sufficiently strong to recommend system integration, Dallas and TRWD intend to enter into an agreement to share conveyance infrastructure and water and begin the design and construction process. The on-going operations planning and project phasing has preliminarily projected an additional water supply source need for TRWD by 2018. Water projections needs for Dallas varies depending on modeling and operations assumptions, but based on preliminary analysis Dallas' additional water supply source needs may go beyond 2018. Because this is a joint project between TRWD and Dallas, infrastructure phasing may be required to efficiently service the water needs for TRWD and Dallas customers. Common critical pipeline segments required to convey water for both TRWD and Dallas will likely be constructed under an initial phasing plan with Dallas only pipeline segments being constructed in subsequent phases.

This report is funded by the Texas Water Development Board (TWDB) regional water supply planning grant. Future planning, studies, and design may be funded through other TWDB programs, such as the Water Infrastructure (WIF) loan program. Part of the Integrated Pipeline (IPL) Project planning phase is selection of a pipeline route. This work was completed in two steps. The first step was to select facility (pump stations, outlets, tanks, etc.) sites and a pipeline corridor, defined as a pipeline centerline with a ½ mile buffer on either side within which the final pipeline will be constructed. This report describes the analysis to refine the pipeline corridor to a route, a pipeline centerline within the corridor with a smaller buffer and greater certainty, though still based on desktop analysis methods. During the corridor selection phase of the project, several corridor alignments were compared based upon 5 principal criteria:

- Schedule
- Environmental Constraints
- Cost (capital, energy, and life cycle)
- Constructability
- Performance (hydraulic, operational)

A comparative analysis of multiple corridors was developed and presented in *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 2.* After the submittal and review of Report No. 2, an additional corridor was identified as a viable alternative. The IPL team prepared an additional comparative analysis between the newly defined corridor (Corridor 7) and the corridor recommended and selected in Report No. 2 (Corridor 1/5 hybrid).

A workshop meeting was held on March 16, 2010 to make four decisions: 1) select the final preferred corridor; 2) select the number of booster pump stations; 3) recommend the lowest life-cycle cost pipe size; and 4) decide if deep tunnels would be constructed through Midlothian and/or the Crowley portions of the pipeline. Decisions on items 1 through 4 were made during the meeting with an understanding that decisions 2 through 4 will require confirmation during the operations study in the next phase of the IPL project.

In that meeting, comparisons between Corridor 1/5 hybrid and Corridor 7 were made based on the five principal criteria described above and Corridor 7b was selected as the preferred corridor. Environmental reconnaissance helicopter flights along the selected corridor began the following week and all cost estimates, hydraulic calculations and other relevant tasks moved forward based on the alignment of Corridor 7b.

1.2 Report Purpose and Overview

The overall Integrated Pipeline has been subdivided into reaches (designated A through I and as shown in **Figure 1-1**) depending on the proposed design flow rate of the pipe and based on cost allocation methodologies described in the October 2009 *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 1*.

The purpose of this report is to present the final recommended pipeline route and preliminary facility sites (pending full operations study) for the Integrated Pipeline project (IPL). The selected pipeline route will be refined to a final alignment in the next phase of work, which will also include a full Operations Study that will finalize selection of facility sites.

Because Dallas is reviewing multiple alternatives to bring water into their system from the IPL (see *Dallas Delivery Location Analysis* Technical Memoranda), this report does not analyze, cost, or recommend a pipeline route for Segment H, the connection between the IPL and Dallas' delivery point.

In order to keep the main report body more concise, much of the analyses supporting pipeline route are contained in the appendices. The main report is structured as follows:

- Section 1 – Introduction
- Section 2 – Route Selection and Descriptions: The purpose of this section is to describe the pipeline segments of the IPL route.
- Section 3 – Facility Site Selection: Preliminary facility site selections are discussed in this section of the report; including lake pump stations, booster pump stations, storage tanks, and outlet structures.
- Section 4 – Hydraulic Modeling: Prior assessments focused on the existing transmission system as well as the proposed (integrated system). Peak capacities of the proposed transmission pipeline were established along with general alignment corridors. This section focuses on the selected IPL configuration for peak flow conditions including sizing of the pipelines and capacity/power requirements for the pumping stations.

Specific routes and pump station locations have been identified and facility sizing has been established for the IPL route. This section also addresses hydraulic criteria, analysis tools and approach associated with selected IPL configuration.

- Section 5 – Costs: This section describes the main IPL project cost analysis and the current basis for the conceptual level opinion of probable capital cost and life cycle cost. Project milestones such as the conceptual and final design will generate more detail so that estimates improve as project definition improves. This section first describes parameters used in the cost analysis and its methodology. Next, capital cost estimates are summarized for each segment and facility, followed by life-cycle cost estimates.
- Section 6 – Summary of Selected Route: This section of the report provides a comprehensive tabular view of the main IPL route and the quantitative and qualitative descriptive fields associated with the IPL configuration.
- Section 7 – References: This section includes a comprehensive list of references cited in the report.

Appendices contain results of the following studies that support the selection of the IPL route:

- Redundancy Study and Potential Power Suppliers
- Geology and Geotechnical Considerations
- Environmental and Cultural Resources Analysis
- Permitting Inventory
- Infrastructure Sizing
- Cost Spreadsheets
- Risk Analysis
- Preliminary Surge Analysis
- Route Maps
- Integrated vs. Independent Project Costs
- Conflict Analysis
- Route Maps
- Phasing Analysis
- Project Opinion of Probable Cost including Segment H

1.3 Methodology

Selection of the IPL pipeline route and facility sites began with a pipeline corridor selection, detailed in *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 2*. Report 2 presented multiple pipeline corridor options and the final preferred corridor was selected based on a methodology described in Sections 7 and 8 of that report. Starting with the final selected corridor, a detailed desktop conflict analysis addressing qualitative and quantitative factors was used to select the preferred IPL route, a refinement to the roughly one-half mile wide corridor. Details of the conflict analysis are noted in Appendix J of this report.

1.4 Key Terms

Alignment: here defined as a final pipeline centerline that will be used in construction bid packages. This will be defined in conceptual design and may be slightly refined throughout the final design phases.

Corridor: here defined as a pipeline centerline with a ½ mile buffer on either side within which the final pipeline will be constructed, selected based on primarily desktop analyses..

Criteria/Evaluation Criteria: here defined as the standard by which the corridors are ranked based on project objectives.

Integrated Pipeline: The raw water transmission system integrating TRWD and Dallas supply transmission from Lake Palestine and Cedar Creek and Richland-Chambers Reservoirs.

Route: here defined as a pipeline centerline within the corridor with a smaller buffer and greater certainty than a corridor, though still based on primarily desktop analysis methods

Section 2
Route Selection and Descriptions

This section describes the recommended pipeline route for the Integrated Pipeline Project (IPL). The section is divided into 8 parts that describe Segments A through I plus a final part that describes next steps in the process. Dallas' branch line to their delivery point at either Bachman Lake or Joe Pool Lake, defined as Segment H, will not be discussed in this report as the final delivery point has not been determined at this time. Segment G is evaluated here but this Segment may be eliminated in future studies depending on the Dallas delivery location and results from the full operations study in the next phase of work.

For purposes of the analysis, the pipeline was divided into various pipeline segments depending on the proposed design flow rate of the pipe and in consideration of potential ownership and cost allocations between TRWD and Dallas. The **Table 2-1** lists the various pipeline segments and design flow rates. Pipe diameters as listed here and referenced hereafter are pending full Operations Study results to set their final diameters.

Table 2-1. IPL Segment Descriptions with Anticipated Pipeline Diameter, Design Flow Fate and Cost Allocation

Segment	From	To	Pipeline Diameter	Flow Rate (MGD)	Potential Cost Allocation
A	Lake Palestine	Cedar Creek Connection	84"	150	100% DWU[1]
B	Cedar Creek Connection	Richland-Chambers Connection	108"	277	Joint
C	Richland-Chambers Connection	Bachman Take-off Point	108"	347	Joint
D	Bachman Take-off Point	Connection to Benbrook Pipeline	84"	197	100% TRWD
E	Cedar Creek Reservoir	Connection to the Main Pipeline	72"	127	100% TRWD
F	Richland-Chambers	Connection to the Main Pipeline	66"	70	100% TRWD
G	Main Pipeline	Existing TRWD Lines	108"	347	Joint
H	Existing TRWD Lines	Bachman WTP	84"	150	100% DWU
I	KBR Take-off Point from Main Pipeline	Kennedale Balancing Reservoir	84"	197	100% TRWD

The route was selected on the best information available to the route selection team without the benefit of accessing property or talking with various entities with jurisdiction along the pipeline route. A route width of 450 feet wide was selected to bracket the landowners that would be contacted for survey access permission. Once the property is accessible, this 450 foot buffer on the route centerline will be cleared for environmental and archeological conflicts. Engineering evaluations and discussions with landowners may bring about the need to deviate the pipeline from the current route centerline. The goal will be to remain in the 450 foot wide buffer;

---

[1] Under the existing form of the Team Charter, TRWD will share only in the cost for purchase of additional right of way in this segment.

however, it is anticipated that some additional areas will require access permission and environmental clearance.

Mapping

A map of the pipeline route with each segment label may be found on the following page, **Figure 2-1**. A detailed mapbook of the pipeline route at a scale of 1” = 500’ may be found in Appendix K. The mapbook illustrates the pipeline route centerline with a solid orange line and the proposed 150’ easement shown with dashed orange lines. Property lines are shown in white. The main pipeline has been stationed beginning at Lake Palestine and ending at the Benbrook Connection in southwest Tarrant County.

Classifications

For each of the routes discussed in this report, the route was classified as to the land type. A length for each land type was determined to assist with cost estimating and to evaluate the construction difficulty for the various routes. A brief definition of each classification used to classify the routes is below.

1. **Rural**: The pipeline route encompasses a majority of undeveloped or farmland and there are only sporadic structures in the area near the route. This classification has been divided into the following sub classifications
    a. Pasture: The easiest construction with very few limitations or restrictions
    b. Croplands: Also easy construction; however, land costs are usually higher due to crop replacement and sensitivity of easement restoration (for example, no rocks left and 2’ of top soil be replaced).
    c. Wooded: The contractor will have to add cost to clear trees and work space will be reduced to half the ROW width in this area to reduce construction impact.
2. **Urban**: The pipeline enters a more congested area that has the potential to slow down the pipe laying crew due to limited work space and conflicts with roads, existing utilities, and other structures. This classification has been divided into the following sub classifications
    a. Light Urban: The pipeline route encompasses a majority of area that contains some low- to medium-density subdivisions, but still has a large amount of open space. If there are existing roadways along the route, the roads are rural sections or large open parkways with landscape buffers and/or large medians.
    b. Medium Urban: The pipeline route encompasses a majority of area that has high to medium-density subdivisions throughout, some retail and commercial. There is some open space and/or large parkways with landscape buffers and/or medians.
    c. Heavy Urban: Dense development including residential, retail, and commercial and little to no setback from the roads.

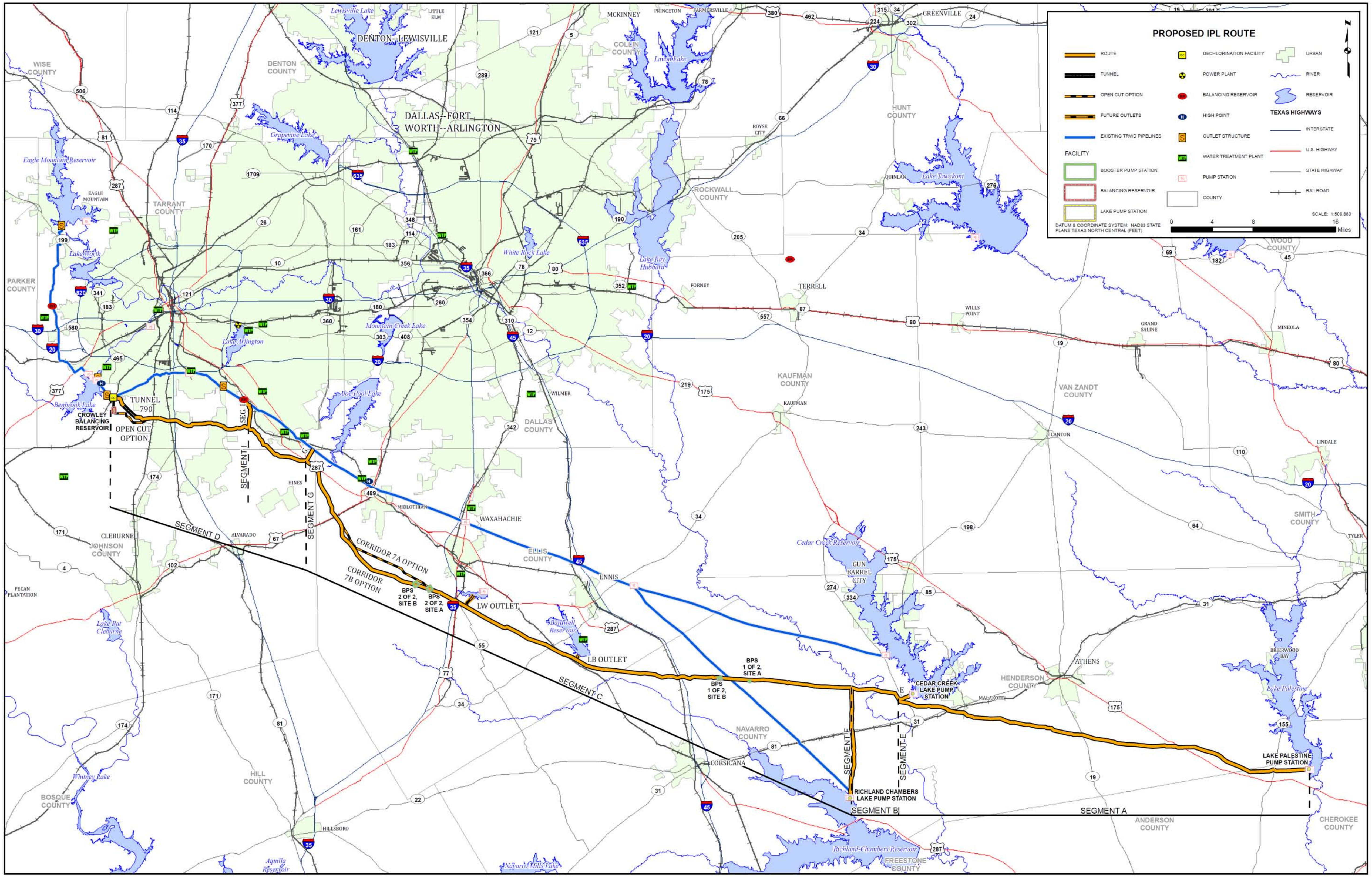

Figure 2-1. Route Overview

3. **Open Cut Crossings**: Crossings that can be open-cut without a tunnel
    a. Minor Road: These are typical county roads and some city streets with lower vehicle counts.
    b. Water Body: Small water bodies such as creeks or ponds that can be dewatered temporarily to facilitate the installation of the pipeline.
4. **Tunnels**:
    a. Crossing Tunnels: This length of the route crosses topographic features or existing facilities such as roadways, railroads, or major utilities that are assumed will need to be tunneled underneath during construction due to the heavy impact that pipeline construction would have on the area. For this stage of the study all existing highways and major roadways were assumed to be tunneled.
    b. Deep Tunnels: In areas of heavy urbanization a deep tunnel, perhaps 40 feet to 100 feet deep, was studied to avoid conflicts. Deep tunnels may also be utilized to reduce power costs by lowering the controlling high point of the proposed pipeline.

Easement Assumptions

Unless specifically noted otherwise, all routes were studied for a 150 foot wide permanent easement. This width allows for the initial construction of one pipeline and future construction of two more pipelines for a total of three pipelines within the easement. It should be noted that certain segments may not need to be planned for three pipelines and a 150 foot width; however, for cost estimating and route selection purposes, a 150 foot wide easement has been assumed. The final easement widths should be determined in the conceptual design phase based on the number of planned pipelines, the design basis of the pipeline and the agreed upon easement restrictions.

2.1 Segment A – Palestine to Cedar Creek

2.1.1 Overview

The beginning point for Segment A is the Lake Palestine Pump Station, which is north of The Meadows subdivision on the southwest side of Lake Palestine. A description of the Lake Palestine Pump Station site is included in Section 3. Segment A is the easternmost segment of the proposed Integrated Pipeline. The route begins at the proposed Lake Palestine Pump Station site and ends at the junction of Segment A and Segment E, southwest of Cedar Creek Reservoir. Refer to **Figure 2-2** for an overall map of Segment A.

This segment of the route has a design capacity of 150 MGD. Sizing of the pipeline is discussed in Chapter 4 of this report. The proposed route is within the boundaries of Henderson County, except for a small portion of the corridor near Lake Palestine which is in Anderson County.

Table 2-2 shows the construction classification for segment A. As seen in the table, Segment A is largely comprised of rural land with 97% of the segment being either pasture or wooded.

Table 2-2. Segment A Route Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	2,441	Minor Road	677
			Water Body	1,764
	Rural	213,869	Pasture	117,970
			Cropland	-
			Wooded	95,899
	Urban	2,747	Light Urban	2,747
			Medium Urban	-
			Heavy Urban	-
Tunnel	Crossing Tunnel	1,337	Railroad	142
			River	-
			Major Road	1195
	Deep Tunnel	-	Deep Tunnel	-
Total Length - Segment A				**220,394**

The following facilities and connections are located within Segment A:

- The Lake Palestine Intake Pump Station is located on the most eastern portion of the IPL. The pump station is discussed in detail in Section 3 of this report.
- Segment E Connection is located at the most western point of Segment A, at the junction of Segment A and B. Segment E is addressed as a separate line segment later in this report section.

A proposed outlet to Cedar Creek Reservoir was originally planned for this pipeline segment near the east end of the dam embankment. TRWD prefers to make the line segment from Cedar Creek to the main pipeline, Segment E, bi-directional to serve as a possible outlet into Cedar Creek if necessary.

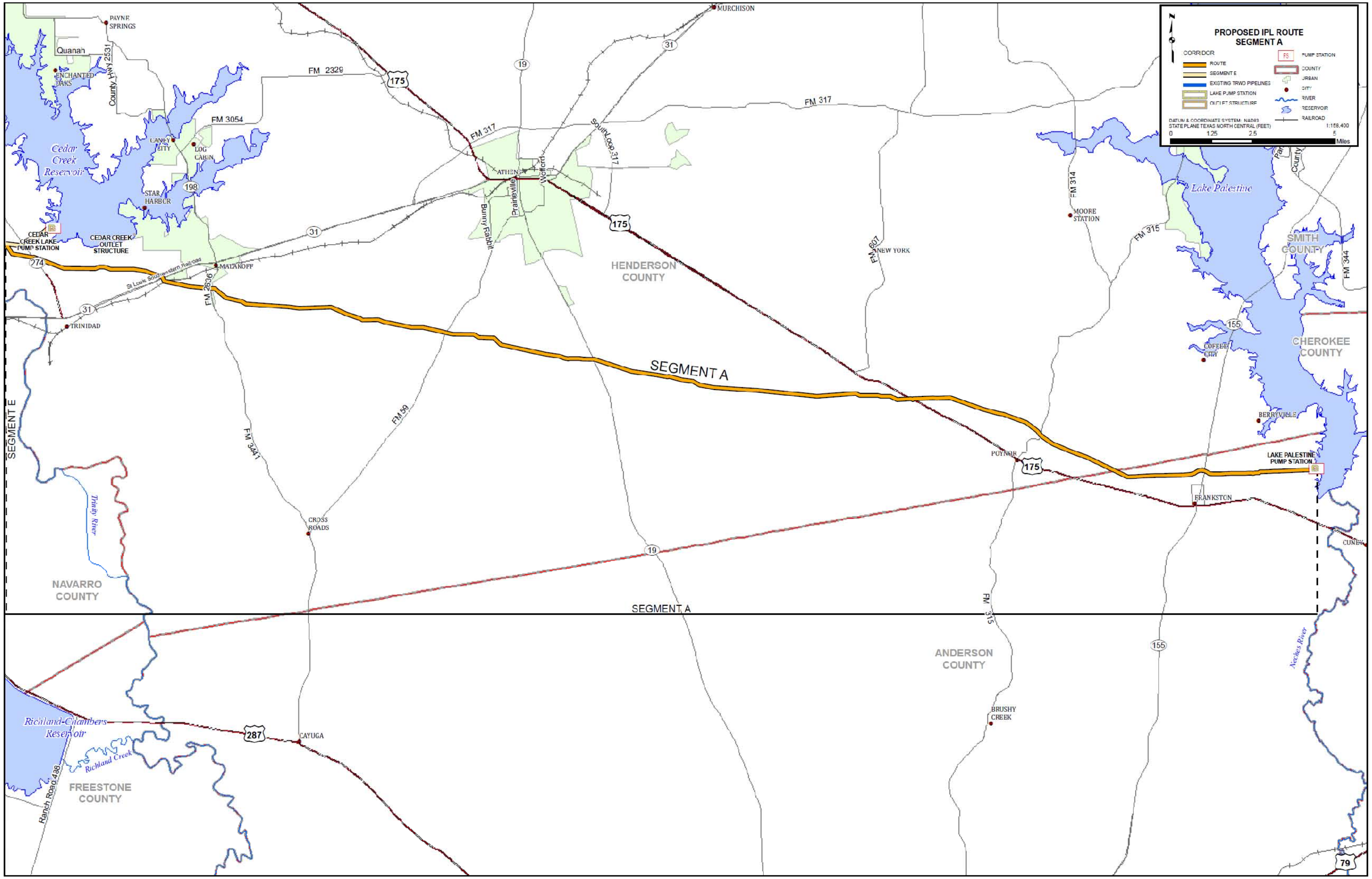

Figure 2-2. **Segment A**

2.1.2 Route Description and Conflict Analysis

From the proposed Lake Palestine Pump Station, Segment A proceeds to the west-southwest, and then follows along the north side of CR 307. Next, the route moves to the south side of CR 305. The route then passes to the north of Frankston High School. The corridor study placed the proposed pipeline just north of Frankston High School, but it was discovered that the high school has added multiple tennis courts where the route was originally located. Thus the route was moved further north due to the Frankston Riding Center and a car dealership just north of the high school and tennis courts. The following photo (**Figure 2-3**) shows the Frankston High School area facing east. In the photo, the high school, tennis courts, riding center and the car dealership building can be seen. The route will pass in the area to the north of the car dealership.

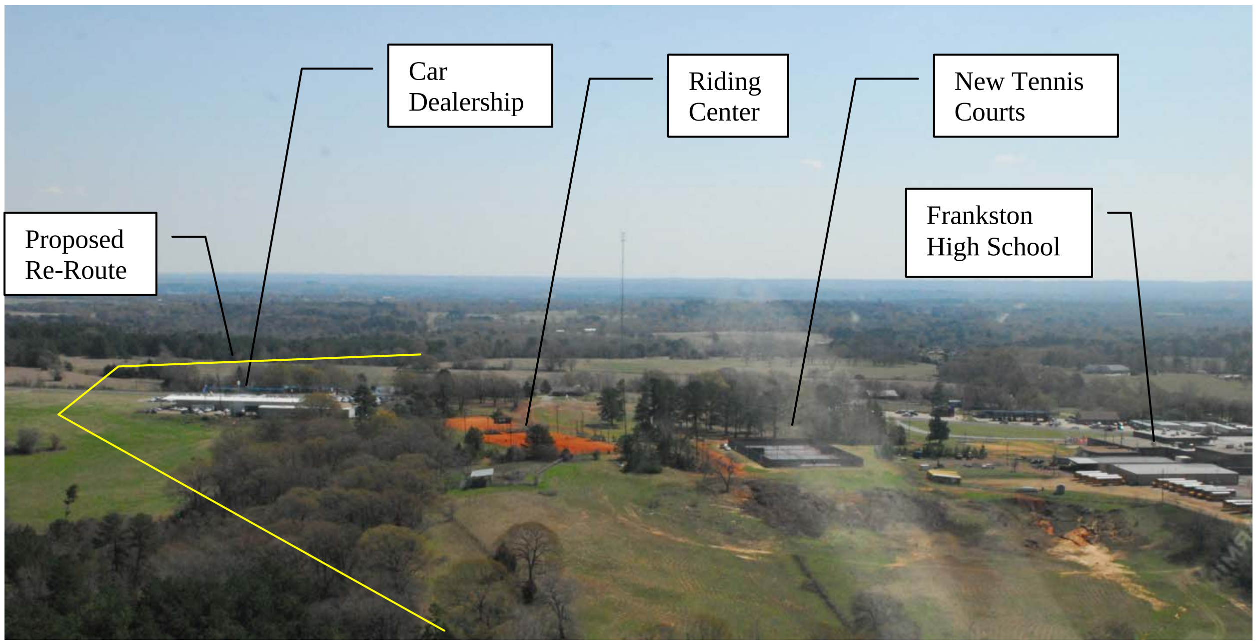

Figure 2-3. Frankston High School Area

Two miles west of Frankston High School, the corridor proceeds northwest. The route passes near LaPoynor High School. A conflict analysis was conducted for the area around the high school. Two options were studied for this area, a northern option and a southern option. (See Appendix J for the complete memorandum and exhibits of the conflict analysis.) The northern option was chosen because it is the shorter, less expensive, and impacts fewer parcels. In addition, the northern option avoided the lakes and water crossings associated with the southern option.

After the route passes north of LaPoynor High School, the route proceeds west-northwest for approximately 23 miles, routing through mainly rural pastures and wooded areas. The route passes roughly five miles south of Athens. After the route crosses the St. Louis Southwestern Railroad and US 31 near Malakoff, the route turns to the northwest and passes south of the Cedar Creek Reservoir. Three options in this area were analyzed. The northern route is the shortest option, but contains six water crossings while the central option has only two creek crossings.

Therefore, the central option was chosen as the best route. (See Appendix J for the complete memorandum.

Segment A ends at the Segment E junction. The Segment A route is approximately 41.7 miles long. **Table 2-3** is a summary of all the areas in which a conflict analysis was performed for Segment A and summarizes the decisions made.

Table 2-3. Conflict Analysis

Conflict Name	ID Number	Decision
CR 301	A1	The northern option is most direct with the least amount of bends.
LaPoynor HS	A2	Routed north due to shortest length and fewest number of parcels impacted.
Hallmark Lake	A3	The southern option requires the shortest length and is less costly.
Cedar Creek	A4	The central option requires the fewest number of water crossings.

Note: Conflicts A1 and A3 were both small conflicts with severed parcels. They were analyzed to minimize parcel severance, but ultimately the most direct routes were chosen; see Appendix J.

2.1.3 Hydraulics

There are several high points located in Segment A that could affect the hydraulics of the system. The highest point reaches a ground elevation of 550 feet MSL while several others reach a ground elevation of 530 feet MSL. Depending upon the location and elevation of the tank/reservoir at BPS 1 of 2, these high points could create an operational issue each time the booster pump station is turned off. The high points will drain toward the BPS storage reservoir with the potential of overflowing the reservoir. In addition, the drained portion of the line will need to be filled slowly each time the system is started to carefully evacuate air. This problem can be solved by lowering the high points or locating the BPS 1 of 2 site to match the reservoir elevation with the pipeline high points. The 550 foot high point can be deep cut for about 1,000 feet near station 810+00 to set the top of pipe at elevation 525 feet MSL. The hydraulics will be discussed further in the facility selection portion of the report and in Section 4.

2.1.4 Crossings

The roads and railroads that will require tunneling on Segment A are listed in **Table 2-4**.

Table 2-4. Segment A Major Crossings

Major Highways	FM Highways	RR/River Crossings
S.H. 155	FM 315	St. Louis Southwestern Railroad
U.S. 175	FM 1615	
S.H. 19	FM 753 (2)	
U.S. 21	FM 59	
S.H. 274	FM 2636 (2)	

Segment A also has four major electrical transmission line crossings that will likely require a crossing permit or agreement.

2.1.5 Environmental

For a detailed analysis of creek crossings see the environmental report in Appendix C. **Table 2-5** is a summary of the environmental areas crossed by Segment A.

Table 2-5. Segment A Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	16	3,044	
Intermittent Creek Crossings	68	15,181	
Wetlands			6
Upland Forest			110
Bottomland Hardwoods			33

2.2 Segment B

2.2.1 Overview

Segment B is defined as the pipe segment between the Cedar Creek Pipeline Connection (Segment E) and the Richland-Chambers Pipeline Connection (Section F). Refer to **Figure 2-4** for a map identifying Segment B. Segment B will be sized to accommodate 150 MGD from Lake Palestine and 127 MGD from Cedar Creek Reservoir for a total combined capacity of 277 MGD. The preliminary studies show this pipe segment will be 108-inches in diameter.

Table 2-6 is a summary of the construction classifications for Segment B. As seen in the table, Segment B is largely comprised of rural land with 98% of the segment being either pasture or wooded.

Table 2-6. Segment B Route Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	215	Minor Road	131
			Water Body	84
	Rural	25,591	Pasture	18,419
			Cropland	-
			Wooded	7,172
	Urban	-	Light Urban	-
			Medium Urban	-
			Heavy Urban	-
Tunnel	Crossing Tunnel	353	Railroad	-
			River	353
			Major Road	-
	Deep Tunnel	-	Deep Tunnel	-
Total Length - Segment B				**26,159**

There are no proposed facilities situated within the Segment B route, but the following are the connections located within Segment B:

- Segment E Connection from Cedar Creek Lake (at the junction of Segment A and B)
- Segment F Connection from Richland Chambers Lake (at the junction of Segment B and C)

Each of the above connections is addressed as separate segments within this section of the report.

2.2.2 Route Description and Conflict Analysis

Segment B is a short rural segment without any delivery points. The route for Segment B begins at the Segment A-E-B connection and extends north-northwest for half a mile and then proceeds west-northwest through a rural semi-wooded area. Approximately 2.5 miles west-northwest of the connection to Segment E the segment crosses the Trinity River. It is assumed the River Crossing will be tunneled. The next significant element of the pipeline is the connection to Segment F where Segment B ends. The overall length of the Segment B route is 5.0 miles.

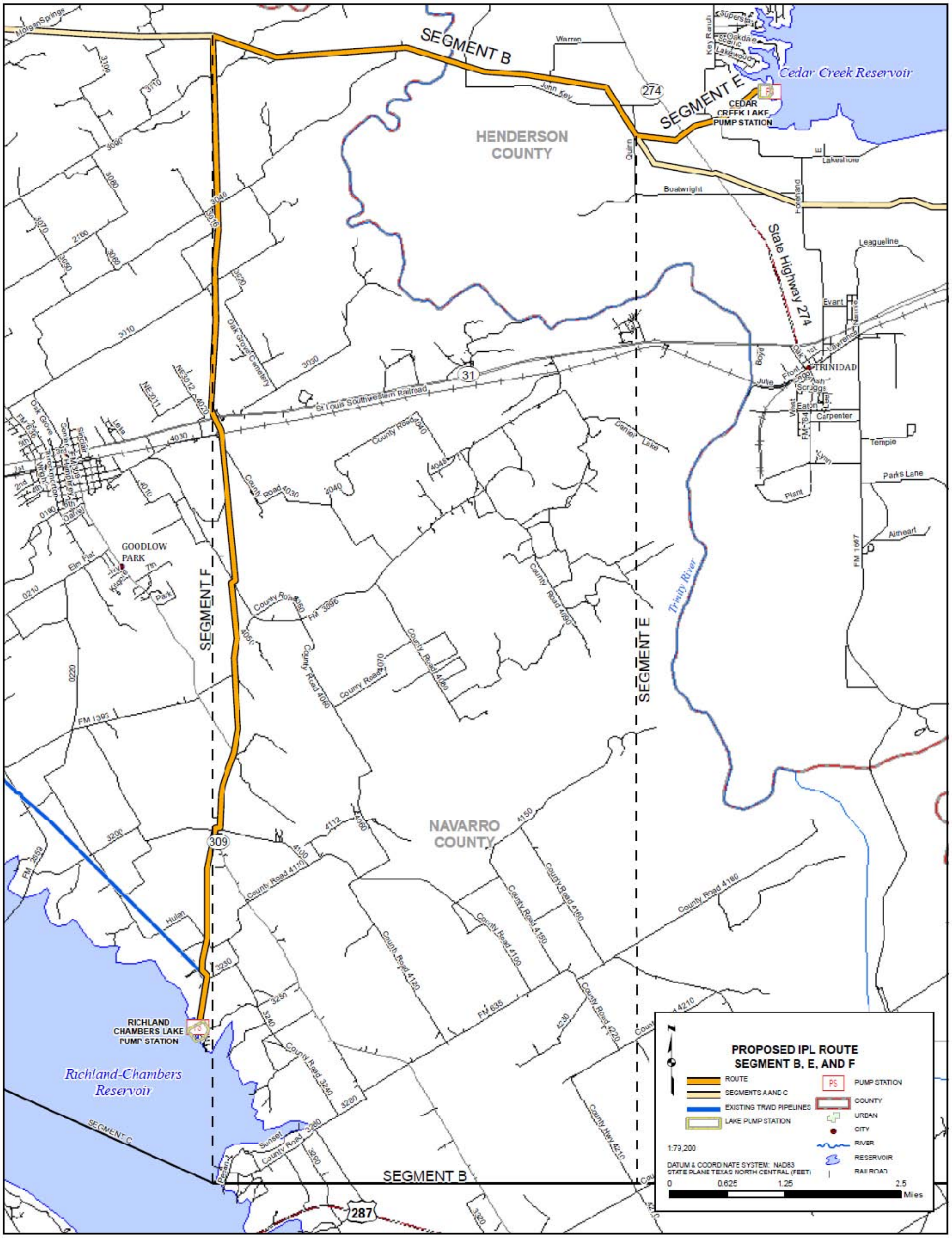

Figure 2-4. **Segments B, E, & F**

2.2.3 Crossings

Segment B has the one major crossing of the Trinity River, and does not have any major road crossings. Geotechnical borings will be required for the crossing of the Trinity River for tunnel design. The original corridor crossed the Trinity River slightly further south, but the route was moved north to move away from a rural subdivision and out of an old river oxbow to avoid potential poor soil conditions. **Figure 2-5** shows a picture of the Trinity River looking south. It is anticipated that the pipeline will cross the river in the straight run of the river in the foreground. It is anticipated that this river crossing will be constructed with a tunnel from approximately 20-40 feet beyond the tops of banks.

Figure 2-5. Trinity River Crossing (Facing South)

2.2.4 Environmental

For a detailed analysis of creek crossings and other environmental impacts see the environmental report in Appendix C. **Table 2-7** is a summary of the environmental areas crossed by Segment E.

Table 2-7. Segment B Route Environmental Crossings

	Number	Length	Area (ac)
Perennial Creek Crossings	-	-	
Intermittent Creek Crossings	4	766	
Wetlands			14
Upland Forest			3
Bottomland Forest			18

2.3 Segment C

2.3.1 Overview

The beginning point for Segment C is located west of Cedar Creek Reservoir where the pipeline segments B, C, and F all intersect while the end of Segment C is at the connection to Segments D and G. See **Figure 2-6** for a map showing the entire segment. Segment C bears west from the F and B connection and travels south of Bardwell Lake crossing I-45 midway. From Bardwell Lake the route turns northwest passing south of Lake Waxahachie, crossing I-35E and arriving at a point to the south of hill country near Midlothian. The hill country south of Midlothian acts as a turning point for the route as it heads more northerly towards the ending point at the D and G connection near the intersection of S.H. 360 and 287. Segment C is the longest IPL segment accounting for 42% of the entire route.

The final route preferred for Segment C changed significantly from the corridor (Corridor 5) selected in the previous corridor study. During the detailed analysis of the corridor, several challenges presented themselves including a wildlife refuge, several urban areas near Midlothian and significant impacts to USACE property around Bardwell Lake. For this reason, other corridors (Corridor 6 & 7) were proposed, studied and compared against Corridor 5. An evaluation of the corridors led the owners to choose the southern Corridor 7 as it missed USACE property and is a more rural route. In addition, a specific corridor, identified as Corridor 7b, that routed south of Midlothian was found to be more advantageous from an energy savings standpoint as it missed several highpoints. A detailed analysis comparing the above corridors may be found in Appendix J as C11. Corridor 7b was preferred by the owners and is described hereafter. **Table 2-8** summarizes the breakdown of this segment.

Table 2-8. Segment C Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	1,813	Minor Road	1,115
			Water	698
	Rural	310,388	Pasture	166,885
			Cropland	85,975
			Wooded	57,528
	Urban	14,249	Light Urban	14,249
			Medium Urban	0
			Heavy Urban	0
Tunnel	Crossing Tunnel	2,938	Railroad	767
			River	0
			Major Road	2171
	Deep Tunnel	0		
Total Length - Segment C				**329,388**

Both booster pump stations on the IPL are located within segment C. The first or upstream BPS is situated near the RC pipeline crossing. The second or downstream BPS is west of I-35E near FM 66. Both of the BPS sites are presented with two options in section 3.

There are five proposed connections within Segment C.

1. The Segment F Connection is located at the beginning of Segment C.
2. **RC Cross-Connection**: A connection to the existing RC pipeline will be made where the RC pipeline and the IPL cross. This intersection is just east of FM 1603 near Chatfield. The connection adds reliability as it allows several bypassing and pumping options. The connection also allows deferment of Segment F construction.
3. **Bardwell Reservoir Outlet**: Approximately 15,000 feet east of the State Highway 34 crossing, a connection will be made for the Bardwell Lake outlet. The outlet is planned as a future connection and is not anticipated to be built with the IPL. The future connection will be approximately 2,570 feet long. It will approach the lake from the south, west of Bardwell Dam. Approximately 1,400 feet of the connection will cross USACE property thus requiring an easement from the USACE. The City of Waxahachie currently uses Bardwell Lake as a water source and can pump Bardwell water to Lake Waxahachie or to their WTP. The city has plans to expand their WTP from 15 MGD to 27 MGD. This connection will help accommodate the city's future demands.

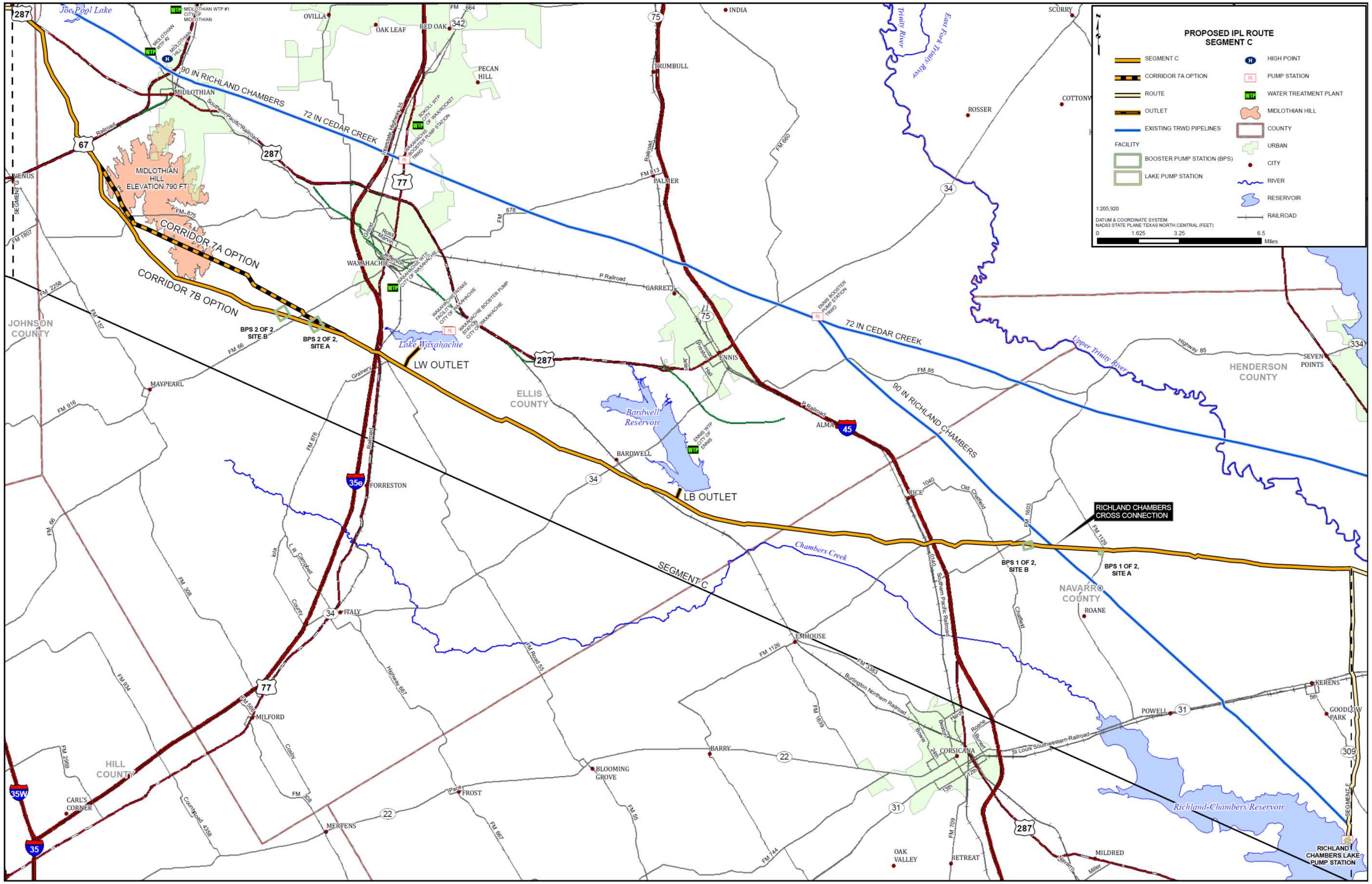

Figure 2-6. **Segment C**

4. **Lake Waxahachie Outlet**: A little over a mile east of I-35E will be a future connection to Lake Waxahachie. The outlet will be an approximate 7,194 feet in length approaching the lake from the south. Similar to the Bardwell connection, this connection will contribute to the supply for the city of Waxahachie. The connection will not require USACE permitting, but will require easements through private lake front property. The lake is owned by the Ellis County Water Control and Improvement District No. 1.
5. The Segment G connection defines the end of Segment C. Segment G delivers 150 MGD to Dallas and is addressed separately as a segment in this section of the report.

2.3.2 Route Description and Conflicts

From the beginning point at the F and B connection, Segment C travels approximately 10 miles west to the intersection of FM 1129 and FM 636. The majority of this route crosses open rural land, with several minor road crossings and a crossing of a residential area, the Colina Vista subdivision on Colina Vista Road east of FM 1129. The Colina Vista Subdivision tracts are approximately 10 acres each, and the route does not require the removal of any houses. The route crosses the existing 90-inch RC pipeline where a cross-connection is proposed. There are two alternate booster pump station sites located in this area, Site A located near the intersection of FM 1129 and FM 636 and Site B just west of the RC cross-connection new FM 1603. These two sites are discussed further in Section 3.

Two additional residential areas are crossed before the route reaches I-45. The first is at the crossing of FM 1603 approximately half a mile to the west of BPS 1 of 2 B. This residential area is composed of approximately 10 acre tracts, with homes on these tracts generally abutting the roadway. The route crosses perpendicular to FM 1603 through an undeveloped tract, then continues west across the backs of the parcels.

The second residential area is the Double R subdivision outside of Rice situated just east of I-45. This subdivision consists of approximately 5 acre tracts. At the time of this route study, little housing construction has occurred in this area. This subdivision was identified as a conflict area, and a route analysis comparing three routes was performed. This route analysis is included in Appendix J as C2a-Rice. None of the conflict options require the demolition of houses but they all sever some of the properties in the subdivision. The southern option was chosen for the route due to reduced severed lengths, cost benefits, and environmental advantages.

From the west side of I-45, the route continues traveling west through mostly crop and pasture land to the south end of Bardwell Reservoir. The main pipeline does not route through USACE property which was one of the significant advantages of Corridor 7b over other corridor options which had environmental and USACE conflicts on the north side of Bardwell Lake.

From the future Bardwell outlet, the route turns northwest and crosses the BNSF Railroad. The route continues for approximately 12 miles through rural crop and pasture land to the future Lake Waxahachie outlet. Going south of Lake Waxahachie helps avoid environmental and urban conflicts that are on the north side of the lake.

On the west side of the lake, the pipeline crosses the UP Railroad, US Highway 77, and I-35E which are all adjacent to each other. One mile further west is where Corridor 7a and 7b diverge. The recommended route follows Corridor 7b which avoids high points in Midlothian reducing pumping costs and eliminating the need for a Midlothian deep tunnel. Near the point where 7a and 7b converge back together at US Highway 67 the original 7b route crossed a pond. A conflict analysis was done for this area comparing two routes. The conflict is included in appendix J as C8a-ToysRUs. The eastern option was chosen as it was less expensive and avoided the pond.

After crossing US Highway 67, the route bears northwest approximately 6.5 miles through rural property before tying into Segments G and D. Directly to the southeast of the G connection, Segment C parallels US Highway 287. State Highway 360 currently ties into US Highway 287 along this paralleling portion. In the future, State Highway 360 will likely be extended to the south, crossing both US Highway 287 and the IPL route. This should be investigated further in the conceptual design to determine if the pipe under the future SH 360 should be encased or deepened.

Table 2.9 shows the conflict analysis areas that were studied for Corridor 7b on Segment C. The complete conflict analysis for Segment C can be reviewed in Appendix J.

Table 2-9. Segment C Conflicts

Conflict Name	ID Number	Decision
Rice	C2a	South option was chosen for severance, environmental and cost benefits.
Toys R Us	C8a	Eastern option was chosen as it missed the pond conflict and presented cost savings.
New Southern Option	C11	The corridor 7b was chosen due to reduced urban impact and reduced pumping costs by routing around Midlothian Hill.

2.3.3 Hydraulics

Segment C is planned to carry 150 MGD from Lake Palestine, 127 MGD from Cedar Creek Reservoir, and an additional 70 MGD from Richland-Chambers Reservoir for a total of 347 MGD. This segment will be 108 inches in diameter. Segment D of the IPL will be downsized to 84 inches in diameter as Dallas water is delivered through Segment G.

One of the primary reasons the 7b route was preferred over others was for reduced pumping costs due to lower static heads. Other routes (1a/5, 1b/5, 1b/6, 7a) were considered which passed through higher elevations near Midlothian. See Conflict C11 in Appendix J. The alternate options either require increased pumping costs or deep tunneling options. A life cycle cost analysis performed on the routes showed that there are life cycle cost savings in reducing the high point in the pipeline to elevation 790 feet MSL. The Corridor 7b re-route reduced the high point from elevation 850 to elevation 790 and was found to be more cost effective than tunneling through these high points with other route options.

2.3.4 Crossings

Tunnel crossings in Segment C include 2 interstate highways, 1 state highway, 2 US highways, 14 FM roads, and 4 railroads. There is also a rail track that is not a mainline railroad near the Toys R Us conflict. **Table 2-10** summarizes which major roads will be crossed utilizing tunneling.

Table 2-10. Tunneled Crossings

Major Highways	FM Highways	Railroad / River Crossings
I 35 E	1129	Southern Pacific Railroad
I 45	1446	BNSF Railroad (near SH 34)
SH 34	1493	UP Railroad
US Highway 67	1603	BNSF Railroad (near US 67)
US Highway 77	636	Branch Line at Business Park
	66	
	875	
	876	
	977	
	984 (Crosses four times)	
	985	

Segment C will also include approximately 24 oil and gas crossings and 8 electrical transmission line crossings. These crossings are anticipated to be open cut.

2.3.5 Environmental

Table 2-11 summarizes environmental conflicts along segment C.

Table 2-11. Segment C Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	5	970	
Intermittent Creek Crossings	113	21,402	
Wetlands			6
Upland Forest			109
Bottomland Forest			28

2.4 Segment D

2.4.1 Overview

Segment D continues from C at the connection point of G and ends at the Benbrook Pipeline tie-in located less than one mile east of the existing Benbrook outlet. The intersection of segments C, D and G is near the intersection of US Highway 287 and the US Highway 287 Business route which is southeast of Mansfield. See **Figure 2-7** for a depiction of the entire segment.

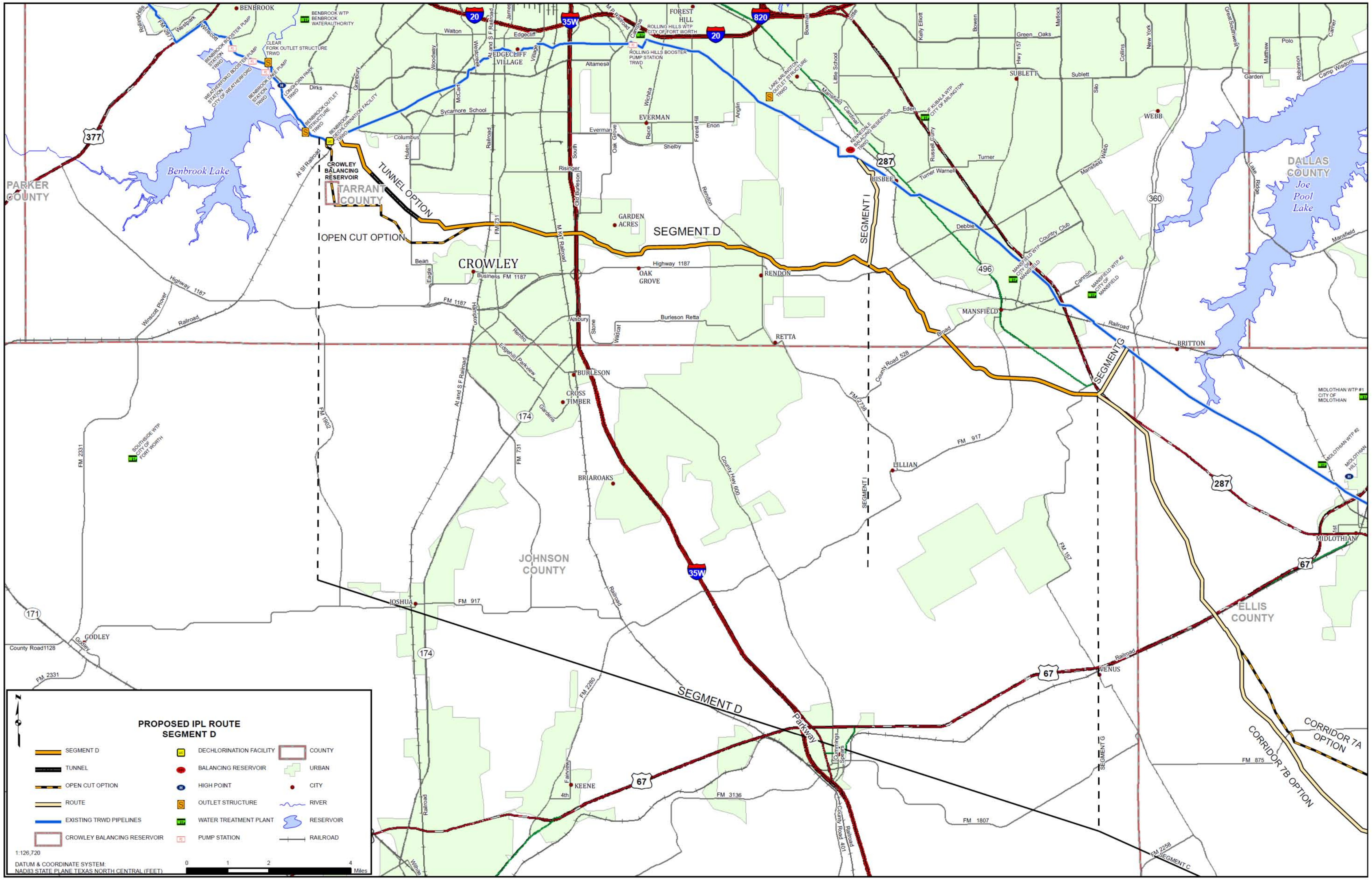

Figure 2-7. Segment D

The total length of segment D is 21.6 miles accounting for 15% of the entire mainline of the IPL route. Over 80% of the segment is composed of rural land. Currently the only deep tunnel on the IPL route is located near the end of segment D near Crowley. **Table 2-12** summarizes the breakdown of this segment:

Table 2-12. Segment D Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	1,137	Minor Road	924
			Water	213
	Rural	93,032	Pasture	56,708
			Cropland	14,139
			Wooded	22,185
	Urban	10,412	Light Urban	10,197
			Medium Urban	215
			Heavy Urban	0
Tunnel	Crossing Tunnel	1,070	Railroad	189
			River	0
			Major Road	881
	Deep Tunnel	8,480	Hydraulic Advantage	8,480
Total Length - Segment D				**114,131**

With a two booster pump operation and a deep tunnel at Crowley, there are no facility sites situated along this segment. However, if the tunnel option through Crowley is found unfeasible, an open cut option with the Crowley Balancing Reservoir may be considered. The Crowley Balancing Reservoir is discussed as an option in segment 3 of this report. There are three segment D connections:

- The Segment G Connection, which is discussed separately, is currently planned to divert 150 MGD to a Dallas delivery point.
- The Segment I (KBR) Connection which is discussed separately connects to D near the US Highway 1187 crossing. Segment I is 84 inch in diameter to carry 197 MGD to the Kennedale Balancing Reservoir.
- Currently, the IPL terminates at the connection to TRWD's existing 90" Benbrook Pipeline. The Benbrook Pipeline was built in the mid 1990's and is prestressed concrete cylinder pipe (PCCP) through the open cut sections and steel pipe through the tunnel segment. The Benbrook Tunnel begins on the west side of Granbury Road, on USACE property. Connecting west of Granbury Road near the existing TRWD dechlorination facility in the open cut section is simplest from a construction standpoint. However, such a connection requires a USACE easement which entails an environmental analysis and mitigation. To reduce impact to USACE property, the connection is currently planned to be on the east side of Old Granbury Road as shown in **Figure 2-8**. This is in the tunneled portion which is approximately 30 feet deep. Thus, the connection will be in a deep

trench and the casing will need to be removed from around the existing pipe. Connecting to the east is less desirable for construction, but more desirable from a schedule and property standpoint as permitting and mitigation is avoided.

2.4.2 Route Description and Conflicts

From its beginning at the Segment G connection, the Segment D pipeline routes northwest approximately seven miles to the point where Segment I connects to the main pipeline. Just southeast of the Segment I intersection is conflict area D1-Mansfield. See Appendix J for conflict analysis D1-Mansfield and D1a-Mansfield. Upon evaluation of the conflict area, the northeastern route option was chosen. The northeastern option is more rural than the other options bypassing several well pads to the east of an electrical transmission line and crossing FM 1187 before the Segment I connection. The northeastern option was chosen due to reduced environmental impacts, cost advantages and the fact that it missed a new mining operation and several structures. All other options required the demolition of several small homes.

After the Segment I connection, Segment D turns from bearing northwesterly to bearing westerly. Approximately 3 miles west of the Segment I connection, the route passes through another conflict area. See Appendix J for conflict analysis D2-Rendon. Four routes were considered for routing through the urban Rendon congestion. All routes considered require the demolition of houses. The selected route is the northern most which requires the demolition of a single house while the other routes required the demolition of 3, 4, and 5 houses. The house on the chosen route lays just to the east of the intersection of Rendon Road and Valley Ridge road.

The Segment D route continues west to conflict D3-I35; see Appendix J for the conflict analysis. The northern option which routes north of Crowley Middle School at FM 731 was chosen for the route by TRWD on February 10, 2010. Although this was not the least expensive route, it was most favorable due to avoiding urban conflicts and conflicts with the middle school.

West of I-35W, two routes were studied to connect to the Benbrook Pipeline. The first route is an open cut option that winds through several subdivisions to a high point west of Crowley and a site of a potential terminal storage reservoir. The reservoir would have several operational benefits, but adds power cost at low flow rates. From the reservoir, the pipeline bears in a northerly direction and tunnels under a railroad and Old Granbury Road to connect to the Benbrook Pipeline on USACE property.

A second route, called the 790 Tunnel Option, takes a more direct route to the proposed Benbrook connection point and tunnels at elevation 790' MSL under the high ridge passing through Crowley. Although the tunnel option is more expensive in capital costs, life cycle costs show a breakeven point after 100 years. In addition, the tunnel route will have less impact on the environment, less impact on the community and should require less maintenance. The 790 Tunnel Option was chosen by TRWD as the preferred route. **Figure 2-9** shows the two alignments studied through the Crowley area and the portion of the pipeline to be installed in a tunnel.

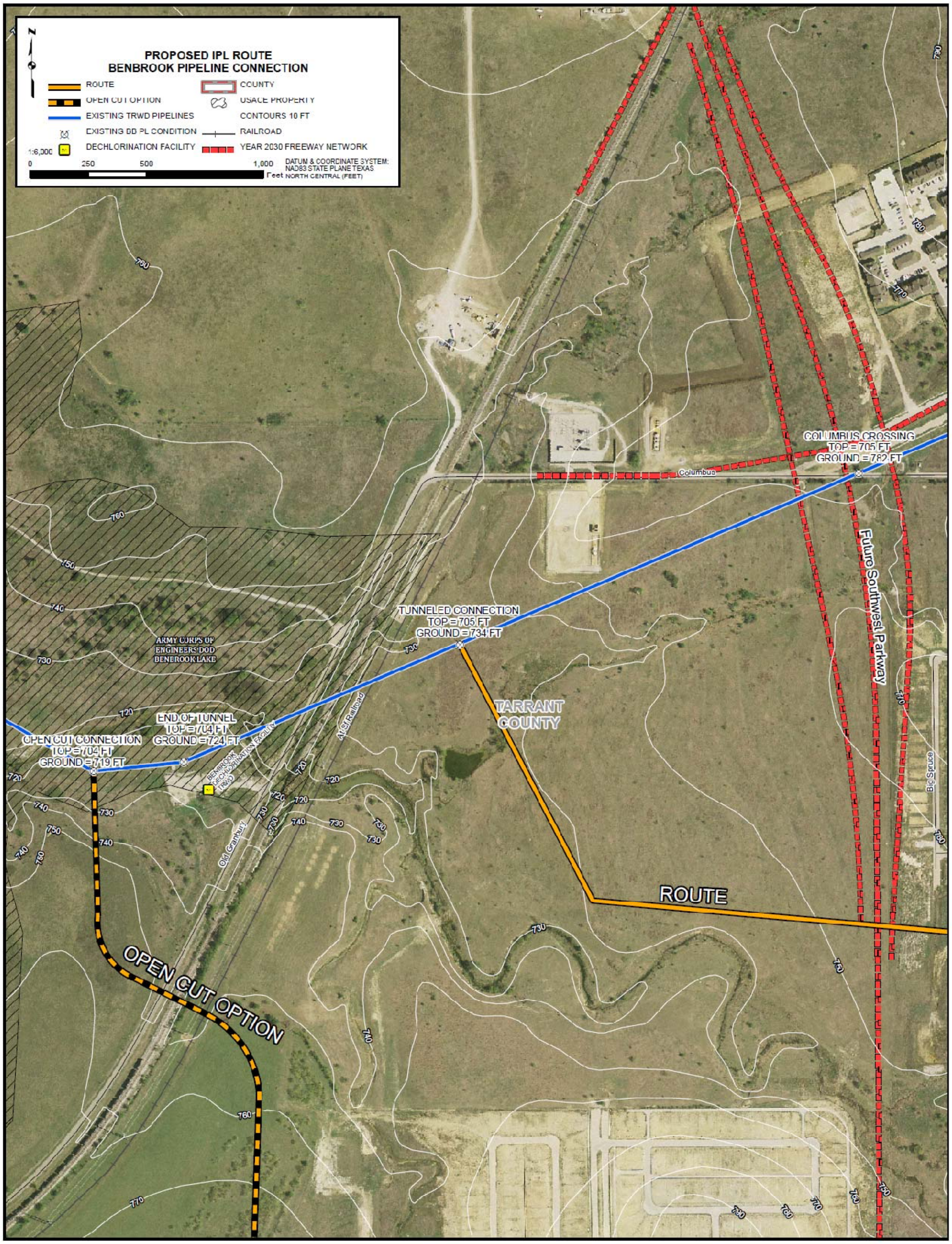

Figure 2-8. **Benbrook Connection**

The chosen 790 Tunnel Option extends from the northern D3-I35 option to a point southeast of Crowley High School. At this point the tunnel passes under the High School property to an open lot lying between a subdivision and a gas facility. The length of the tunnel is 8,480 feet and is approximately 50 feet deep.

From the end of the tunnel the route bears northerly along a subdivision before turning west for the proposed crossing of the future Southwest Parkway. Soon after the proposed Southwest Parkway crossing, the route ties into the existing Benbrook waterline on the east side of Old Granbury road. This portion of the Benbrook line was tunneled which will require a deep connection point. However, by connecting to the east of Old Granbury road instead of the west, USACE property can be avoided.

Table 2-13 shows the conflict analysis areas that were studied for Segment D. The complete conflict analysis' can be reviewed in Appendix J.

Table 2-13. Segment D Conflicts

Conflict Name	ID Number	Decision
Mansfield	D1	Moved to the east of the power-line easement to miss two houses and the new mining operations.
Rendon	D2	Re-routed north to miss two houses.
I35	D3	North route to avoid school and urban conflicts.

2.4.3 Hydraulics

As described above, pumping costs are reduced by utilizing a deep tunnel through the ridge near Crowley. This lowers the high point of the line by approximately 50 feet. An alternative to this is an open cut route to the south of Crowley High school and a balancing reservoir. While the open cut alternative would present lower construction costs, the tunnel was chosen to reduce long term pumping and maintenance cost.

2.4.4 Crossings

Tunnel crossings in Segment D include an interstate highway, four FM roads, and two railroads as listed in **Table 2-14**.

Table 2-14. Tunneled Crossings

Major Highways	FM Highways	Railroad / River Crossings
I-35W	157	MKT Railroad
	917	AT & SF Railroad
	1187	
	731	

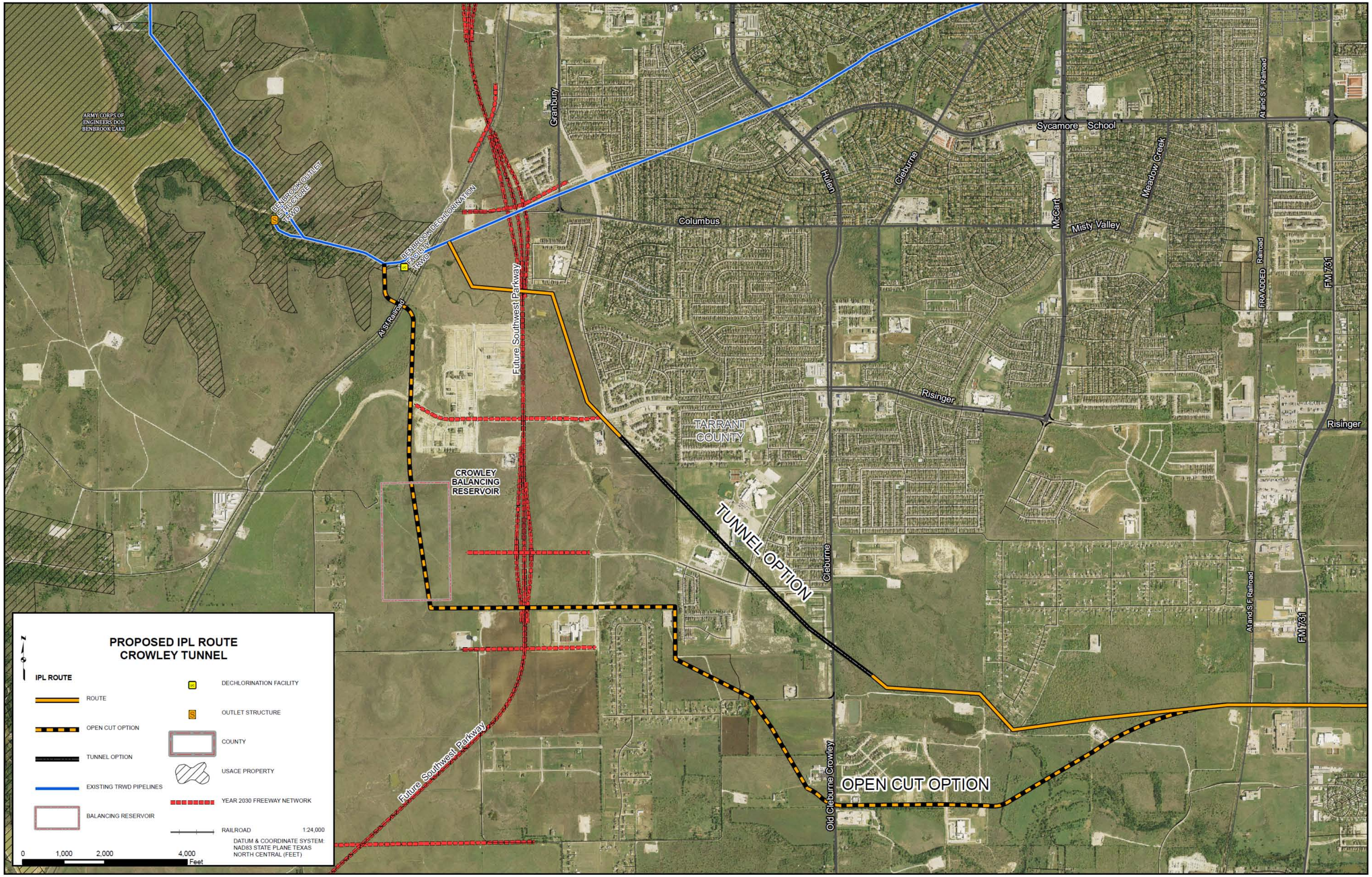

Figure 2-9. **Crowley Tunnel Options and Alternate Open Cut Option**

Segment D will also include approximately 34 oil and gas crossings and 17 electrical transmission line crossings. These crossings will be open cut.

2.4.5 Environmental

Table 2-15 summarizes environmental conflicts along segment D.

Table 2-15. Segment D Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	3	536	
Intermittent Creek Crossings	24	5,272	
Wetlands			2
Upland Forest			6
Bottomland Forest			65

2.5 Segment E – Cedar Creek to Integrated Pipeline

2.5.1 Overview

Segment E begins at the proposed Cedar Creek Reservoir Pump Station at the southwest corner of Cedar Creek Reservoir. Segment E proceeds southwest from the proposed pump station and connects to the Integrated Pipeline at the beginning of Segment B. Segment E has a 72-inch diameter and it has a design capacity of 127 MGD. Refer to **Figure 2-4** for a map featuring Segment E.

Table 2-16 is a summary of the Segment E route construction classification. As seen in the table, Segment E is mainly comprised of rural land with 98% of the route being either pasture or wooded areas. Nearly ninety percent of the segment passes through rural prairies, and the remaining ten percent passes through densely wooded areas.

Table 2-16. Segment E Route Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	29	Minor Road	29
			Water Body	-
	Rural	8,370	Pasture	-
			Cropland	7,557
			Wooded	813
	Urban	-	Light Urban	-
			Medium Urban	-
			Heavy Urban	-
Tunnel	Crossing Tunnel	118	Railroad	-
			River	-
			Major Road	118
	Deep Tunnel	-	Hydraulic Advantage	-
Total Length – Segment E				**8,517**

The only facility located within the Segment E route is the Cedar Creek Reservoir Intake Pump Station at the beginning of the route. A description of the proposed Cedar Creek Reservoir Pump Station is included in Section 3.

2.5.2 Route Description and Conflict Analysis

Segment E has a length of 8,517 feet, and a few bends. One bend is to miss a cemetery and the other to avoid businesses and residences along State Highway 274. The pipeline will pass through the Cedar Creek Reservoir dam embankment which will require a special design with review and approval by TCEQ. This design could require an aerial crossing but a more typical design would be a concrete encased section of pipe through the embankment with select backfill. Tunneling will also be required for the crossing of State Highway 274.

2.5.3 Environmental

For a detailed analysis of creek crossings see the environmental report in Appendix C. **Table 2-17** is a summary of the environmental areas crossed by Segment E.

Table 2-17. Segment E Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	-	-	
Intermittent Creek Crossings	1	196	
Wetlands			1
Upland Forest			1
Bottomland Forest			0

2.6 Segment F

2.6.1 Overview

Segment F begins at the existing Richland-Chambers Reservoir Pump Station on the north shore of Richland-Chambers Reservoir as shown in **Figure 2-4**. The end point of Segment F is approximately 11 miles north at the end of Segment B and the beginning of Segment C. Segment F generally runs north from the Richland-Chambers Reservoir Pump Station to the east side of Kerens and continues north to the connection point with Segments B and C. **Table 2-18** summarizes the breakdown of this segment:

Table 2-18. Segment F Route Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	552	Minor Road	400
			Water	152
	Rural	56,727	Pasture	36,358
			Cropland	5,803
			Wooded	14,566
	Urban	0	Light Urban	0
			Medium Urban	0
			Heavy Urban	0
Tunnel	Crossing Tunnel	489	Railroad	120
			River	0
			Major Road	369
	Deep Tunnel	0	Deep Tunnel	0
Total Length – Segment F				**57,768**

Segment F is proposed to carry 70 MGD from Richland Chambers Reservoir. This segment will be 66-inches in diameter.

2.6.2 Route Description and Conflicts

The route parallels the existing 90-inch Richland Chambers pipeline for the first 3,600 feet then travels north toward Kerens. The route travels across rural areas to State Highway 309, parallels the west right-of-way of SH 309 for 700 feet, crosses Highway 309, and then parallels the east right-of-way line for 4,400 feet. This jog across the road helps decrease wooded area crossing on the west side of SH 309. The route continues north across mostly open rural land to the crossing of the St. Louis Southwestern Railroad and State Highway 31 approximately 1.6 miles east of Kerens. North of the highway, the route continues to the connection with Segments B and C through mostly open pasture land.

No conflict analysis areas were required during the Segment F route selection.

2.6.3 Crossings

Tunnel crossings in Segment F include 2 state highways, 1 FM road, and 1 railroad. **Table 2-19** summarizes which major roads will be crossed utilizing tunneling.

Table 2-19. Tunneled Crossings

Major Highways	FM Highways	Railroad / River Crossings
SH 309	3096	St. Louis Southwestern
SH 31		

Segment F will also include approximately 3 oil and gas crossings and 3electrical transmission line crossings. These crossings are anticipated to be open cut.

2.6.4 Environmental

Table 2-20 summarizes environmental conflicts along Segment F.

Table 2-20. Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	2	409	
Intermittent Creek Crossings	10	2,150	
Wetlands			3
Upland Forest			15
Bottomland Forest			5

2.7 Segment G

2.7.1 Segment G Overview

Segment G begins near the intersection of US Highway 287 and State Highway 360 where pipeline Segments C and D intersect as shown in **Figure 2-10**. The end point of Segment G is at the connection to the existing Richland-Chambers pipeline, approximately 1.4 miles to the north. Segment G generally runs north from Segments C and D to the connection point across open rural land. **Table 2-21** summarizes the breakdown of this segment:

Table 2-21. Segment G Route Classification

	Major Classification	Length (LF)	Detailed Classification	Length (LF)
Open Cut	Crossings	27	Minor Road	27
			Water	0
	Rural	6,759	Pasture	172
			Cropland	5,989
			Wooded	598
	Urban	0	Light Urban	0
			Medium Urban	0
			Heavy Urban	0
Tunnel	Crossing Tunnel	334	Railroad	0
			River	0
			Major Road	334
	Deep Tunnel	0	Deep Tunnel	0
Total Length – Segment G				**7,120**

2.7.2 Route Description and Conflicts

Three routes were studied for segment G all of which traveled roughly 1.5 miles northerly to the existing RC-pipeline. See Appendix J for the conflict analysis comparing the three options. The western option, which was chosen due to shorter length and reduced cost, travels north from the beginning point at Segments C and D across an open field to the connection point with the existing Richland-Chambers pipeline.

2.7.3 Hydraulics

Segment G is proposed to carry 347 MGD from the IPL to the Richland-Chambers pipeline. This segment will be 108-inches in diameter. This will allow Dallas to deliver 150 MGD to Joe Pool Lake or to Bachman WTP through Segment H. With Segment I, TRWD does not need the ability to deliver 197 MGD through Segment G; however, the added flexibility and redundancy may justify keeping Segment G in the IPL

2.7.4 Crossings

Tunnel crossings in Segment G include 1 US highway. **Table 2-22** summarizes which major roads will be crossed utilizing tunneling.

Table 2-22. Tunneled Crossing

Major Highways	FM Highways	Railroad / River Crossings
US Highway 287	----	----

Segment G will also include approximately 1 oil and gas crossings with no major electrical transmission line crossings. The crossing is anticipated to be open cut.

2.7.5 Environmental

Table 2-23 summarizes environmental conflicts along Segment G.

Table 2-23. Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	-		
Intermittent Creek Crossings	2	339	
Wetlands			-
Upland Forest			2
Bottomland Forest			1

2.8 Segment I

2.8.1 Overview

Segment I, also called the KBR connection, branches from Segment D near the crossing of FM 1187. After traveling north approximately three miles through rural pasture and light urban conflicts, the route will join TRWD's existing pipeline. From this point, the Kennedale Balancing Reservoir is located 1,000 feet to the northwest. It has not been determined if the pipeline can connect to the existing pipelines at this location, or if the pipeline will need to be extended to the KBR, paralleling the existing TRWD pipelines. See **Figure 2-10** for the route location. **Table 2-24** summarizes the breakdown of this segment.

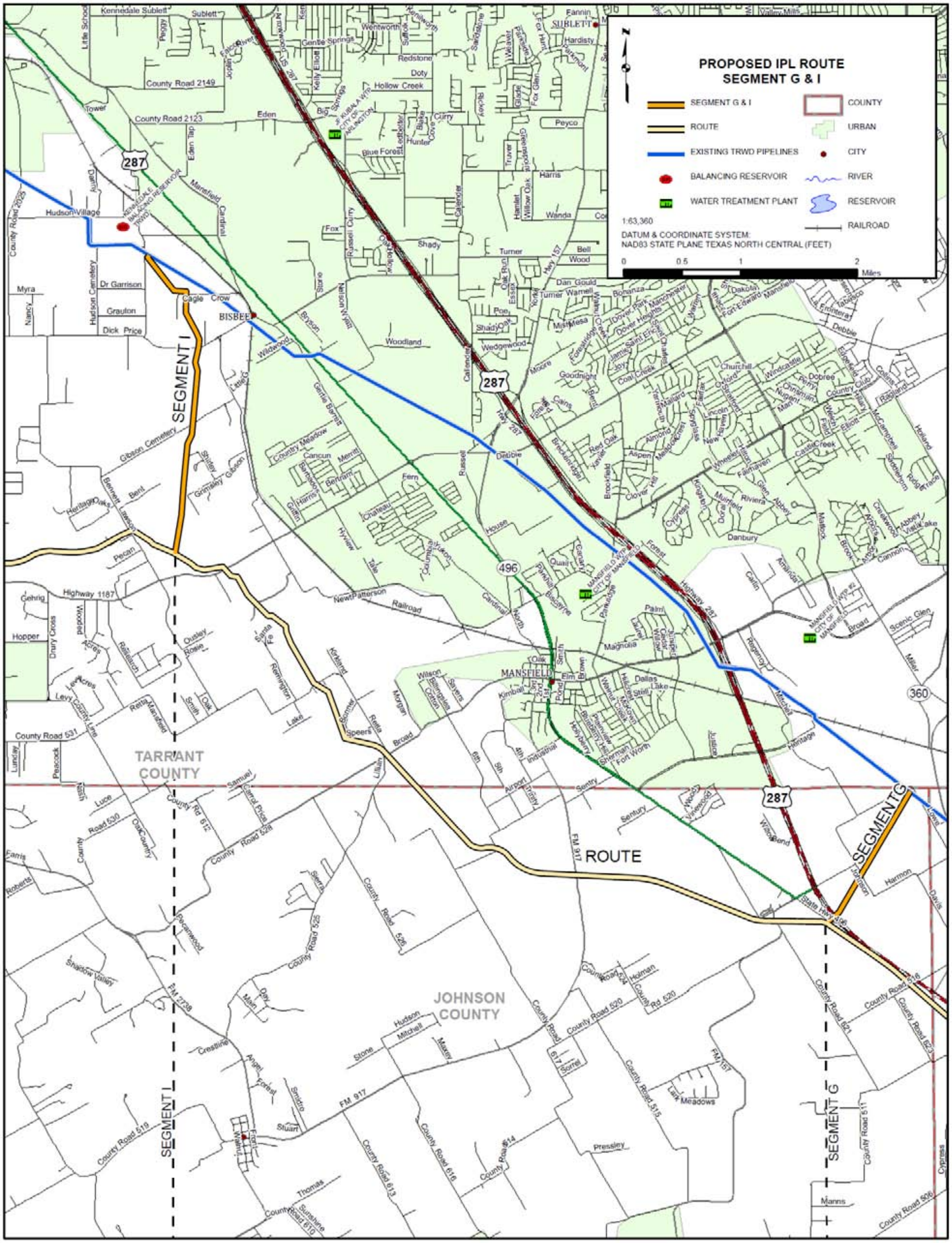

Figure 2-10. Segments G & I

Table 2-24. Segment I Classification

<table>
<tr><th></th><th>Major Classification</th><th>Length (LF)</th><th>Detailed Classification</th><th>Length (LF)</th></tr>
<tr><td rowspan="8">Open Cut</td><td rowspan="2">Crossings</td><td rowspan="2">178</td><td>Minor Road</td><td>178</td></tr>
<tr><td>Water</td><td>0</td></tr>
<tr><td rowspan="3">Rural</td><td rowspan="3">13,105</td><td>Pasture</td><td>8,922</td></tr>
<tr><td>Cropland</td><td>0</td></tr>
<tr><td>Wooded</td><td>4,183</td></tr>
<tr><td rowspan="3">Urban</td><td rowspan="3">1,482</td><td>Light Urban</td><td>1,482</td></tr>
<tr><td>Medium Urban</td><td>0</td></tr>
<tr><td>Heavy Urban</td><td>0</td></tr>
<tr><td rowspan="4">Tunnel</td><td rowspan="3">Crossing Tunnel</td><td rowspan="3">0</td><td>Railroad</td><td>0</td></tr>
<tr><td>River</td><td>0</td></tr>
<tr><td>Major Road</td><td>0</td></tr>
<tr><td>Deep Tunnel</td><td>0</td><td>Hydraulic Advantage</td><td>0</td></tr>
<tr><td colspan="2">Total Length – Segment I</td><td colspan="2"></td><td>14,765</td></tr>
</table>

2.8.2 Route Description and Conflicts

A field visit on March 25, 2010 confirmed that several possible routes paralleling a gas line are not feasible. Thus, a portion of the route was shifted approximately 1,000 feet to the east of the originally conceived route. The route now bears north until crossing Dick Price Road. At Dick Price the route turns to the northwest gradually drawing closer to the existing waterline.

2.8.3 Hydraulics

The purpose of this segment is to provide a cross connection to the existing East Texas System. The cross-connection provides the ability to increase the delivery rate to KBR without having to parallel the existing 90-inch and 72-inch pipelines through the urban Mansfield area. In turn, this will increase reliability and will give TRWD multiple options in managing water within their existing network.

2.8.4 Crossings

There are no major road or railroad crossings within segment I. The route crosses several minor roads which are anticipated to be open cut. From south to north the roads are:

- Gibson Cemetery Road
- Dick Price Road
- Cagle Crow Road

The pipeline also crosses several driveways, approximately four oil and gas lines and one electrical transmission line.

2.8.5 Environmental

Table 2-25 summarizes environmental conflict along segment I.

Table 2-25. Segment F Environmental Conflicts

	Number	Length, ft	Area, acre
Perennial Creek Crossings	1	175	
Intermittent Creek Crossings	1	28	
Wetlands			1
Upland Forest			8
Bottomland Forest			1

2.9 Next Steps

With the conclusion of this route selection, the pipeline effort will transition from a desktop route study to a final surveyed alignment which will be used in the final design of all segments.

To date, the corridor and route studies have been primarily "desktop" studies using aerial photography, available records and databases, and readily available property data. In order to refine the route to the final alignment, significant field work will be required. In general, the following tasks will be performed in the conceptual design phase:

- Surveyors will research all boundary information for affected and potentially affected properties and provide a database of the landowner and property information.
- Landowner right of entry permission will be obtained on all properties the route crosses as well as adjoining properties. Permission to access adjoining properties may be needed in order to help facilitate minor re-routes around conflicts that are discovered in the field.
- Engineering, environmental, and archeological teams will walk the entire route and identify conflicts in the field. These conflicts will be analyzed and the alignment will be modified to avoid or mitigate the impacts. Subsurface Utility Engineering (SUE) will be required to locate existing utilities.
- Surveyors will establish project control for aerial photography and land survey, and provide photography and topographic survey.
- Once the alignment is established, easement documents will be provided to TRWD and Dallas for acquisition.

At the end of the conceptual design phase, the centerline of the proposed IPL will be established, along with corresponding 150 foot-wide right of way. This alignment will be used for the final design effort and environmental permitting.

Section 3
Facility Sites

This section of the report describes the proposed facilities for the Integrated Pipeline Project. The following table lists the facilities discussed in this section of the report.

Table 3-1. Summary of Facility Sites

Lake Palestine Pump Station	Anderson	150 MGD	Initial (pending Dallas decision)
Cedar Creek Lake Pump Station	Henderson	127 MGD / 190 Peak	Initial
Richland-Chambers Lake Pump Station	Navarro	70 MGD Initial / 250 MGD Future	Initial
Booster Pump Station 1 of 2	Navarro	350 MGD	Initial
Booster Pump Station 2 of 2	Ellis	350 MGD	Initial
Crowley Balancing Reservoir	Tarrant	200 MG Initial / 400 MG future	Delayed or Deleted with Crowley Tunnel

The timing of construction for all pump stations is contingent on the final phasing analysis to be completed in the conceptual design phase of this project. Timing of construction for the Lake Palestine Pump Station is contingent on Dallas' decisions as to the timing of their need for additional supplies. The Crowley Balancing Reservoir was proposed during the corridor selection phase of the project. The conclusion from recent studies is to build a tunnel through high ground in the Crowley area, thus possibly eliminating the need for the balancing reservoir. Because the decision as to building this tunnel will be refined in the Conceptual Design Phase, the description and site study for the balancing reservoir has been included in this report.

3.1 Lake Pump Stations

This section describes the three lake pump stations at Lake Palestine, Cedar Creek Reservoir and Richland-Chambers Reservoir. The lake pump station sites are well established based on previous studies. For lake pump stations, the optimum site would be on a steep bank on the lake shore that provides close access to deep water and high ground out of the flood pool. The site would also have good foundation soils. The optimum site would also be near public road access and close to high voltage power.

3.1.1 Lake Palestine Pump Station

The Integrated Pipeline begins at a proposed intake pump station site on the west side of Lake Palestine. The recommended location is approximately one mile north of the Blackburn Dam and was selected as part of the *Lake Palestine Utilization and Pipeline Alignment Study, June 1989*. The recommended property was purchased by Dallas based on the conclusions of that report. A location map of the Lake Palestine Pump Station is illustrated in **Figure 3-1**.

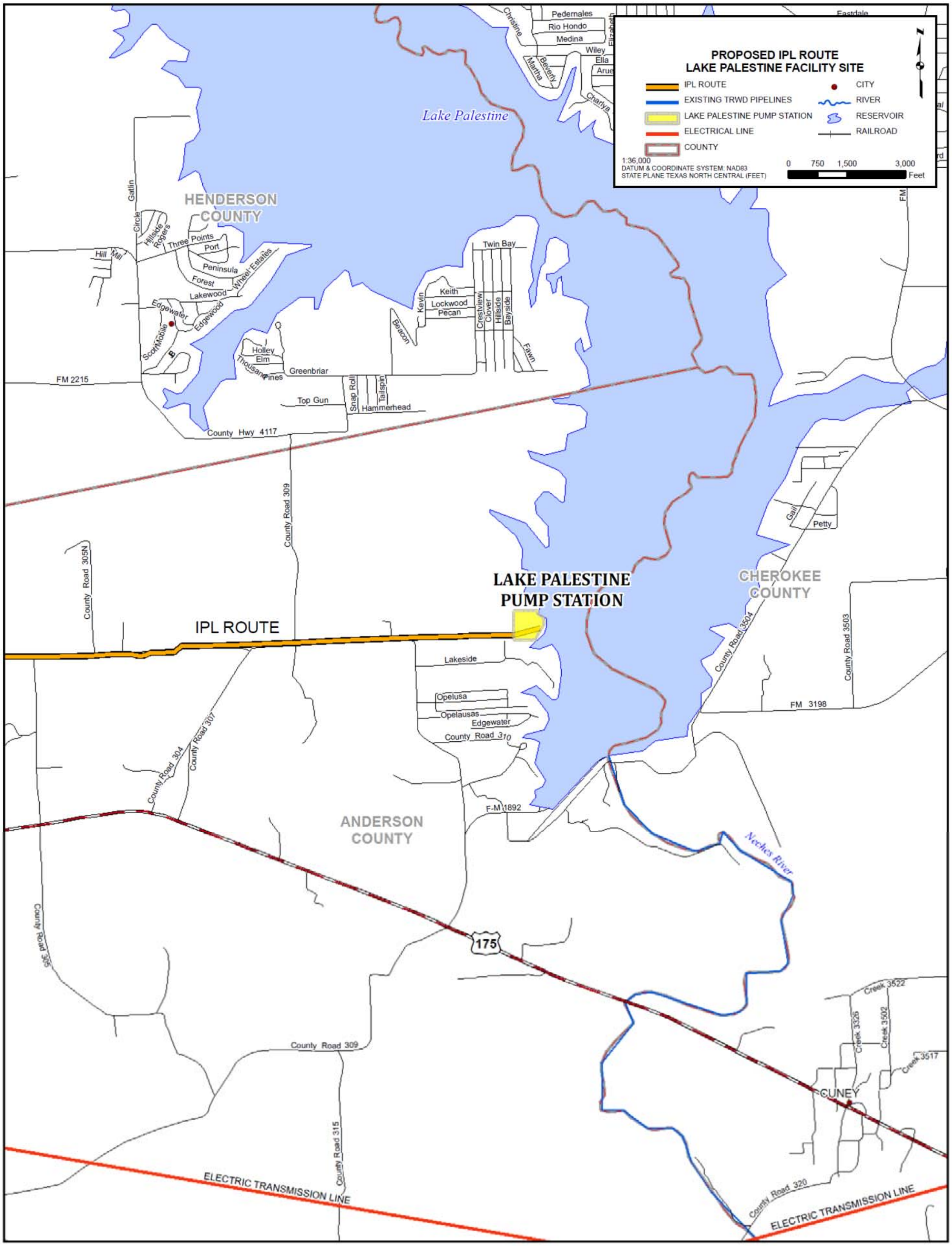

Figure 3-1. Lake Palestine Location Map

The selected site is adjacent to deep lake water, has good foundation soils, access to power, and has sufficient space to allow flexibility in the intake design. Deeper water at the pump station site will increase reliability. Other sites were explored to verify that the previously recommended site was the most preferred and this study recommends the same site.

Figure 3-1 shows that the pump station is located 1.5 miles north of U.S. Highway 175. Access to the pump station is off County Road 309, an existing two-lane asphalt road. It is anticipated that a new 3,000 foot long access road will be needed from C.R. 309 to the site. The access road would likely be constructed in the proposed pipeline easement.

The site is a wooded lot that fronts the southwest side of the lake. A photograph of the site is shown in **Figure 3-2**.

Figure 3-2. Photograph of the Lake Palestine Pump Station Site

Rayburn Electric Co-op has a 138 KV transmission line approximately 1.5 miles south of the recommended site. The electric transmission line runs from the northwest to the southeast and crosses Highway 175 about 3,000 feet west of the CR 309. It is anticipated that the power line can be routed along C.R. 309 and into the site paralleling the access road and pipeline. **Figure 3-1** shows the power line in relation to roads.

Lake levels are important design criteria influencing the location and layout of an intake pump station. **Table 3-2** is a summary of key elevations for Lake Palestine, based on information from the TWDB report "Volumetric Survey of Lake Palestine, June 2003 Survey".

Table 3-2. Key Elevations for Lake Palestine

Top of Dam	364.0
Design Water Surface (Flood Conditions)	355.3
Spillway Crest (Conservation Pool)	345.0
Low Flow Outlet (Drought Conditions)	309.5

The old river channel bottom has an elevation of 300 feet. According to the area and capacity curve for Lake Palestine in the TWDB "Engineering Data" report, an intake elevation of 315 feet will access 95 percent of the lake's storage capacity. In order to pull water from an elevation of 315 feet, it is anticipated that the pump will need approximately 10' of submergence; therefore an intake channel at an approximate elevation of 300-305 feet is preferred. In order to access such a lake bottom elevation, an intake channel approximately 1,200 feet in length is needed to be dredged to reach the old river channel. **Figure 3-3** shows an aerial map of the proposed lake pump station site along with contours from the 2003 TWDB Volumetric Survey.

In 1988, a boring was taken on the pump station by McClelland Engineers and is described in their letter report dated July 25, 1988. The boring at the site shows a 1-2 foot thick layer of silty sand at the surface. Beneath this sand, a stiff to very stiff sandy clay was present to a depth of 14 feet. A sand layer three feet thick overlaying the bedrock was encountered from 14 to 17 feet. A greenish gray carboneous shale was encountered at depths of 17 feet to 32 feet. A 6 to 8 foot thick layer of porous sandstone was present from 32 feet to 38 feet. Below the sandstone is another 36' of carbonaceous shale with layers of sandstone to a depth of 74 feet where the boring was terminated. McClelland reports that water was encountered at depths of 14 to 15 feet, near the top of the sandstone layer. Shortly after encountering the water, the level rose to depths of 3 to 8 feet which was above the lake level.

The proposed site is suitable for several intake options including the following:

- A dredged intake channel with a wet-dry pit on shore that houses horizontal split-case pumps at the bottom of the pit, similar to DWU's Lake Fork Pump Station.
- A dredged intake channel to a sump pit on the shore with vertical turbine pumps set above the wet-well.
- A platform type pump station with vertical turbine pumps in the lake with a dredged channel to reduce the length of the bridge deck, similar to TRWD's Benbrook Lake Pump Station.
- A sump pit constructed on shore with intake pipes bored or tunneled into the lake with a dredged channel to the intake screens to reduce pipe length.

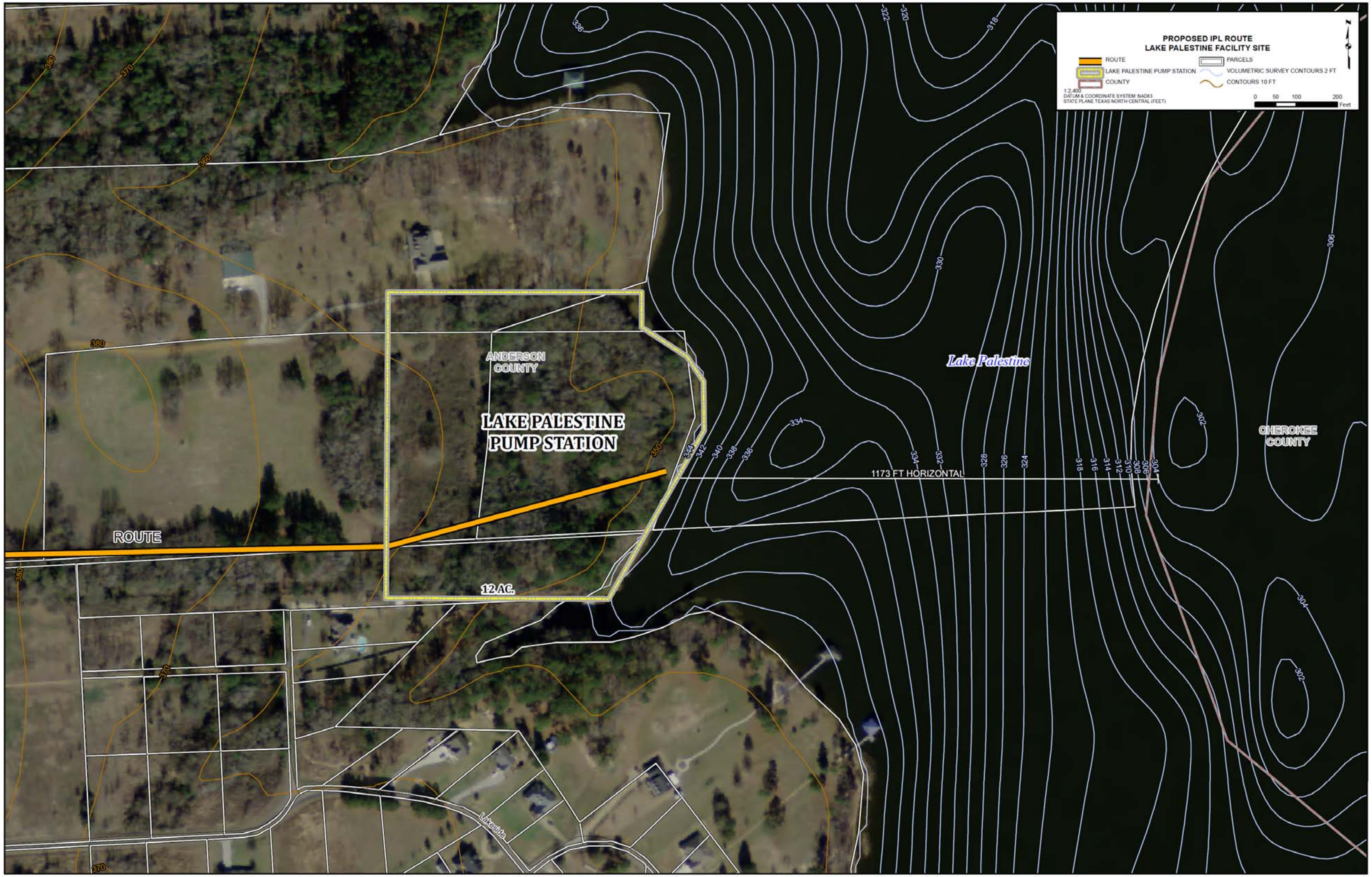

Figure 3-3. Lake Palestine Site Map

These options along with others should be evaluated in the conceptual design phase to determine the best layout in terms of capital costs, environmental impact, reliability, maintenance requirements and owner preference.

Future steps in the conceptual design phase should include geotechnical work and survey. Additional geotechnical borings are required on the site and in the lake. A topographical survey and a bathymetric survey are also recommended early in the conceptual design phase to facilitate layouts.

3.1.2 Cedar Creek Pump Station

Cedar Creek Reservoir supplies 127 MGD to the Integrated Pipeline through pipeline Segment E. Lake Pump Station sites were studied on both the east and west side of the reservoir during the corridor study. The selected pump station site is on the west side of the reservoir, approximately 1.5 miles north of the main transmission pipeline. The site is a large wooded area near the dam with adequate room for construction staging and is owned by TRWD. **Figure 3-4** shows a location map of the proposed Cedar Creek Pump station.

TXU/Oncor transmission lines are located 5,000’ from the proposed pump station site. The nearby electric transmission lines provide 69 KV, 138 KV, and 345 KV and can be seen in **Figure 3-4**. State Highway 274 is located almost a mile southwest of the site. Mankin Road can be taken from SH 274 to get within half a mile of the site. Mankin Road connects to Key Ranch Road to the north and Forehand Road to the east. An access road must be constructed either from Mankin Road, Forehand Road or Key Ranch Road to access the pump station site.

Data on Cedar Creek Reservoir was obtained from the Texas Water Development Board “Report 126 - Engineering Data on Dams and Reservoirs in Texas, Part II”. The TWDB “Engineering Data” shows that the lake is impounded by Joe Hogsett Dam, elevation 340.0 feet above mean sea level. The 100-year flood elevation for Cedar Creek Reservoir is 325.0 feet at the top of the spillway gates. Conservation pool level is 322.0 feet. It is recommended that the proposed pump station be located at a site with an elevation several feet above 325 feet MSL, preferably closer to 334 feet to match the flood protection of the existing TRWD pump station which is located further north along the lake shore.

The Texas Water Development Board performed a bathymetric survey in July of 2005 for the purposes of determined the volume of the reservoir. Based on the survey and volume calculations, the following distances from the site shoreline to various contours are listed along with the storage available at each elevation.

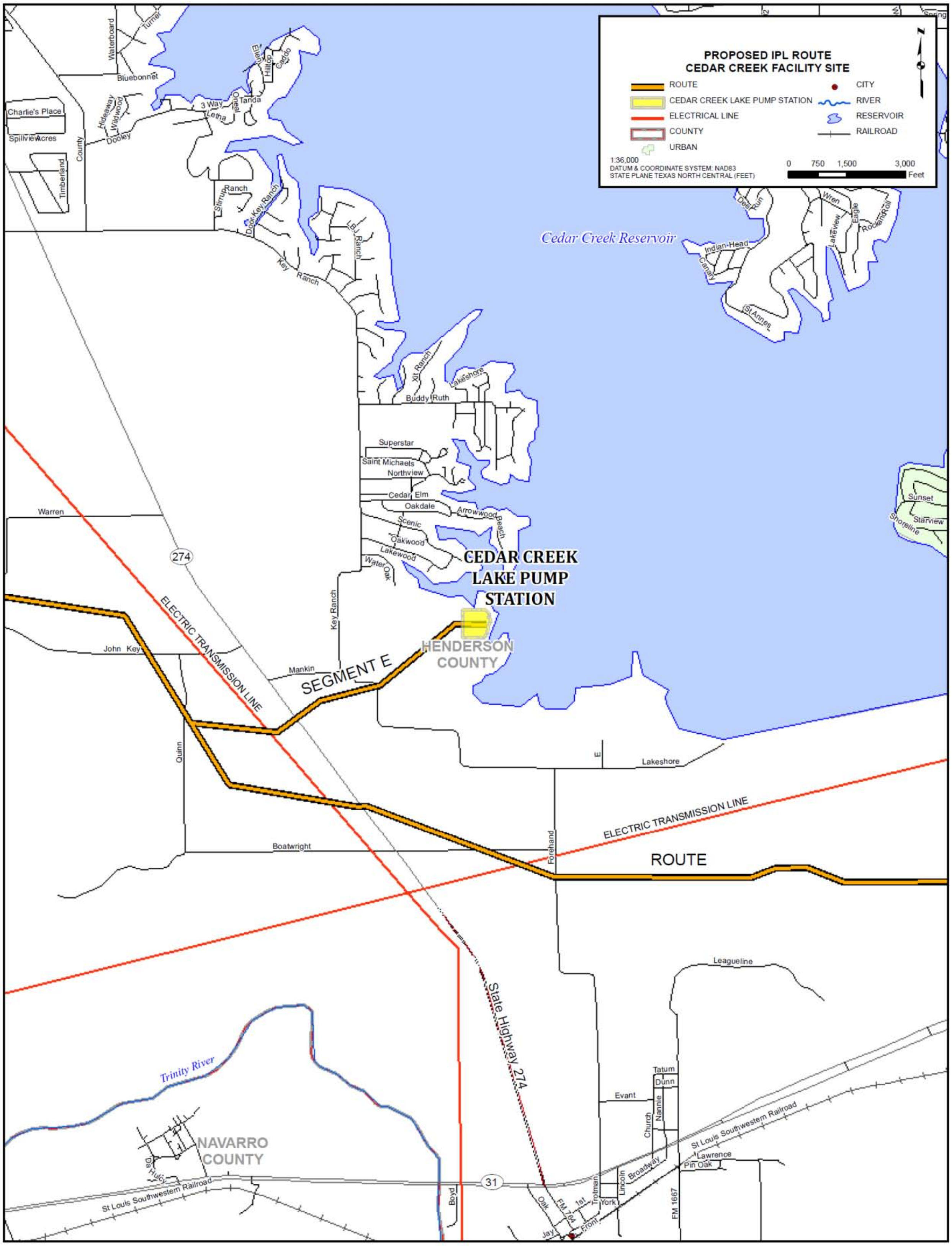

Figure 3-4. **Cedar Creek Facility Site Location**

Table 3-3. Cedar Creek Intake Channel Criteria

Elevation	Distance to Elevation (Feet)	Storage Capacity (ac-ft)	Percent of Storage Capacity
270	4,200’	1,264	99.80 %
275	2,200’	4,978	99.22 %
280	2,000’	14,257	97.76 %
285	1,100’	37,182	94.16 %
322	0	637,180	

According to the storage capacity table for Cedar Creek Reservoir in the TWDB April 2007 Report, an intake channel with a bottom elevation of 285 feet will access 94.2 percent of the lake’s storage capacity. An intake channel bottom elevation of 280 feet will access 97.7 percent of the lake’s storage capacity. Since the existing intake pump station can access water down to 275.0 feet, it seems access to 280.0 feet is adequate; however a deeper intake channel may be required to pump down to elevation 280.

A trapezoidal drainage channel runs east-west along the south side of the proposed pump station site. The soils excavated from this channel raised the site above the lake flood level. The preferred pump station site elevation is above the 330-foot contour line according to USGS maps of the area. Flood level for the lake is 325 feet. This proposed site is heavily wooded but is not located near any residential areas and the proposed pump station site is large enough for multiple pump station layout options. See **Figure 3-5** for site details.

Similar to the Lake Palestine site described above, the proposed Cedar Creek Lake Pump Station site is suitable for several intake options including the following:

- A dredged intake channel with a wet-dry pit on shore that houses horizontal split-case pumps at the bottom of the pit, similar to DWU’s Lake Fork Pump Station.
- A dredged intake channel to a sump pit on the shore with vertical turbine pumps set above the wet-well.
- A platform type pump station with vertical turbine pumps in the lake with a dredged channel to reduce the length of the bridge deck, similar to TRWD’s Benbrook Lake Pump Station.
- A sump pit constructed on shore with intake pipes bored or tunneled into the lake with a dredged channel to the intake screens to reduce pipe length.

It may be possible to use the trapezoidal drainage channel as part of the intake channel for the proposed pump station. The channel will need to be enlarged but may reduce the amount of dredging required to reach the proper elevation. A bathymetric survey is recommended for this site to verify lake depths as well as borings on land and in the lake.

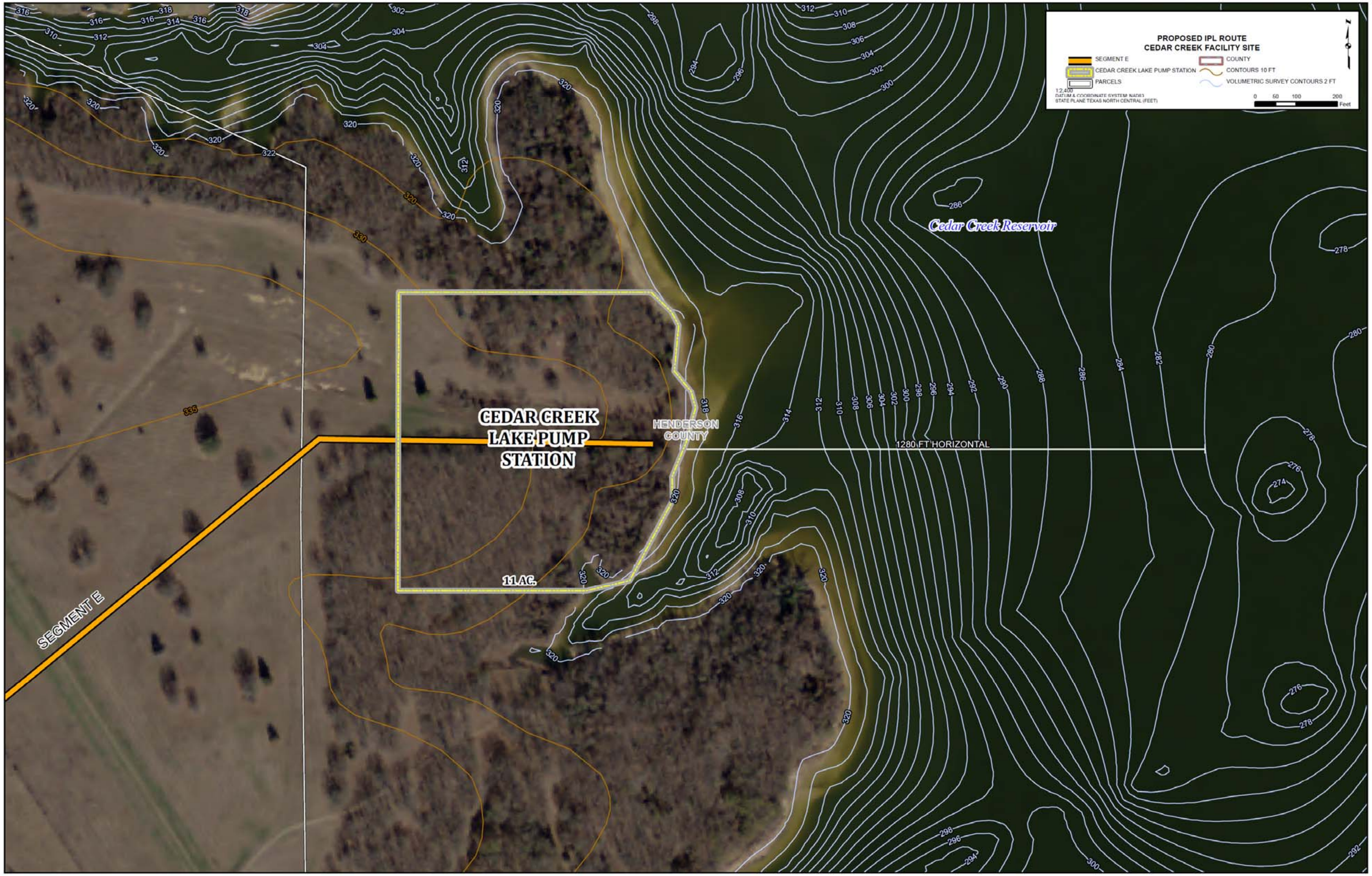

Figure 3-5. **Cedar Creek Facility Site**

3.1.3 Richland-Chambers Pump Station

Tarrant Regional Water District constructed the Richland-Chambers Project between 1984 and 1989. The intake facilities were constructed in 1985, before the lake was completed. The pump station was bid in 1987 and completed in 1989. The pump station is located on the northern shore of Richland-Chambers Reservoir. Access to the pump station is off State Highway 309 between S.H. 31 and U.S. 287 east of Corsicana. County Road 3250 provides access to the site. A location map is shown as **Figure 3-6**.

The intake facilities include an intake tower in the lake and two 14' square conduits connecting the intake tower to the sump on the shore. The 106'x69' sump was built on the shore with the intake facilities. The intake tower was designed for an ultimate capacity of 480 MGD at a velocity of less than 2 fps. Currently only one of the 14' conduits is connected to the existing sump. The facility was master planned for a future pump station to mirror the existing sump and pump station. The end of the northern conduit has a block out that will ultimately connect the future sump to the conduit. The two conduits can be isolated with stop gates on the intake tower.

The existing RC Lake Pump station has six 5500 HP pumps, each rated to pump 50 MGD at 529 feet of head. Three pumps are used in low capacity operations to move 147 MGD while 5 pumps are used in high capacity operations to move 250 MGD.

It is anticipated that the future pump station will also include six pump slots; however, it is not anticipated that all slots will be used for the proposed 70 MGD capacity of the Integrated System. The site includes space for the new pump station and a new substation. A site plan of the pump station site is shown on **Figure 3-7**. The location of the future pump station and the future substation is identified.

The existing 90" Richland-Chambers Pipeline runs in a northerly direction leaving the pump station site. The pipeline ROW is 180' wide. The pipeline is off-set 25' to the east of the easement centerline, 115' of the west side of the easement. A 4" waterline runs 5' off the west easement line and a 138kV power line runs 5' to 10' inside the eastern edge of the easement.

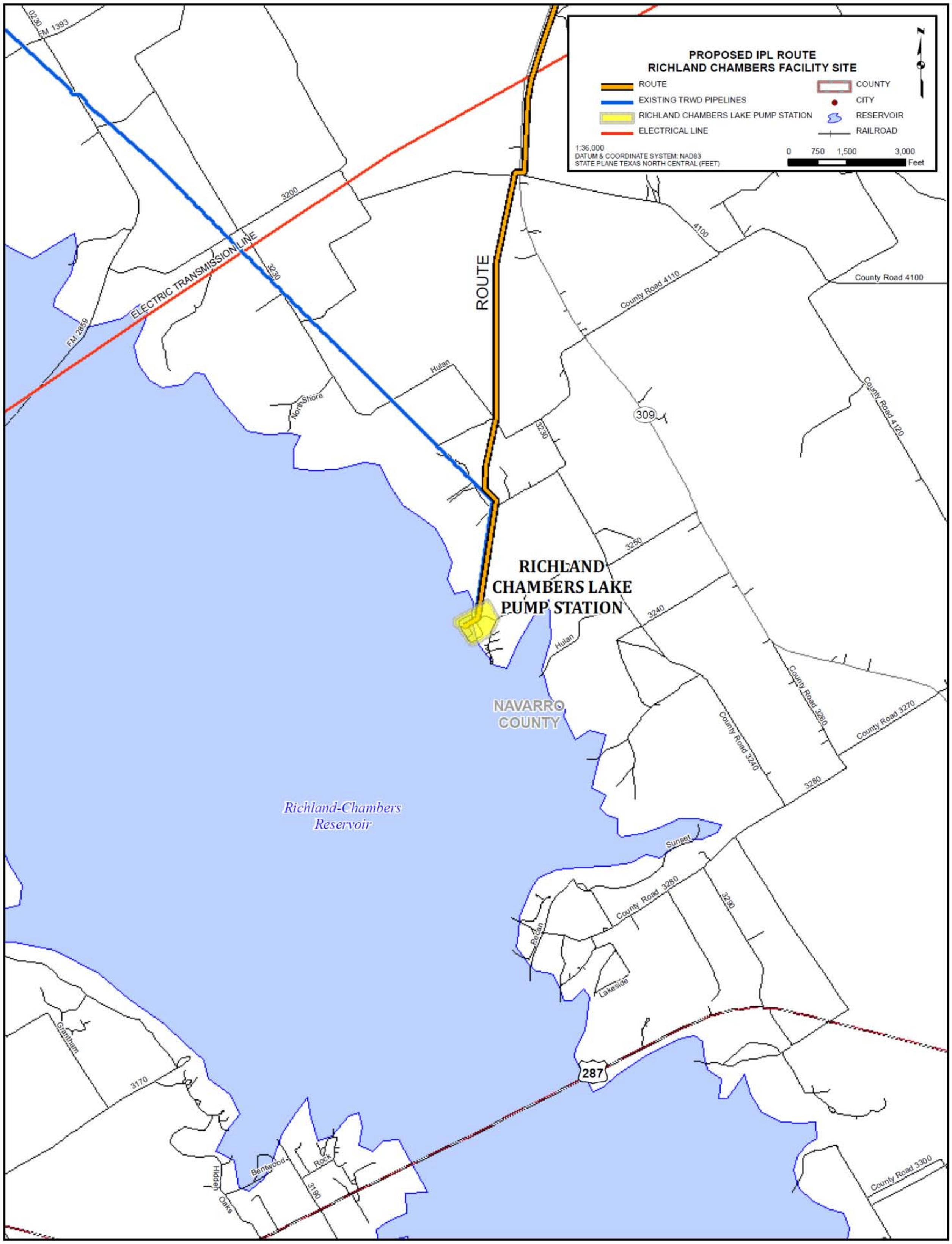

Figure 3-6. Richland-Chambers Facility Site Location

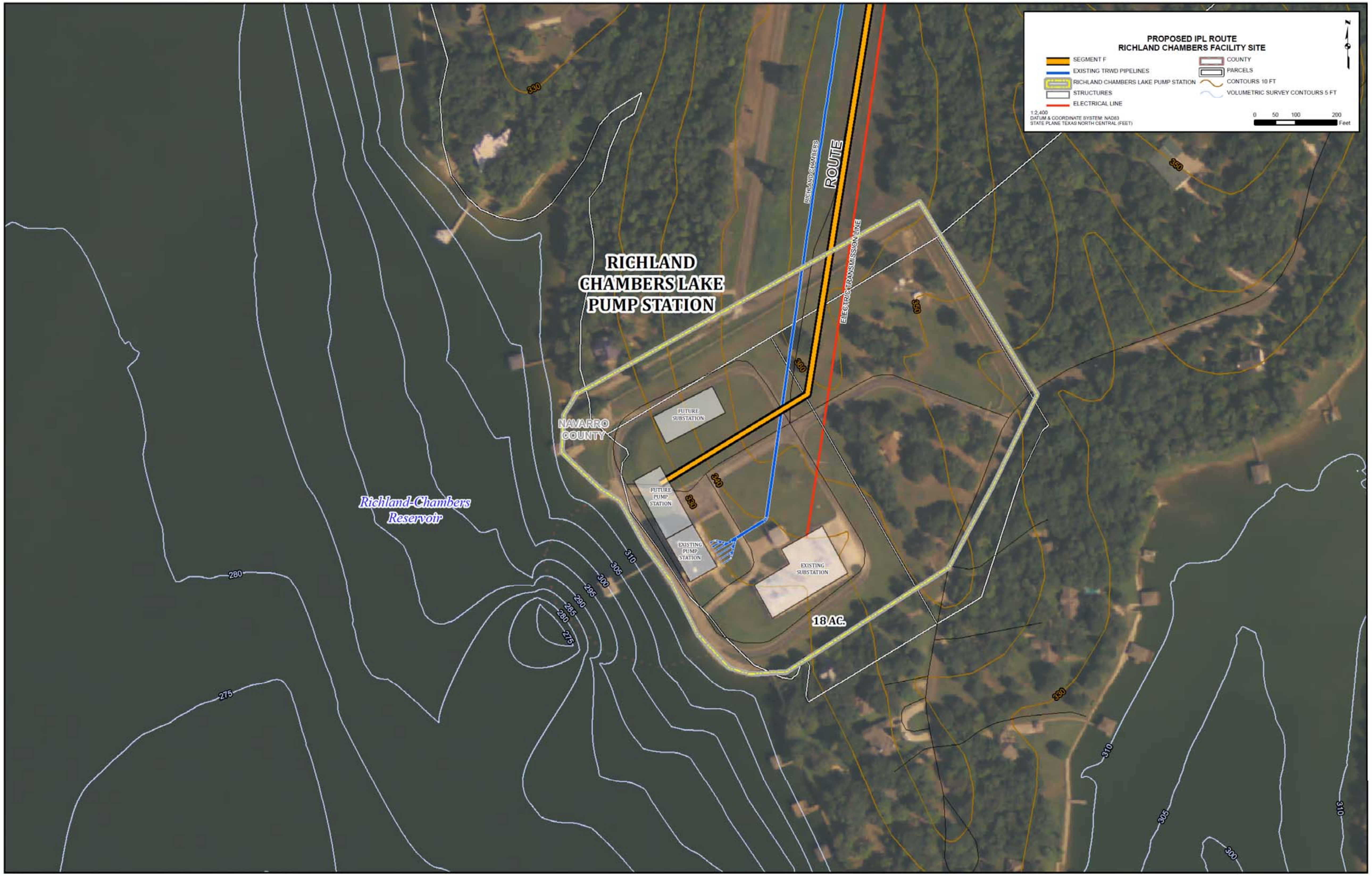

Figure 3-7. **Richland-Chambers Pump Station Site Layout**

3.2 Booster Pump Stations

Two booster pump stations are recommended along the main pipeline corridor to pump water west to TRWD and Dallas. The following section describes the two booster pump station (BPS) facilities. For each booster pump station, two alternate sites were chosen and evaluated with a recommendation made as to the preferred site. Evaluation criteria include access, proximity to power, soil conditions, hydraulics and ease of operations.

3.2.1 BPS 1 of 2

Two sites were considered for the location of BPS 1 of 2. Both options are located within Segment C between the Segment F Connection and I-45. The two options identified for the location of BPS 1 of 2 are referred to as:

- BPS 1 of 2, Site A
- BPS 1 of 2, Site B

A map showing the location of both options can be seen in **Figure 3-8**. The two site options are separated by approximately 15,000 LF along the proposed pipeline with option A as the more eastern and option B as the more western of the two. The existing TRWD Richland-Chambers Pipeline crosses in between these two options.

BPS 1 of 2 A

Site A, the more eastern, is located on the west side of FM 1129, near the intersection of FM 636 at Station 2990+00 of the IPL. The site is located directly off of FM 1129 and is due south of an existing electrical substation as seen in **Figure 3-9** which shows a photo of the proposed site.

Site A is bound by FM 1129 to the southeast and an electrical transmission right-of way to the north. The substation is located to the northeast of the site with a small pond immediately to the south of the substation. This end of the site has an elevation of 460 feet. The exact layout and location of the site depends on the type of storage facility chosen. Two options have been considered:

- Ground storage tanks may be preferred hydraulically to try and match the high points on Segment A of the pipeline. It is anticipated that the top of pipe can be set at an elevation of 525. The storage tanks could have a bottom elevation of 450 and a top elevation at 525 to keep the pipeline full and prevent the line from draining into and overflowing the tanks. The downside is the cost of taller tanks and the number of tanks that would be required to provide the adequate storage to ride through a power outage at one pump station site.
- An alternate operational concept is to build an earthen reservoir for increased storage to allow one pump station to ride though a power outage at another site. For large volumes of storage, an earthen reservoir is more cost effective. The downside is that the optimum embankment may only be 30 to 40 feet in height. As this site may have a bottom elevation of 440 feet MSL, the maximum water surface elevation for this reservoir may be only 470-480 feet. Enough freeboard could be built into the reservoir to allow water from the highpoint to drain into the reservoir, or an alternate means of keeping the pipeline full could be used such as a stand pipe.

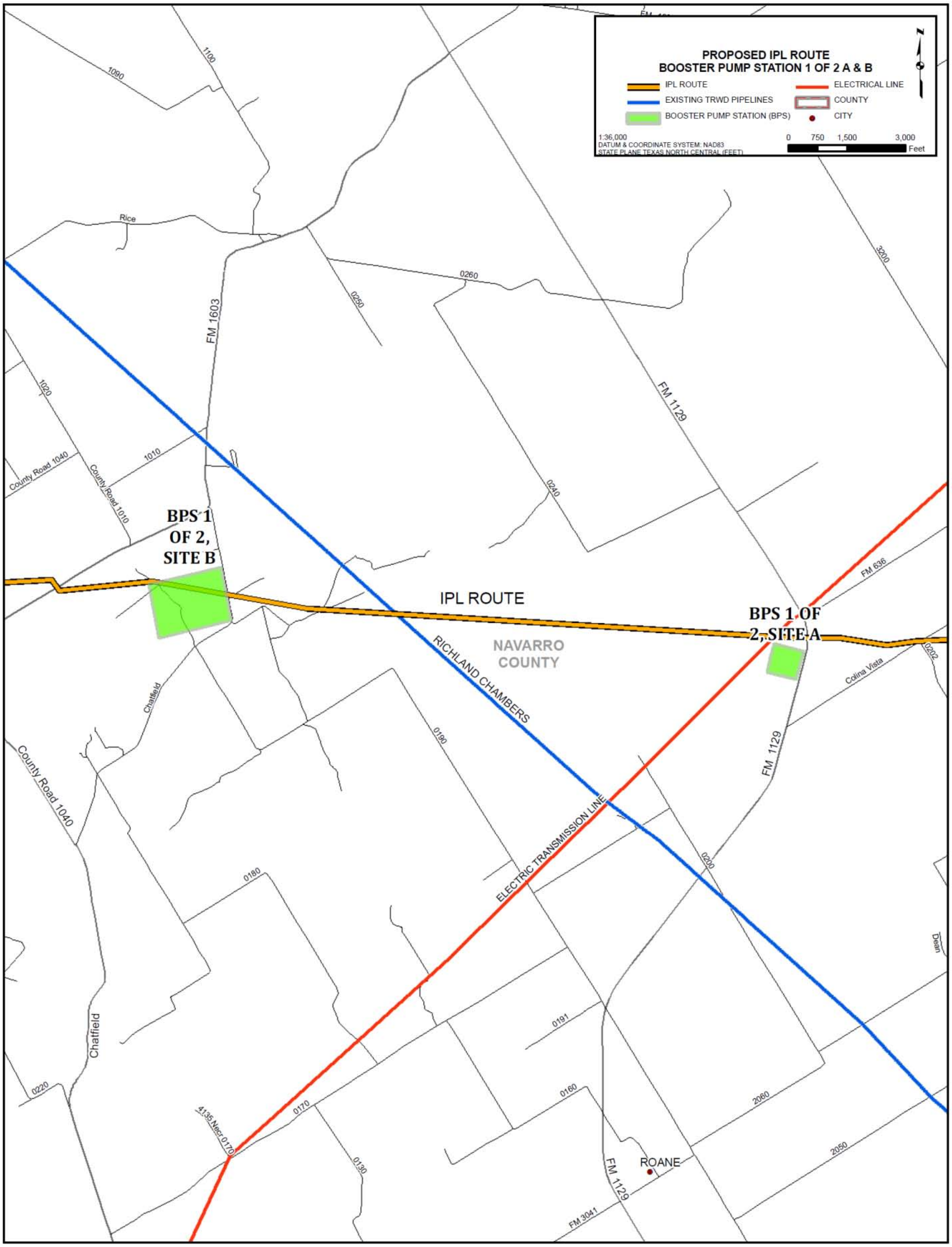

Figure 3-8. **BPS 1 of 2 Location Map**

If ground storage tanks are preferred, then the limits of the site should be shifted as far east as possible to take advantage of the high ground on the northeast corner and the proximity to the electrical substation. If an earthen reservoir is preferred, then the limits of the site can be shifted west to provide for more room between the highway and the electrical transmission line. See **Figure 3-10** for site details with the possible site boundaries and contours.

Figure 3-9. BPS 1 of 2, Site A, Facing West

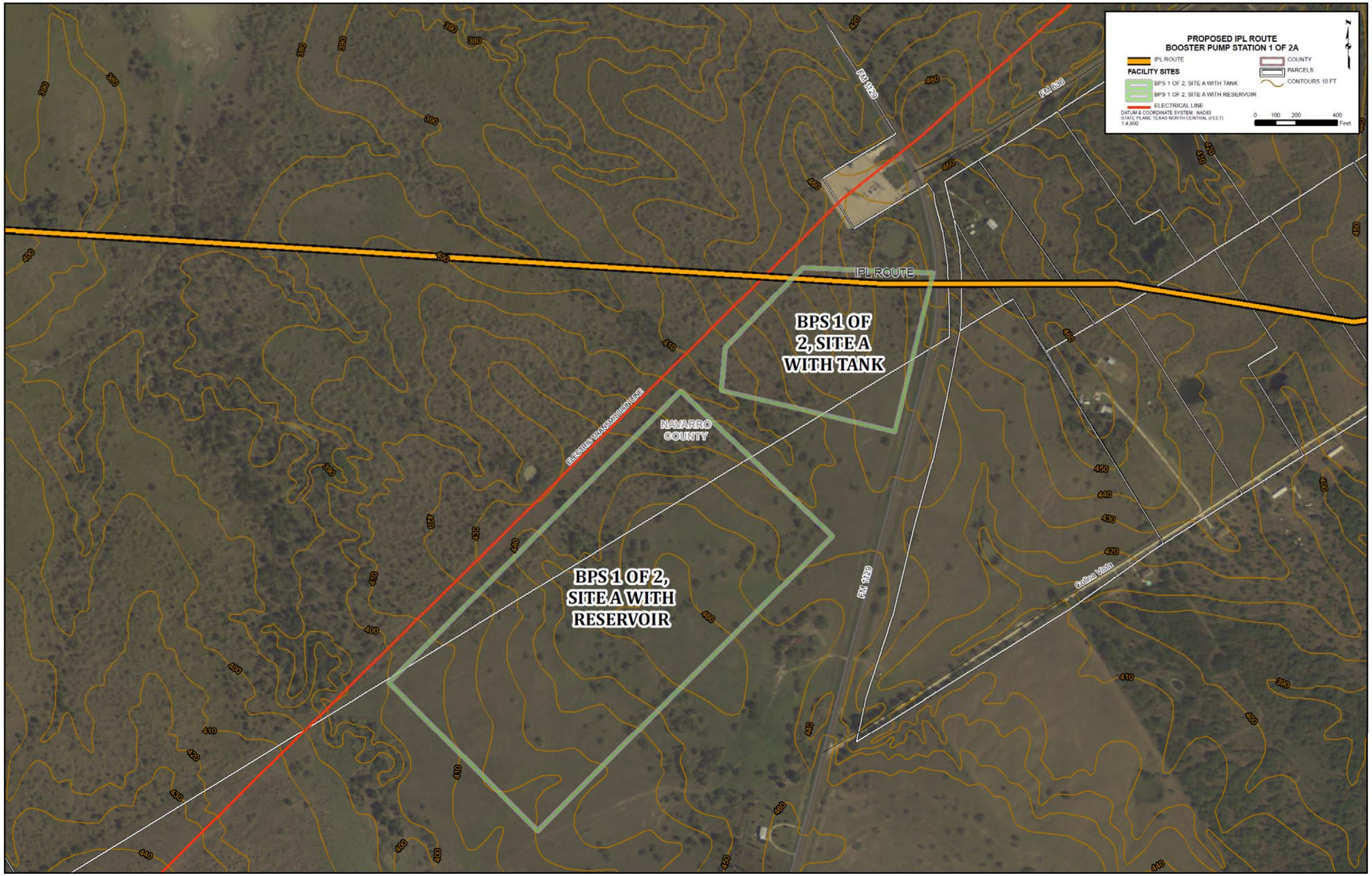

Figure 3-10. **Site Layout of BPS 1 of 2 A**

BPS 1 of 2 B

Site B is located in a field, approximately 0.3 miles south of FM 1603, directly off of Chatfield Road. The site is near Station 3140+00 of the IPL. **Figure 3-11** shows a photo of the proposed site. The black line shows the site boundary. Included inside of the site boundary will be the reservoir and pump station.

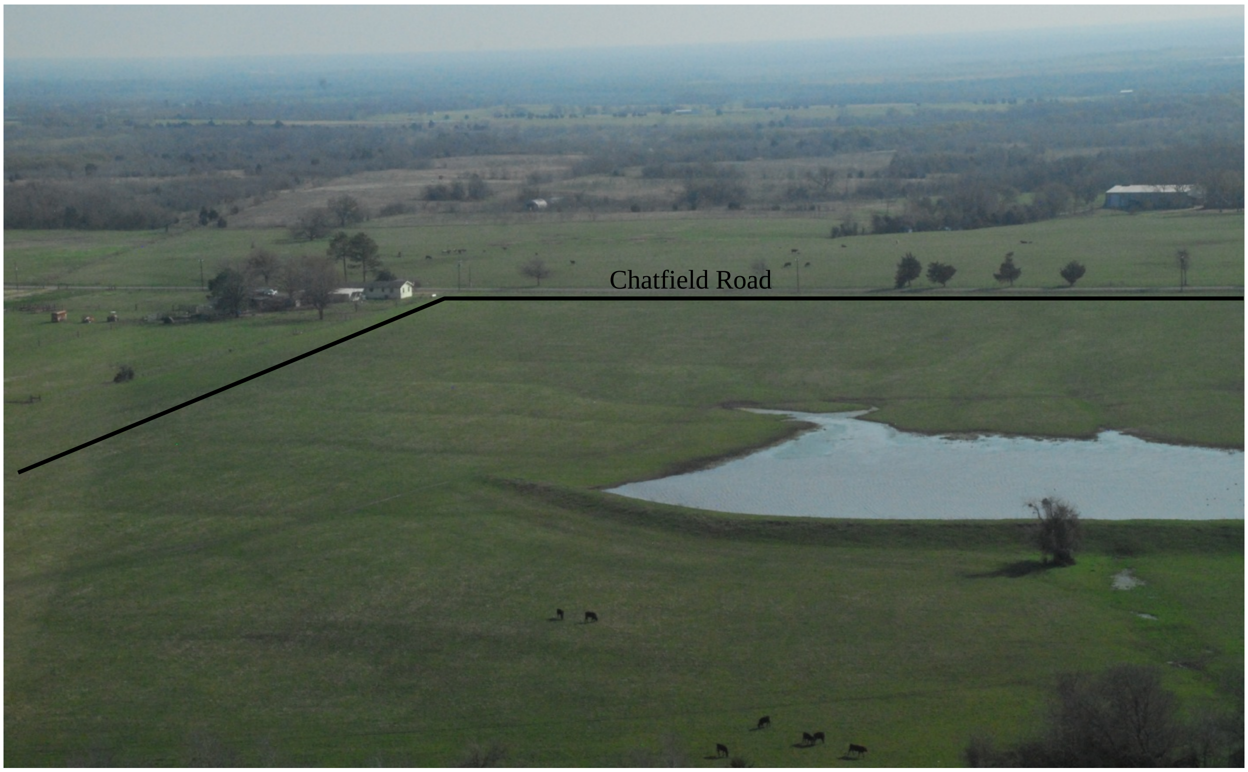

Figure 3-11. BPS 1 of 2, Site B, Facing East

Option B is on a large, relatively flat area that will allow for an earthen reservoir and pump station. The proposed site is approximately 61 acres, providing room for a 1,200 foot by 1,200 foot earthen reservoir. The footprint of the reservoir may be decreased, while maintain volume, pending site specific cut and fill requirements. An existing earthen tank is located in the middle of the site and will need to be removed during construction of the reservoir. **Figure 3-12** illustrates the boundary and topography of the proposed site.

Due to its location relative to the existing RC pipeline, this site allows multiple operating scenarios. The typical arrangement is for the pipeline to feed into the reservoir and then gravity flow into the suction side of the booster pump station. A line is needed to bypass the reservoir to connect directly to the suction side of the pump station. This will allow pumping when the reservoir is down for maintenance. A standpipe could be installed on this leg to control system pressures. A bypass around the reservoir and pump station will also be needed to allow pumping directly from the lakes to the second booster pump station. Lastly, a pipeline could be built back to the RC pipeline, approximately 4,800 feet, to allow for pumping through either the proposed IPL or the existing 90” RC line.

Site B is located on the west side of the connection to the RC Pipeline. This allows for water from Richland-Chambers to be pumped to BPS 1 of 2 and continue on to Benbrook or to be routed back to the RC Pipeline and potentially bypass the Ennis Pump Station.

The pump station may have either horizontal or vertical turbine pumps and will be located downstream of the reservoir at a lower elevation to allow the reservoir to drain completely.

Comparison of BPS 1 of 2 Sites

Property - Site B holds size advantages as it is larger in area than Site A. Site A is limited due to the restriction of the electrical transmission line on the northern boundary of the site. Although an earthen reservoir could be built on either site, Site B lends itself more to reservoir construction.

Geology - A preliminary analysis of the soils and geology in both locations was performed. The National Cooperative Soil Survey and the Geologic Atlas of Texas were used for the analysis. The soil for Site A is mostly comprised of clay. The main issue for concern with the clay at Site A is the soil's propensity to shrink and swell. For the tank, there will need to be possibly 10 to 15 feet of excavation and backfill for site improvement to prevent any shrinking and swelling. The soil for Site B is comprised of multiple soil types with the majority being sandy loam. Shrink and swale is less of an issue for Site B than Site A. The soil type is favorable for a reservoir on Site B; however, if the reservoir is cut deep enough, it may encounter a sandy formation which could cause water loss. The use of a clay or synthetic liner can be used to prevent this from occurring. There is not much difference between how the soils at the different sites will affect the pump station, but the soils at Site B are slightly more favorable.

Access - Site A has great access to a nearby power source and is directly off of an FM highway. Site B also has good access to roads, as it is situated directly off of Chatfield Road which intersects FM 1603 approximately 0.3 miles north of the facility site. However, the closest electrical substation to Site B is approximately 3 miles to the east.

Operations and Hydraulics - The ability for Site B to have a reservoir greatly increases its operation and storage capabilities. In general, the further west the booster pump station is located, the less pipe above 250 psi is required downstream of BPS 1 of 2. See **Figure 3-13** for the hydraulic profile showing the pipe pressure. Furthermore, with Site B on the west side of the RC Pipeline connection, water from the Richland Chambers Reservoir can be pumped to the reservoir at Site B and through the IPL.

There are several high points along the pipeline that are upstream of both sites and reach higher elevations than both sites. One high point is at elevation 550 feet MSL while the others are at 530 feet MSL.

The bottom of the tank at Site A would be at an elevation of 450 feet MSL. With an 80 foot tall tank, the max elevation of the tank will be 530 feet MSL to match several of the high points upstream. If Site A is chosen for BPS 1 of 2, the high point which reaches an elevation of 550 feet will have to be deep cut to an elevation of 530 feet for approximately 1,000 feet along the IPL. This will ensure that the tank at Site A does not overflow during pump stoppage.

Figure 3-12. **Site Layout of BPS 1 of 2, Site B**

It is anticipated that the reservoir at Site B will be approximately 30 feet tall with a ground elevation of 460 feet MSL and a max water level of 490 feet MSL. Note that the elevation of the pipeline upstream of Site A rises above 490 feet MSL. When pumps are not running, the water in the pipeline above 490 feet will flow by gravity to the reservoir causing potential overflow events. However, overflow can be prevented with sufficient freeboard in the reservoir. The high points along the pipeline create valleys that will store the water and remain full. In the event of a power outage, water remains inside the valleys and drains from only a portion of the pipeline. The total volume of water in the pipeline that will not be contained in valleys, but will feed into the reservoir is slightly over 1MG. With a reservoir having an inside perimeter of 1,000 feet by 1,000 feet, the freeboard required to prevent overflow is less than two inches. **Figure 3-13** features the hydraulic grade line of the pipeline from Lake Palestine to BPS 1of 2 and it shows the valleys created by the high points.

If freeboard is used on the reservoir at site B for water to drain into, the 550 foot high point will not need to be deep cut. Using freeboard at Site A requires the water tank to be approximately 250 feet in diameter which rules this operation scenario out. Thus, if site A with a tank is selected, the high point reaching 550 feet MSL upstream of the site must be deep cut for 1,000 feet.

Utilizing freeboard as discussed for site B results in portions of the pipeline being dewatered during pump stoppage. This necessitates special considerations during the start up of pumps while filling the pipeline. If avoiding dewatering of lines is preferred during pump stoppage, a standpipe with an overflow weir could be implemented at site B. A standpipe is required to hold water at an elevation of 530 feet MSL resulting in an approximate 70 foot height. During normal operation the standpipe is bypassed to lower static head. During pump stoppage, the bypass valve is closed to prevent dewatering the pipeline. Like Site A, a standpipe at site B requires upstream pipe to be deep cut so as not to exceed an elevation of 530 feet.

Recommendation

Site A holds power access advantages as it is next to an electrical substation. However, due to hydraulic advantages including the ability to better utilize the RC connection and the ability to house a reservoir, site B is preferred. **Table 3-4** outlines a comparison of the two options. An “x” indicates which site is preferred per category. If both options are marked with an “x” they are considered equal.

Table 3-4. Comparison of BPS 1 of 2

Criteria	Site A	Site B
Operations		x
Hydraulics		x
Size		x
Elevation		x
Road Access	x	x
Power Access	x	
Geology		x

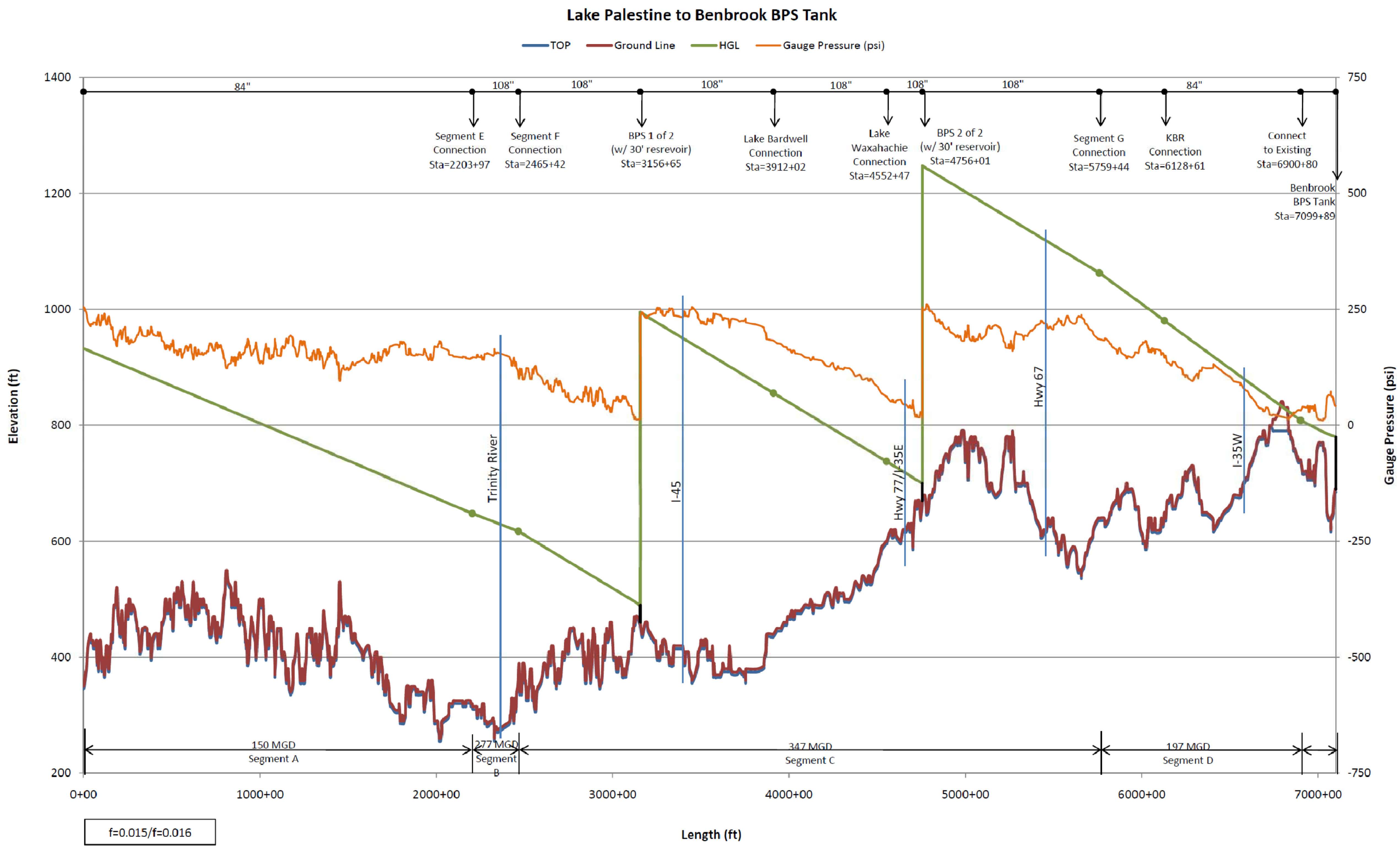

Figure 3-13. **HGL for IPL from Lake Palestine to Benbrook BPS Tank**

3.2.2 BPS 2 of 2

The second booster pump station is also located on Segment C of the pipeline, approximately three to four miles west of I-35E. This is roughly four miles southwest of Waxahachie. See **Figure 3-14** for location details. There are two possible sites identified for this booster pump station:

- BPS 2 of 2, Site A
- BPS 2 of 2, Site B

The sites are about a mile apart, separated by FM 66. Site A is the eastern most while site B is the western of the two options. The elevation of the pipeline route in this area is climbing towards a high point near Midlothian which is about ten miles further northwest along the route. The Midlothian highpoint is approximately 790 feet MSL. A substation is located approximately 4.5 miles southwest of the sites where a transmission line and FM 66 intersect as seen in **Figure 3-14**. Both sites are approximately 130 acres in size to accommodate a BPS and a reservoir. The reservoir will be approximately 1,200 feet x 1,200 feet with 30 feet of water depth and five feet of freeboard resulting in a capacity of 90 MG which provides 6 hours of storage at a demand of 350 MGD. The footprint size is worst case and could likely be reduced pending site specific layout and detailed cut and fill balance.

C7 BPS 2 of 2, Site A

Site A is located southeast of FM 66. Access could be obtained by turning southeast off of FM 66 onto Cunningham Road. Cunningham Road would be followed for 0.3 miles before turning southwest onto Old Maypearl Road. The BPS site is located 1,000 feet down Old Maypearl on the southeast. Old Maypearl curves around the site bounding two sides. Thus, multiple access options are possible.

The selected site is an approximate 2,400’ x 2,400’ cultivated field. The surrounding area is rural pasture and cropland with development primarily along FM 66. Adjacent land could be available if future expansion is anticipated.

The site slopes from 690 feet MSL to 640 feet MSL. A reservoir on the site could have a bottom elevation of approximately 660 feet while the pump station could be built at elevation 650 feet. This would require the reservoir being in the southwest portion of the site to keep it as high as possible. The pump station is laid out to be in the northeast portion of the site to keep it as low as possible. See **Figure 3-15** for site details including contours. Such a configuration, with the bottom of the reservoir above the pump station, would allow the full capacity of the reservoir to be utilized and would improve pumping performance. Also, designing the pump station to be lower than the reservoir would broaden pump choices allowing the use of either horizontal or vertical turbine pumps. If a tank were implemented in place of an earthen reservoir, the site size could be reduced.

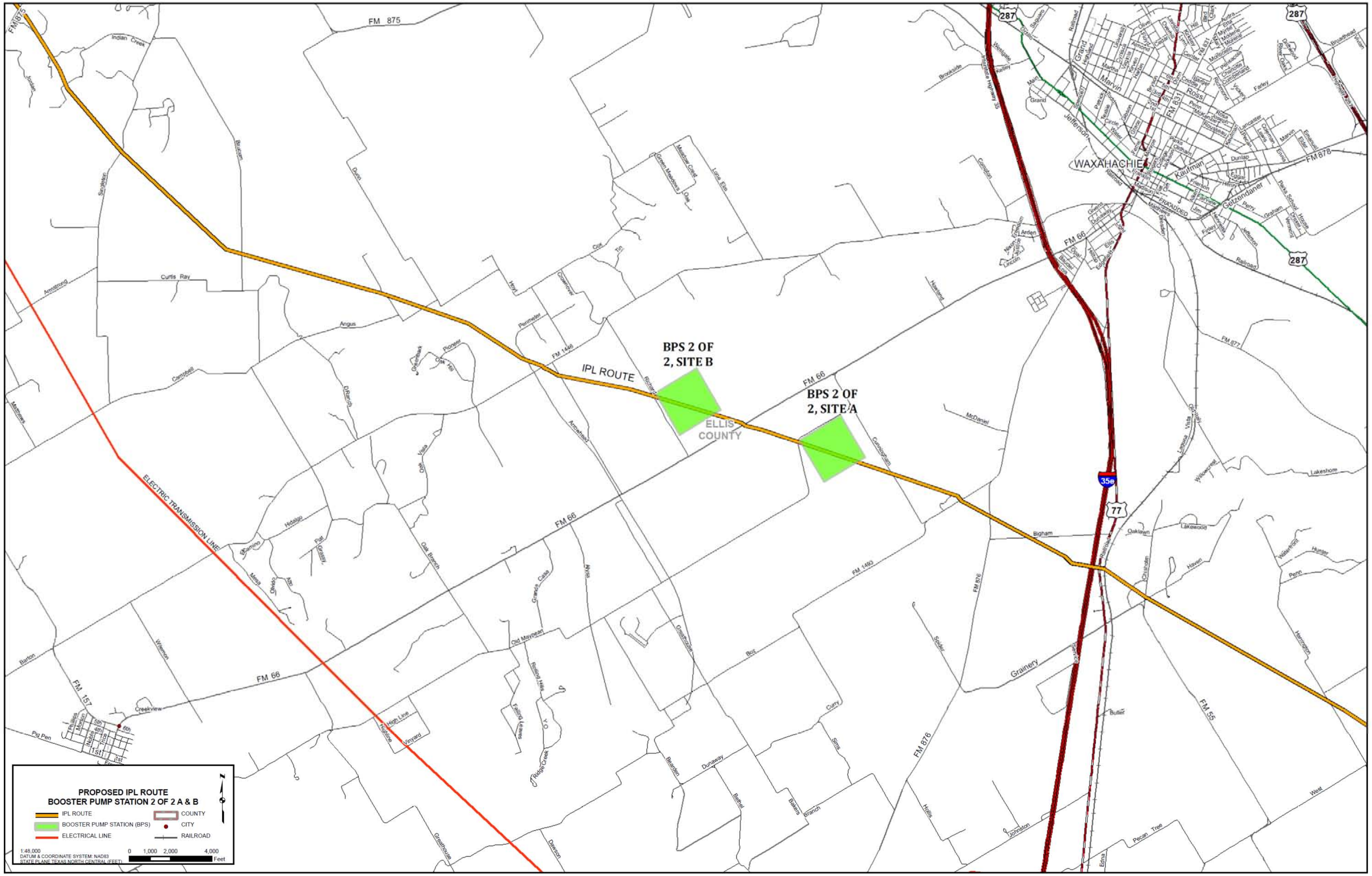

Figure 3-14. **BPS 2 of 2 Location Map**

Figure 3-15. BPS 2 of 2 A Site Layout

C7 BPS 2 of 2, Site B

Site B is situated northwest of FM 66. It can be accessed by turning northwest from FM 66 onto Richard road. The site is approximately 1,200 feet down Richard on the northeast side of the road.

Like site A, site B is approximately 2,400' x 2,400' in size. It is situated on pasture with the surrounding area also being rural pasture. Adjacent land could be available if future expansion is anticipated.

The site slopes from elevation 740 feet to 680 feet. Similar to site A, a reservoir could be built in the southeast corner while the pump station would be built in the northwest corner. See **Figure 3-16** for site details with contours. The bottom of the reservoir would likely be at elevation 700 feet with the pump station at elevation 690 feet. The full capacity of the reservoir could be utilized and the elevation difference between the reservoir and pump station would benefit pump performance. If a tank were implemented in place of an earthen reservoir, the site size could be reduced.

Comparison of BPS 2 of 2 Sites

Property - Both sites are almost identical in size and shape. According to the Natural Resources Conservation Service (NRCS), both sites are composed almost entirely of Austin silty clay as classified by the National Cooperative Soil Survey. Clay soil is preferred for earthen reservoirs. Thus, both sites are expected to be feasible from a geological perspective if an earthen reservoir is selected.

Access - Site A is slightly further off of FM 66, but the pump station is situated close to the front of the property. This results in a short access road that would need to be built on the property. The pump station on Site B is located back away from the road requiring the construction of a much longer access drive. The sites are very similar from a power aspect.

Operations and Hydraulics - The pump station at Site A is located about 50 feet lower in elevation than site B. As seen by the hydraulic profile, **Figure 3-13**, lowering the elevation is preferred. This would decrease the pressure in the pipeline segment between the two booster pump stations where the pressure class reaches above 250 psi.

Figure 3-16. BPS 2 of 2 B Site Layout

Recommendation
The two proposed sites are very similar and offer many of the same benefits. Once the sites are evaluated in detail on the ground, more information may become available setting one substantially better than the other. Currently site A is preferred and recommended. This is primarily due to the vertical advantages and shorter drive length. **Table 3-5** outlines a comparison of the two options. An “x” indicates which site is preferred per category. If both options are marked with an “x” they are considered equal.

Table 3-5. Comparison of BPS 2 of 2

Criteria	Site A	Site B
Operation	x	x
Hydraulics	x	x
Size	x	x
Elevation	x	
Road Access	x	
Power Access	x	x
Geology	x	x

3.3 Storage

3.3.1 Crowley Terminal Storage Reservoir

The Crowley reservoir site is located near the end of IPL segment D approximately 0.5 miles east of where Old Granbury road and Rocky Creek Park road meet. The site is an alternate option in the case that the Crowley deep tunnel is not built. In such an instance, the IPL will route south of the Crowley High School before turning north to make the Benbrook pipeline connection. The reservoir site is located west of the anticipated Southwest Parkway toll road. See **Figure 3-17** for site location.

The site is sized at 2,860 feet by 1,620 feet or approximately 105 acres. The site allows room for two 200 MG reservoirs. One reservoir would be built initially providing one day of storage. The second reservoir would be built later as system demands grow.

The site is located on rural pasture and could be accessed using FM 1902 which is just west of the site. The site is at elevation 870 feet MSL. According to NRCS, the site soil is classified by the National Cooperative Soil Survey as 50% Purves clay and 33% Aledo gravelly clay loam. The remainder of the soil composition is composed of Medlin and Sanger clay.

The Crowley reservoir option offers several operational benefits as listed below:

- Provides a full day storage in case of system downtime.
- Allows for constant pumping rates with changes in demand patterns absorbed by storage.
- Open water surface provides a surge break.
- Open water surface limits system from over pressuring due to accidental control valve closures.
- Provides a delivery point for the future Southwest WTP proposed by Fort Worth.

- Allows for delivery by gravity to Benbrook Outlet Structure, Clear Fork Outlet Structure, Benbrook Water Authority, Weatherford PS, Benbrook BPS, Rolling Hills WTP, and the Kennedale Balancing Reservoir.

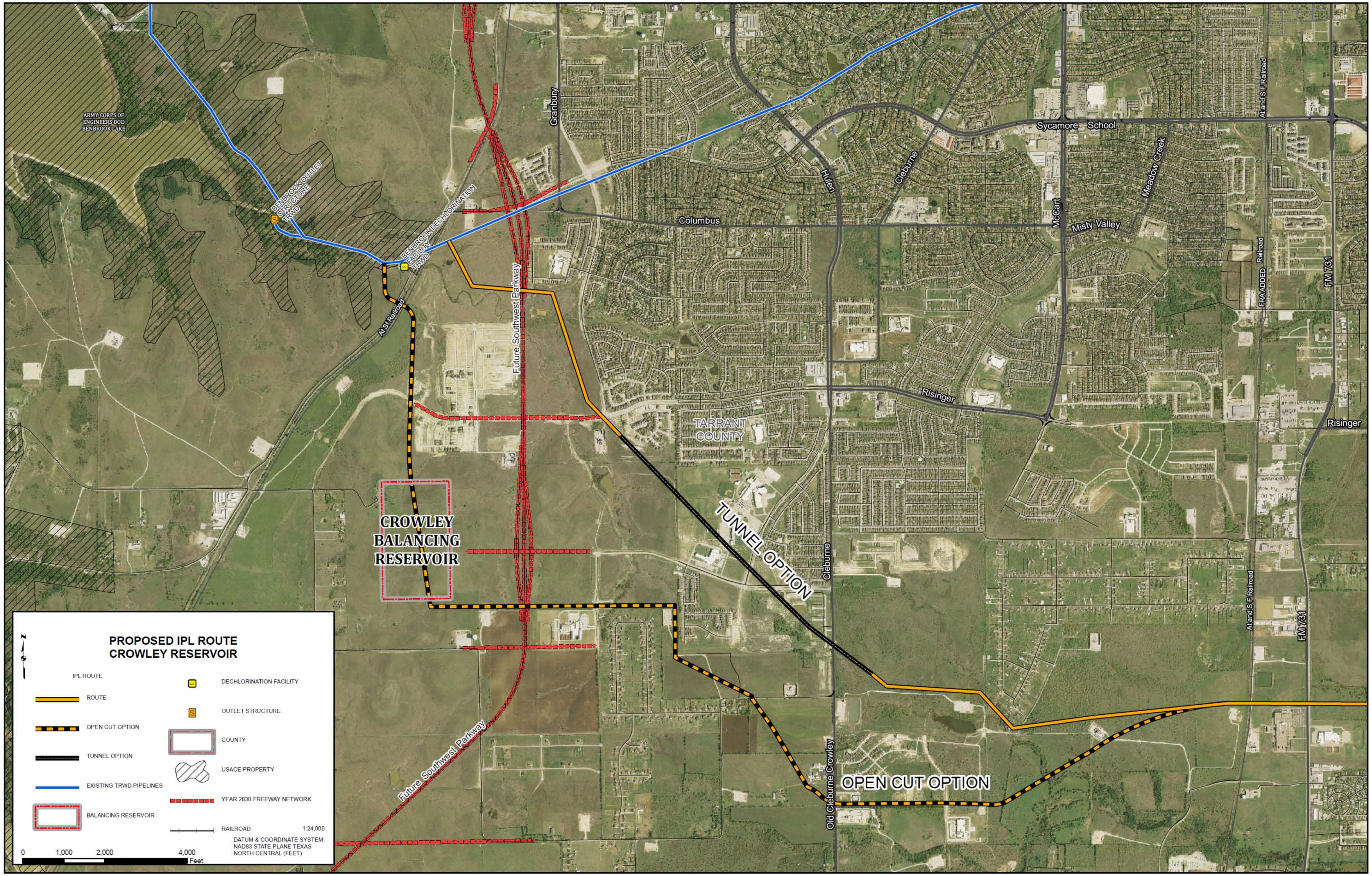

Figure 3-17. **Crowley Terminal Storage Reservoir Location**

Section 4
Hydraulic Evaluation

Prior hydraulic assessments have been presented in *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study Report No. 2* and address peak capacity evaluations for multiple corridors of the proposed transmission pipeline. Since completion of Report No. 2, the corridors have been further refined into a selected corridor which includes a re-route from the corridor recommendations included in Report No. 2. Specifically, this revision impacts segments C and D using a new corridor 7B which changes the alignment to south of Bardwell Reservoir and Lake Waxahachie and takes advantage of a slightly lower peak elevation at the Midlothian high point. The corridor changes are discussed in greater detail in Section 2 of this report.

This Section focuses on the proposed integrated pipeline revised hydraulic criteria and hydraulic performance including pipeline sizing and capacity/power requirements for the pumping stations based on the most recent corridor revisions. Specific corridors and pump station locations have been identified and facility sizing has been established for the revised corridor. This section also includes the basic decision matrix information (associated with hydraulic performance) for the revised corridor.

4.1 Hydraulic Design Criteria

The various hydraulic criteria to be used in establishing pipe sizing, pumping capacity, total dynamic heads and power requirements are detailed in the following sections. Most of the design criteria are unchanged from Report No. 2 and the reader is referred to that report for more detail. Any changes to those previously established criteria are identified and clarified herein. Criteria used in conducting the hydraulic analysis are summarized comprehensively within this section (whether established in Report No. 2 or No. 3).

4.1.1 Pipes

Design Flows

Development of demand allocation and subsequent flows by pipe segment has been established in previous reports. The CDM team has been directed to use the peak flows summarized in **Table 4-1** for purposes of sizing the integrated pipeline facilities. These flows represent peak, future hydraulic flow requirements by pipeline segment serving TRWD and Dallas. **Figure 4-1** illustrates all pipe segments of interest on the project.

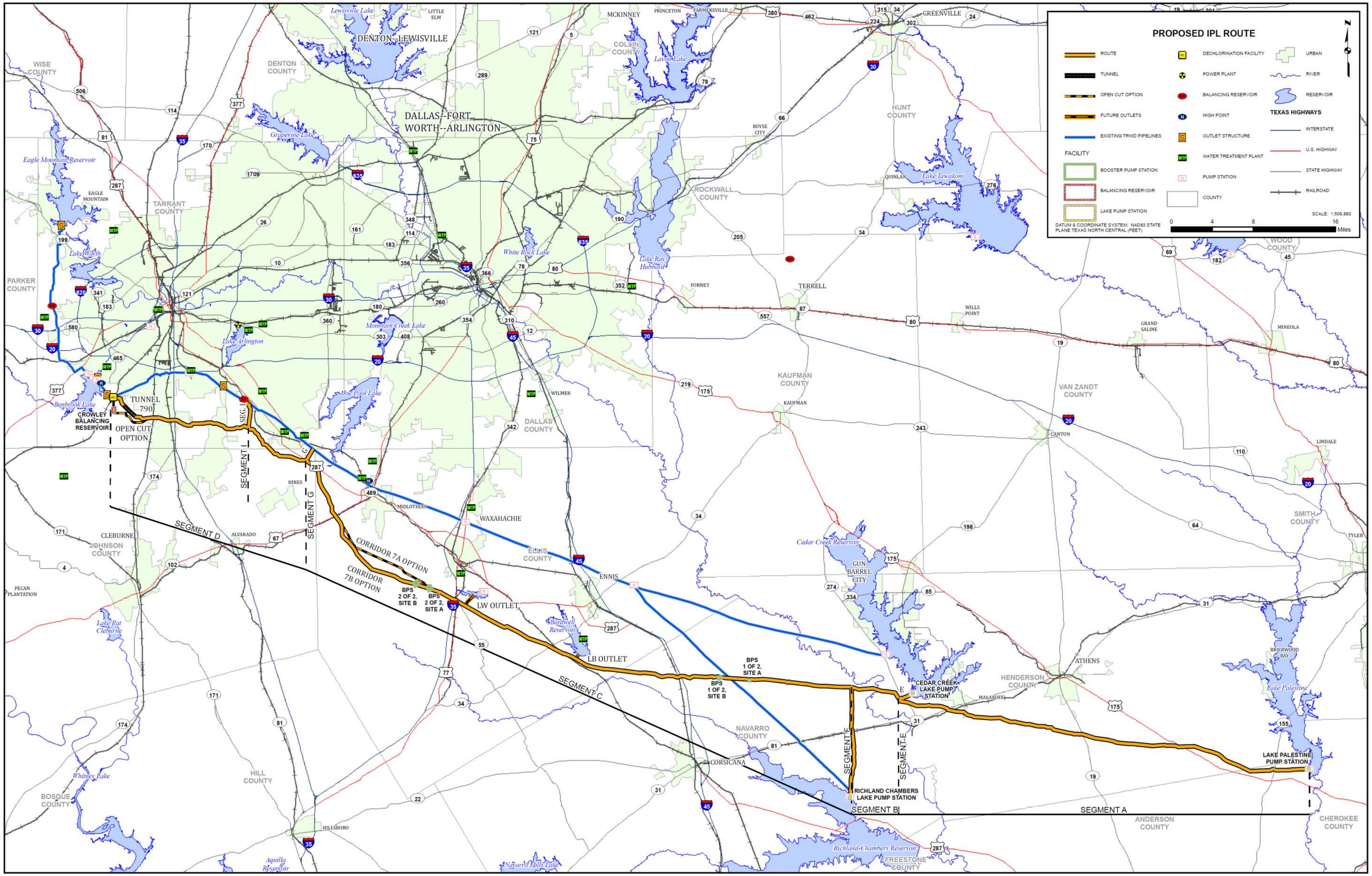

Figure 4-1 **Integrated Pipeline Route Overview**

Table 4-1. Design Flows by Pipe Segment

Segment	TRWD Capacity (MGD)	DWU Capacity (MGD)	Total (MGD)
A	0	150	150
B	127	150	277
C	197	150	347
D	197	0	197
E	127	0	127
F	70	0	70
G	197	150	347
H*	0	150	150
I	197	0	197

*- Peak Dallas flows delivered to a takeoff point at the upstream end of Joe Pool Lake for delivery to Dallas in an as-of-yet undetermined configuration

Friction Factors

Various hydraulic criteria and friction loss assumptions have been established for previous analyses of the Integrated Pipeline. Use of the Colebrook-White formula to predict friction factors is recommended for this phase of planning utilizing the Darcy-Weisbach formula with an absolute roughness value of 0.003 feet. As discussed in Report No. 2, this approach produces similar results to a Hazen Williams C coefficient of 120 (although slightly more conservative). This increased conservatism should be adequate to represent both minor and dynamic friction losses in the transmission piping system at this level of planning. During final design, this approach will be developed further into distinct analyses as recommended under the design standardization.

Pipe Sizing

Optimization of pipe sizing has been performed by comparing capital investment costs versus energy costs on a present worth/life cycle basis. The methodology and results are the subject of separate technical memoranda included in Appendix F and entitled:

- “Transmission Pipe Size Selection – Life Cycle Costs Analysis and Assumptions and Findings” dated July 20, 2009.
- “Infrastructure Sizing, Tunneling, and Pump Station Configuration Analyses – Findings and Conclusions” dated December 17, 2009.
- “Infrastructure Sizing, Tunneling, and Pump Station Configuration Analyses – Findings and Conclusions-Updated” dated February 24, 2010.

Although conclusions indicate that current pressure and velocity limitations and friction criteria are sound for planning level pipe sizing, comparisons between a selected size and one standard pipe size larger and one standard size smaller are comparable in terms of life cycle cost. The analysis is quite sensitive to the length of the life cycle period, demand impacts (and therefore pumping energy used) after 2030, material cost quotations for pipe manufacture and delivery, energy costing assumptions, and impacts of energy savings (vs. capital expenditure) for tunneling. Therefore, additional life cycle and related sensitivity analyses are planned during the

IPL conceptual design phase to optimize pipe size for each segment and facility selection by location. As a result, the final pipe and facility sizing is subject to change from those recommendations included herein.

Table 4-2 identifies the peak flow rates and corresponding pipe sizes used for the hydraulic analysis and form the basis for this analysis.

Table 4-2. Design Flows and Sizes by Pipe Segment

Segment	Design Flow (MGD)	Nominal Pipe Size (Inch)
A	150	84
B	277	108
C	347	108
D	197	84
E	127	72
F	70	66
G	347	108
H	150	84
I	197	84

Maximum Velocity and Peak Operating Pressure

Analysis of velocity and pressure limitations for a variety of piping and pumping configurations for this project indicates that a hard and fast limitation within these categories is not necessary. For example, both steel and PCCP transmission pipe can be economically designed for higher operating pressures in the range of 250 psi and life cycle costing comparisons indicate that the higher pressure pipe (in conjunction with fewer pumping stations) is cost competitive with the alternative configurations. A general limitation of 250 to 275 psi peak operating pressure (primarily at the discharge side of pumping stations) has been applied for the 2 booster pump station configurations. These maximum operating pressures have been updated from those listed in Report No. 2.

Peak velocity for the pipe segments at the designated design flow varies from about 6 to 8.5 fps while the head loss (per thousand feet) varies from about 1 to 2.25. Note that the highest head loss does not necessarily correspond with the highest velocity as this relationship is dependent on pipe size and the ratio of wetted perimeter to cross-sectional area (See Table 4-6). It is reasonable to allow some flexibility in the velocity criteria as long as the head loss is maintained in a reasonable range, low enough that particulates in the raw water will not cause damage to the pipe linings at higher velocities.

Again, these considerations are subject to change and more in depth evaluation is planned segment by segment during the conceptual design phase.

4.1.2 Pump Station

Design Station Capacities

Table 4-3 identifies anticipated pumping station capacities required to meet the future demands of TRWD and Dallas. These flow rates will provide the basis for needed pumping station infrastructure along the transmission system.

Table 4-3. Proposed Maximum Pump Station Capacities

Pump Station	Design Pumping Rate, (MGD)
Intake Pump Stations	
• Lake Palestine	150
• Cedar Creek	127*
• Richland-Chambers	70*
Booster Stations	347

* Capacities under bypass mode may be higher than indicated.

Pump Curves and Variable Speed Application

The preliminary pump selections include vertical turbine pumps for all three lake intake structures and a horizontal split case type for all booster pumping stations. Vertical turbine "barrel" pumps are an option for consideration at the booster pumping stations (as discussed separately as part of the on-going design standardization effort by the IPL Conceptual Design Team).

As part of pumping equipment selection the following target efficiencies were assumed at the design flows.

- Pump efficiency of 85- 90 %
- Motor, efficiency of 95 %
- Variable frequency drive efficiency of 96 %

Although achieving an efficiency of 90 percent is feasible for these large pumps, efficiency of 85 percent will be more typical which may cover a range of pump manufacturers and operating points. An operating efficiency of 95 percent is typical for premium efficiency motors operating under full load conditions. An efficiency of 96 percent is typical for variable frequency drives when operating under full load conditions.

The range of TDH requirements for the chosen pipe size and corridors are given in the **Table 4-4**. The flows and estimated pumping head have been updated from those listed in Report No. 2.

Table 4-4. Total Dynamic Head Requirements

Pump Station	Design Pumping Rate, (MGD)	Total Dynamic Head (ft)
Intake Pump Stations		
• Lake Palestine	150	210-625
• Cedar Creek	127 (190)[1]	136-378 (323-596)[1]
• Richland-Chambers	70 (190)[1]	143-396 (326-602)[1]
Booster Stations (2 booster)		
• Booster No. 1	347 (100)[1]	263-577
• Booster No. 2	347 (190)[1]	152-582

1. Assumes maximum bypass condition with a combination of pumping from Cedar Creek and Richland Chambers and main line pressures limited to approximately 250 psi.

Preliminary screening of vertical and horizontal pump applications for both the intake and booster pumps indicates that a number of offerings are available from several vendors that can meet the high head requirements with as few as 6 to 8 duty pumps (booster stations). It is anticipated that variable speed pumping will be an operational necessity to meet the full range of flows and heads while limiting the number of pump settings in each station. These pump offerings have been screened in greater detail and represent updated information since publication of Report No. 2. More information is included in the separate, on-going design standardization task deliverables from the IPL Conceptual Design Team.

Pump selection will be further refined with recommended selections for the final pipeline alignment as part of the conceptual design phase.

4.1.3 Operational Storage

Balancing reservoirs are possible at a number of locations including the highest point on segment D. This particular location for a balancing reservoir (Crowley) would enable gravity flow to the TRWD West Fork System, including Benbrook Outlet Structure, Clear Fork Outlet Structure, Benbrook Water Authority, Weatherford PS, Benbrook BPS, Rolling Hills WTP, and the Kennedale Balancing Reservoir. A decision to tunnel through the Benbrook highpoint may preclude this location for a balancing reservoir and life cycle costing appears to favor the tunneling option under some scenarios (to be refined further during conceptual design). TRWD operational experience indicates a desired storage volume of approximately 200 MG, which translates to about 24 hours supply under peak operating conditions. Doubling this storage volume in future phases (if sufficient land is available) could double emergency storage to 48 hours or more under moderate to peak delivery conditions. This criterion is acceptable for application to sizing any of the proposed balancing reservoirs in the new transmission system unless there are special circumstances to consider. Some special circumstances for increasing storage could include considerations for emergency supply in the event of an extended system outage or emergency repair and providing additional redundancy for other balancing reservoirs in the system (such as Kennedale).

For suction supply to booster pumping stations, TRWD experience has shown that 4 to 6 hours of operating storage at peak operating capacity is sufficient and provides enough reaction time for starting and stopping pump operation if warranted. Again, more storage may be appropriate if there are special circumstances. For the largest capacity booster pumping station of 347 MGD, suction storage would need to be sized between 60 and 87 MG which could be constructed in two or more phases (interim and future) to enhance operations and maximize deferral of capital investment.

Terminal storage at the delivery points to participants has not been addressed within the scope of this section and is subject to participant-specific operating rules and requirements as appropriate.

4.1.4 Reservoir Ranges/System Operating Rules

For peak flow pipe sizes, the operating levels in the supply reservoirs are summarized in **Table 4-5**. There are no real-time operating rules for pump station operation in the steady state model. For purposes of estimating maximum intake pump station hydraulic power requirements, the "minimum conservation pool" elevations were used. Since the reservoir operating ranges mostly affect pump selection rather than the hydraulic performance, maximum conservation pool was not used for this phase of analysis except to estimate ranges of required pumping head.

Table 4-5. Reservoir Ranges

Reservoir	*Minimum Conservation Pool Elevation, ft*	*Maximum Conservation Pool Elevation, ft*
Lake Palestine	310	345
Cedar Creek	282	322
Richland-Chambers	273	315
Benbrook Lake	682	694

4.2 Hydraulic Analysis

Similar to the methodology used for Report No. 2, hydraulic evaluations in this report were all conducted using MS Excel spreadsheet tools with appropriate updates to reflect modifications for the selected corridor. Specific analyses associated with flow diversions through the G and H segments (for Bachman delivery) were not performed for this updated report as these were not considered sufficiently different from the results presented in Report No. 2 and infrastructure sizing memoranda to justify additional simulation. Joint, full capacity diversions for both TRWD and Dallas through Segment G (347 mgd) requires meeting a minimum HGL elevation of 789 msl as shown in the HGL figures in this section. A split flow diversion (some flow to Benbrook and some through Segment G) requires dissipating excess head somewhere within the G segment. Although this excess head could, potentially, be recovered with hydro turbines, preliminary life cycle analysis of the excess energy utilized during these events (see Appendix H) indicates that high flow split diversions will occur infrequently and may not justify installation of energy recovery facilities.

Segment I has been sized for 84 inch and, based on the current route, a maximum HGL elevation of 773 feet at the IPL turnout has been estimated based on meeting a future maximum control elevation of 742 feet at the Kennedale Balancing Reservoir.

Hydraulic evaluation for this report focused on delivery from Lake Palestine to the Lake Benbrook area within the recommended pipeline route (see Section 2) and a range of flow conditions. As described in Section 1, a workshop meeting was held on March 16, 2010 to select the number of booster pump stations, recommend the lowest life-cycle cost pipe size, and decide if deep tunnels would be constructed through Midlothian and/or the Crowley portions of the pipeline. It was recommended during that meeting that this hydraulic analysis be completed using only the two booster pump station configuration and assuming construction of a tunnel at elevation 790' through the Benbrook high point.

General configuration assumptions used in developing the updated hydraulic analyses include the following:

- Corridors A1 and F2 were used, consistent with the analysis in Report No. 2
- The main line corridor consists of segments A1, B, C (corridor 7B and Corridor 6), D6 as generally depicted in Report No. 2 (but representing the latest pipeline routing for Corridor 7B) and minor updates for the other main corridor segments.
- As presented in Report No. 2, intake pumping stations are represented at Lake Palestine, Richland Chambers Reservoir, and Cedar Creek Reservoir.

Figures 4-2 through **4-5** illustrate all the modeled segments A through F in detail.

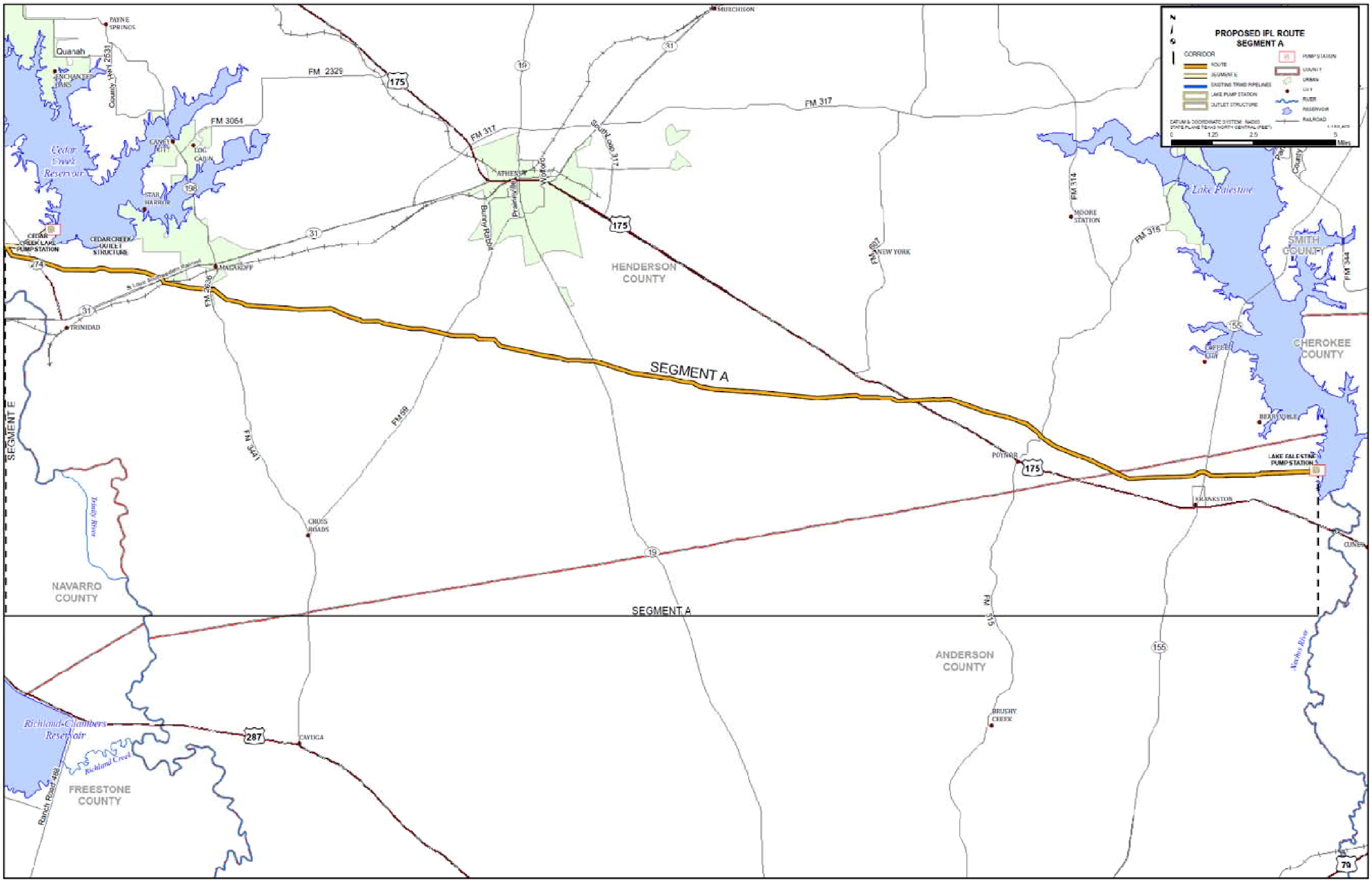

Figure 4-2. **Segment A**

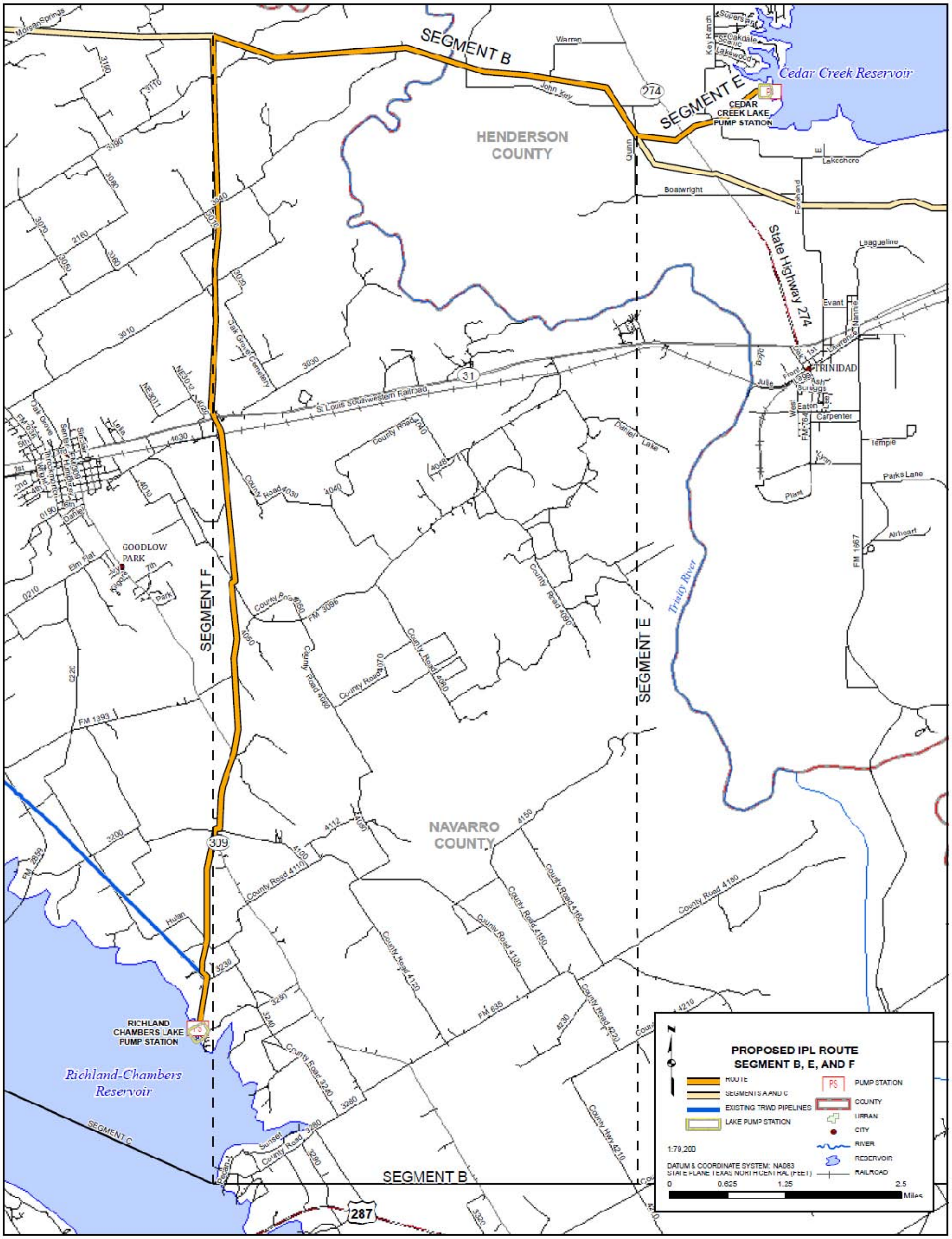

Figure 4-3. **Segments B, E, and F**

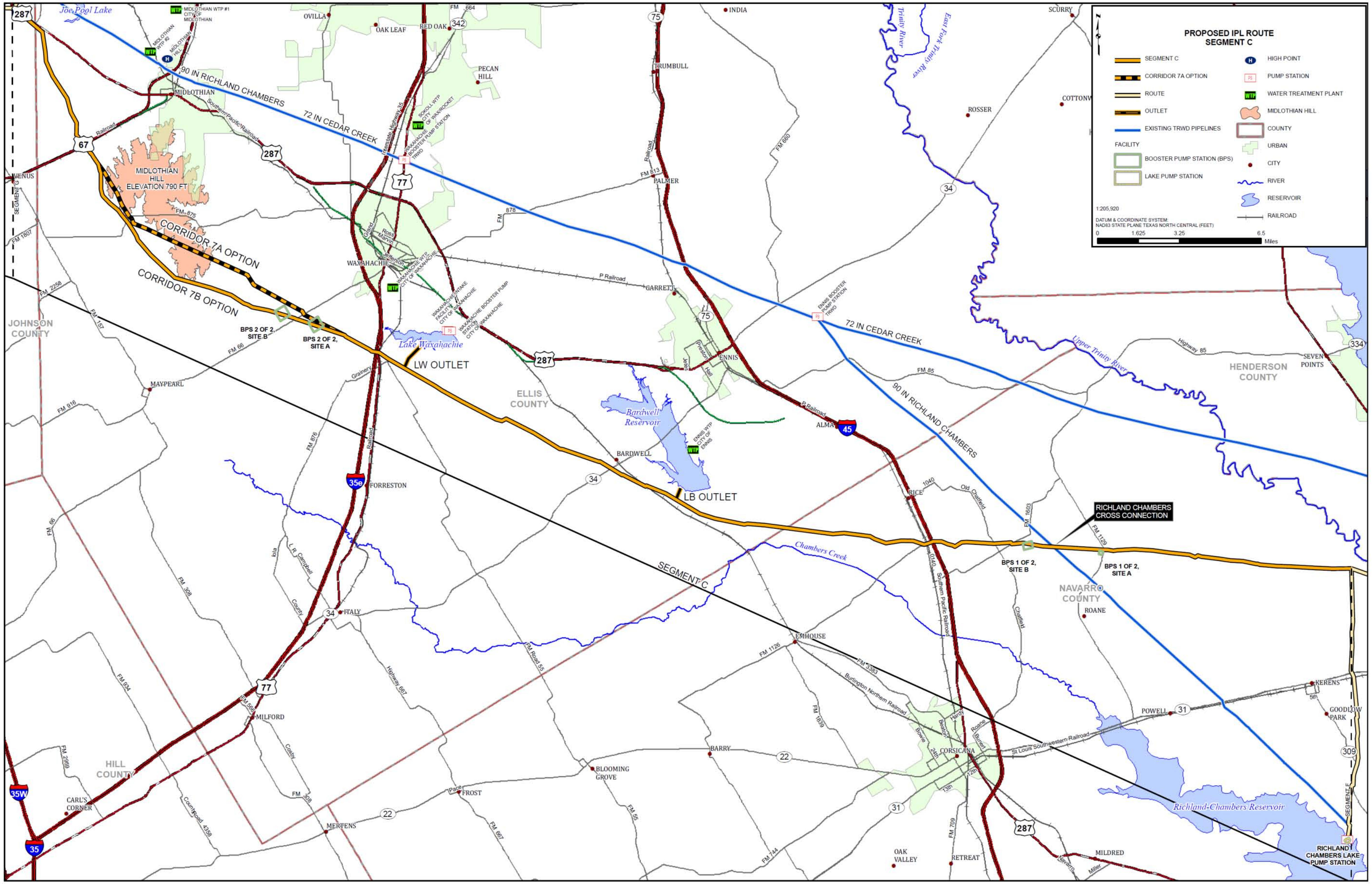

Figure 4-4. **Segment C**

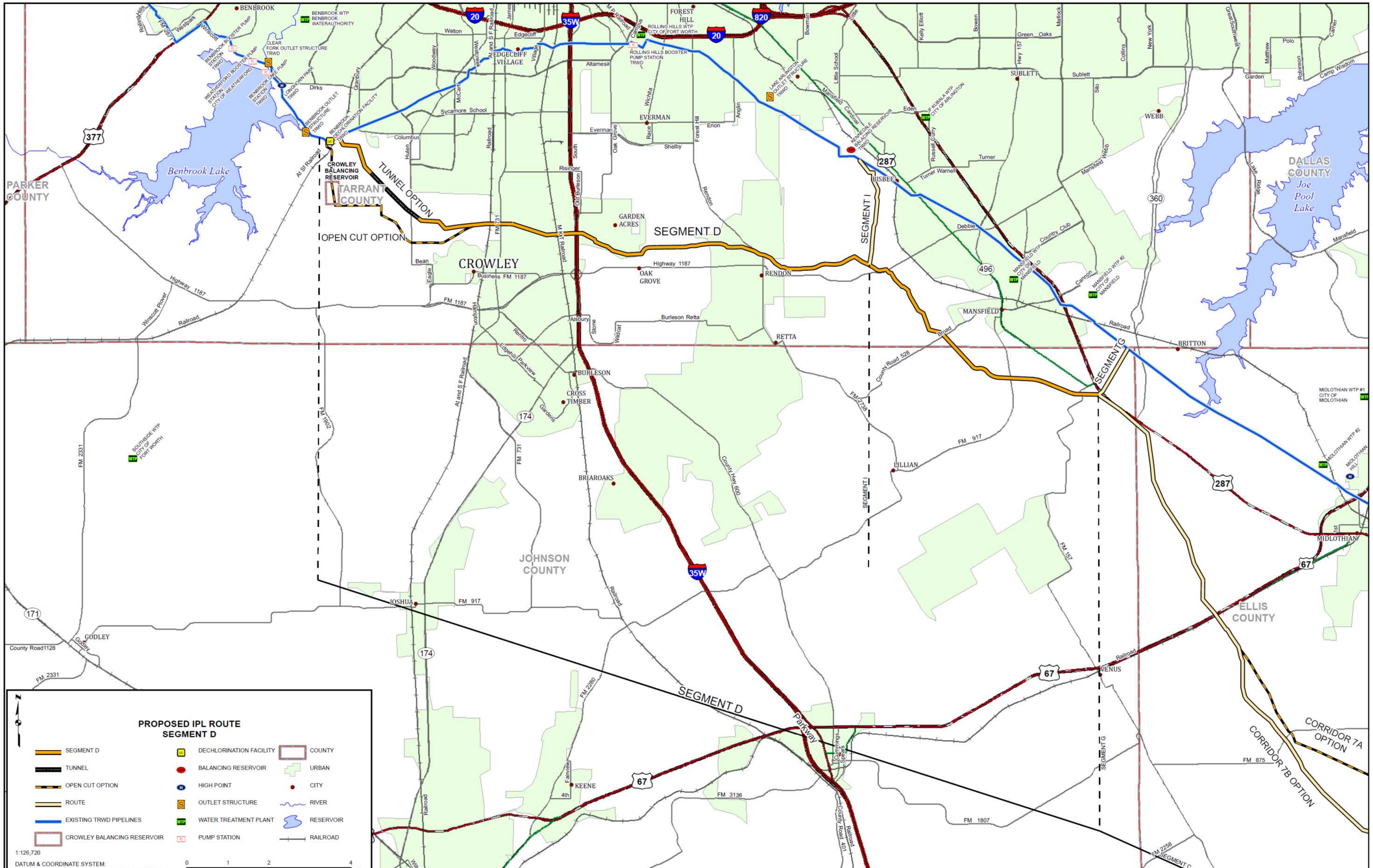

Figure 4-5. **Segment D**

4.2.1 Revised Corridor Results

Main Transmission Pipeline

Figures 4-6 through **4-10** depict the hydraulic grade line (HGL) performance plots for the 2-booster pump station configuration for the final pipeline corridor selected in Report No. 2 and as subsequently modified to incorporate the Corridor 7b (within Segment C) re-route.

Generally, the 2-booster pump station alternative required pumping to about 250 psi. **Figure 4-6** shows peak, future flow conditions (blue HGL) as well as 3 configurations of bypass (see later discussion) while pumping to a future balancing reservoir (Crowley) at the Benbrook high point. Two alternate sites for Booster Station No. 1 are under consideration and were modeled for hydraulic performance but only the currently preferred, alternative 1 site (western most), is presented here. For the chosen pipe sizes, the alternative 1 site helps to maintain the operating pressure on the discharge side of Booster Station No. 1 at or below 250 psi, but will potentially require portions of Segment A nearest to the Lake Palestine pump station to maintain operating pressures slightly above this limit under peak flow conditions. The situation reverses itself if the alternative 2 (eastern) site is used.

Figure 4-7 depicts the peak, future flow conditions while pumping to the 790 msl outfall elevation on the western side of the Benbrook high point (i.e. configuration with a deep tunnel through Crowley). Note that the alignment for this configuration is different from the open-cut construction with a Crowley balancing reservoir option as shown in Figure 4-5. This revised alignment slightly shortens the overall length and the highpoint above the tunnel is slightly lower in elevation, but the hydraulic performance of this alternative is not significantly affected (hence the ground profile in Figure 4-7 is the same as in Figure 4-6 to better depict the visual difference in pumping head for Booster Station No. 2).

This alternative assumes that a tunnel would be constructed through the Benbrook high point so that the HGL can be lowered under all pumping conditions to the Lake Benbrook area. This represents a lowering of approximately 80 feet of static pumping head from booster pump station No. 2 under all operating conditions that pump west towards Benbrook. However, gravity delivery to the Rolling Hills WTP from a balancing reservoir located at the high point would be precluded under this scenario. Further evaluation of the pros and cons of these alternatives will be needed during conceptual design (see “Next Steps” at the end of this section).

Representative HGL plots for corridors E and F2 under peak delivery (non-bypass) conditions are shown in **Figures 4-8 and 4-9.** Refer to **Table 4-6** for required Richland Chambers and Cedar Creek Intake pumping heads for full capacity pumping.

Bypass Operations

A separate analysis was conducted to evaluate flow transmission in pump station bypass mode. Two cases were evaluated and the primary criterion for evaluating each case was to limit main transmission pipeline operating pressures to approximately 250 psi (even if higher horsepower pumps are required at any given station to accommodate the flow and head under a bypass vs. non-bypass scenario). For case 1, pump station bypass analysis was based on trying to maximize flow from Lake Palestine to Lake Benbrook without additional flow injections along the way. For Case 2, a combination of pumping is used from Cedar Creek and Richland-Chambers to maximize bypass of one of the booster stations (a more commonly anticipated bypass theme). The results for the bypass analyses are also included in **Figure 4-6**.

Hydraulic Profile for Corridor-7B, 2 BPS, Base Pipe Sizes

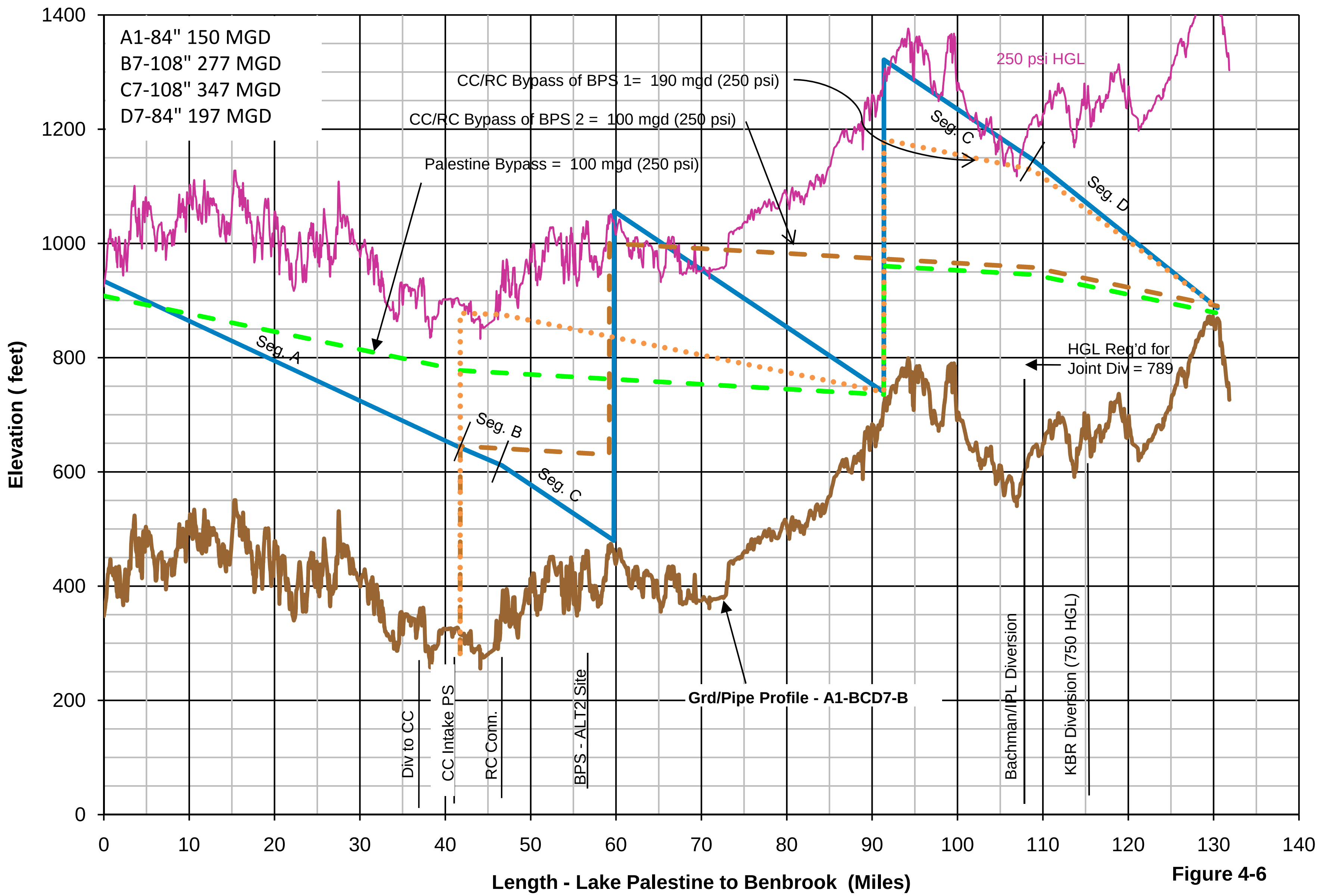

Figure 4-6

Hydraulic Profile for Corridor-7B, 2 BPS, 790 Tunnel, Base Pipe Sizes

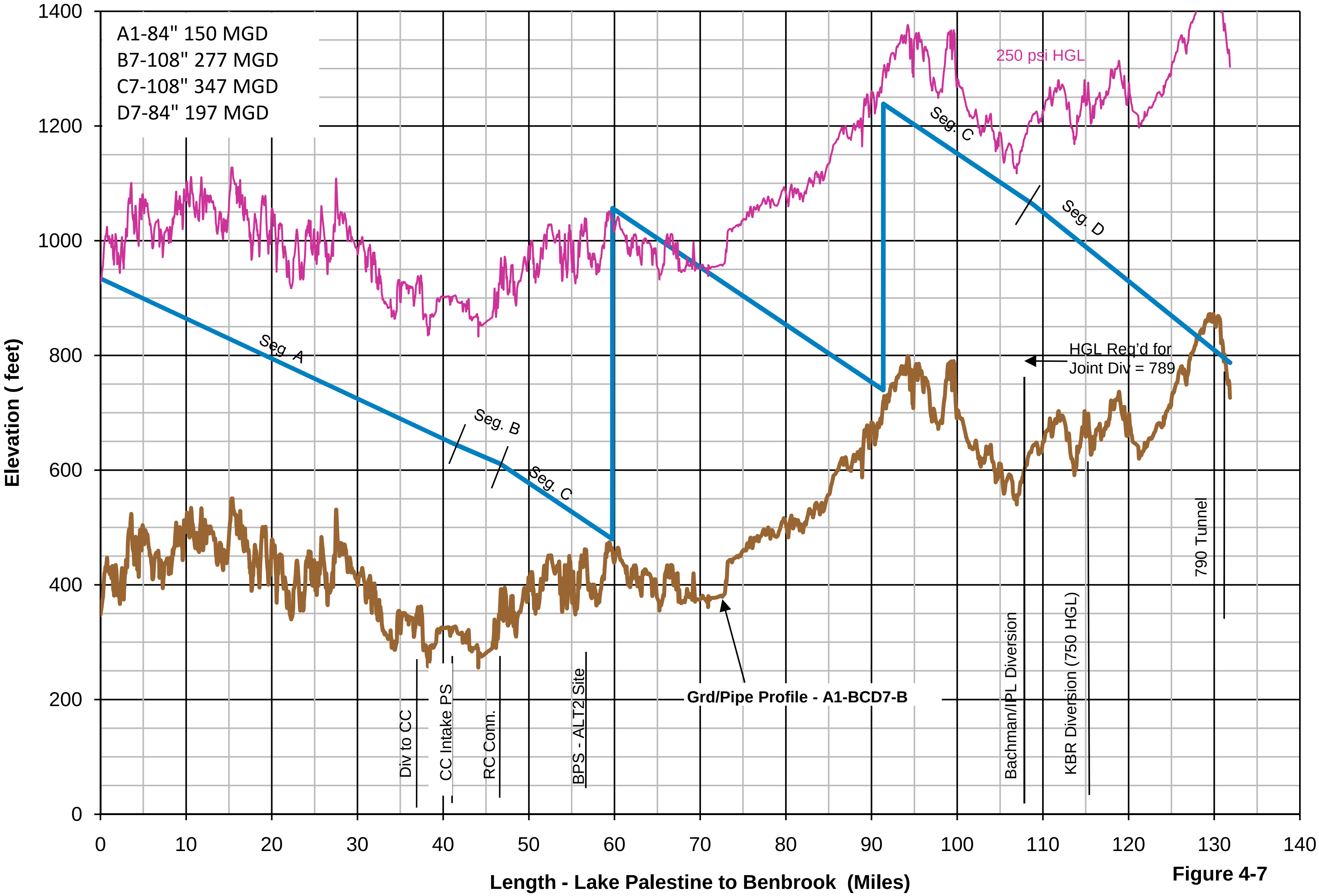

Figure 4-7

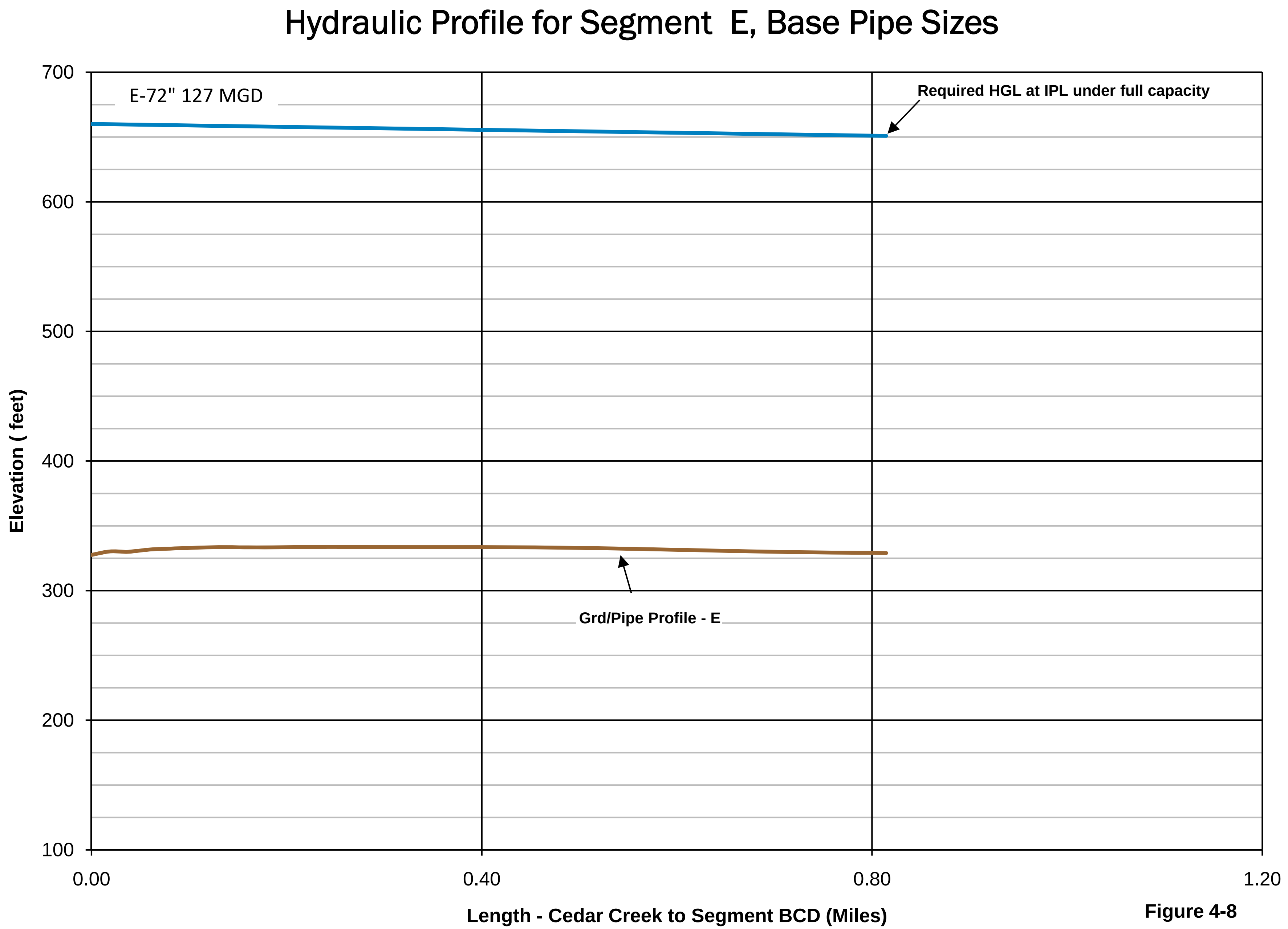
Hydraulic Profile for Segment E, Base Pipe Sizes
E-72" 127 MGD
Required HGL at IPL under full capacity
Grd/Pipe Profile - E
700
600
500
400
300
200
100
Elevation (feet)
0.00
0.40
0.80
1.20
Length - Cedar Creek to Segment BCD (Miles)

Figure 4-8

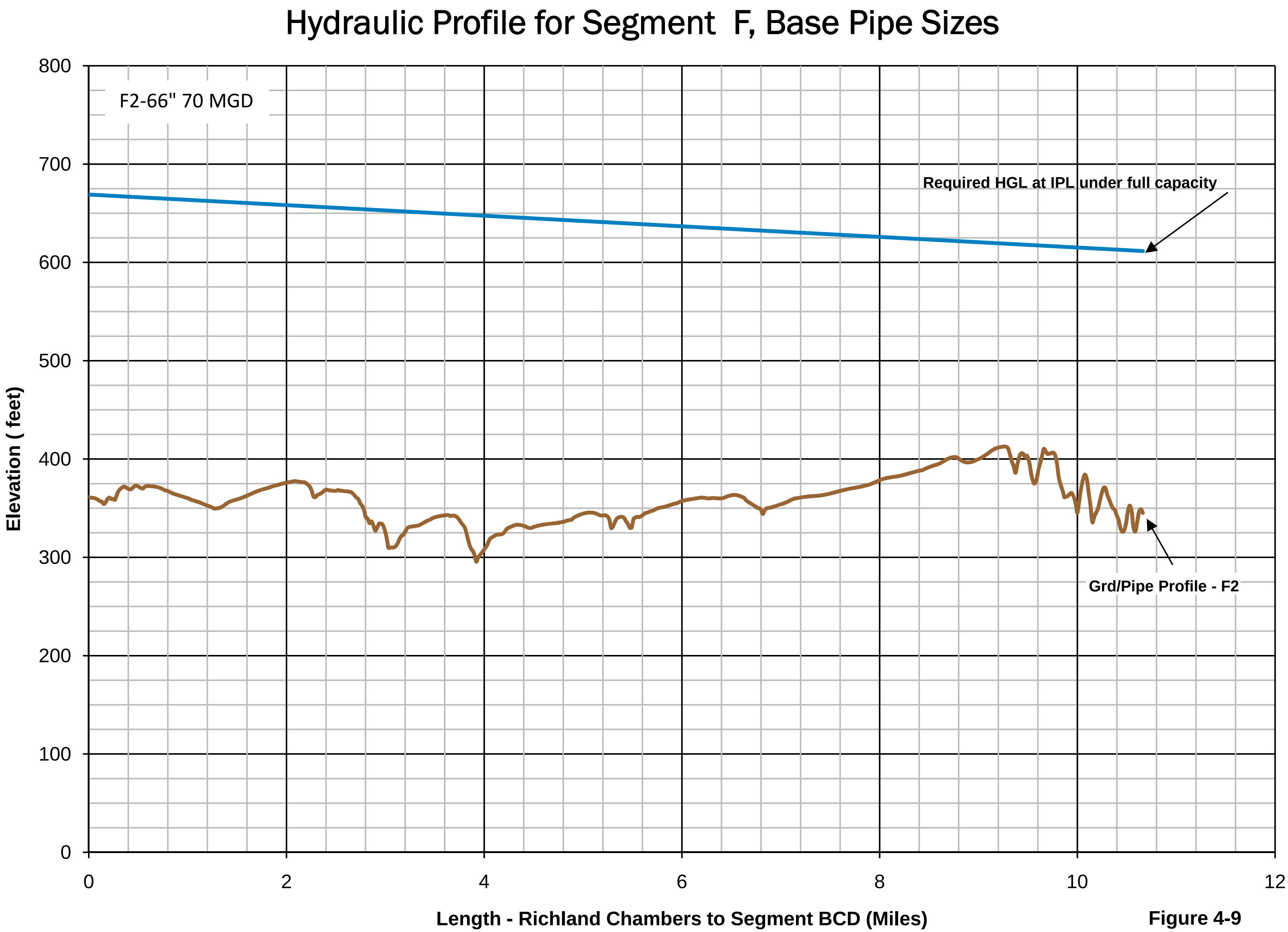
Hydraulic Profile for Segment F, Base Pipe Sizes
F2-66" 70 MGD
Required HGL at IPL under full capacity
Grd/Pipe Profile - F2
Elevation (feet)
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Length - Richland Chambers to Segment BCD (Miles)

Figure 4-9

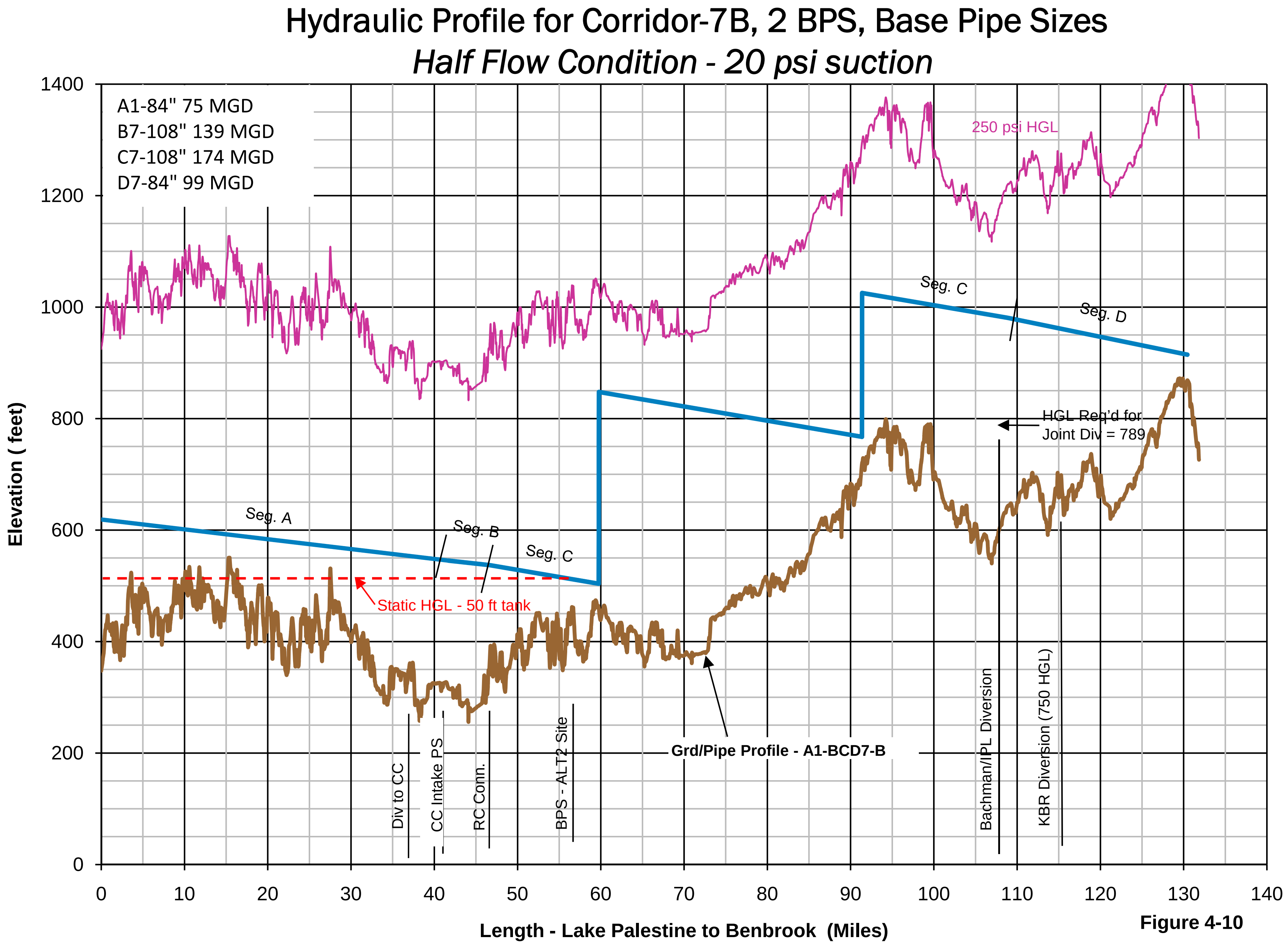
Hydraulic Profile for Corridor-7B, 2 BPS, Base Pipe Sizes
Half Flow Condition - 20 psi suction
A1-84" 75 MGD
B7-108" 139 MGD
C7-108" 174 MGD
D7-84" 99 MGD
250 psi HGL
Seg. A
Seg. B
Seg. C
Seg. C
Seg. D
HGL Req'd for Joint Div = 789
Static HGL - 50 ft tank
Grd/Pipe Profile - A1-BCD7-B
Div to CC
CC Intake PS
RC Conn.
BPS - ALT2 Site
Bachman/IPL Diversion
KBR Diversion (750 HGL)
Elevation (feet)
Length - Lake Palestine to Benbrook (Miles)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140

Figure 4-10

Table 4-6. Hydraulic Results with Corridor 7B Reroute

Scenario	Segment	Flow (mgd)	Pipe Size (in)	Velocity (fps)	Head loss (ft/1000 ft)	Pump Station	TDH (ft)	TDH (psi)	Hydraulic Power (HP)
2 BPS - To Benbrook	A1	150	84	6.03	1.29	Pal Intake	624	270	16,428
	B7	277	108	6.74	1.17				
	C7	347	108	8.44	1.84	BPS1	577	250	35,141
		347				BPS2	582	252	35,446
	D6	197	84	7.92	2.23				
	E	127	72	6.95	2.12	CC Intake	378	164	8,426
	F2	70	66	4.56	1.00	RC Intake	396	172	4,865
									100,306
2 BPS - To Benbrook (790 Crowley Tunnel)	A1	150	84	6.03	1.29	Pal Intake	624	270	16,428
	B7	277	108	6.74	1.17				
	C7	347	108	8.44	1.84	BPS1	577	250	35,141
		347				BPS2	499	216	30,391
	D6	197	84	7.92	2.23				
	E	127	72	6.95	2.12	CC Intake	378	164	8,426
	F2	70	66	4.56	1.00	RC Intake	396	172	4,865
									95,251
2 BPS - To Benbrook (1/2 flow)	A1	75	84	3.01	0.32	Pal Intake	309	134	4,068
	B7	138.5	108	3.37	0.29				
	C7	173.5	108	4.22	0.46	BPS1	344	149	10,475
		173.5				BPS2	258	112	7,857
	D6	98.5	84	3.96	0.56				
	E	63.5	72	3.47	0.53	CC Intake	268	116	2,987
	F2	35	66	2.28	0.25	RC Intake	279	121	1,714
									27,100

For case 1, bypass analysis (conveying Lake Palestine water with one booster pump station bypassed) indicates capacity is limited to about 100 mgd. For case 2, either booster station can be bypassed (alternated), although bypass of booster 1 while maintaining operation at booster 2 can achieve greater bypass capacity while keeping the main transmission line operating pressures at or below about 250 psi. This second case requires utilizing the Cedar Creek and/or Richland-Chambers intake pump stations under high head conditions and could result in operating pressures in the E or F segments exceeding 250 psi (proper pipe sizing and optimization of associated flow contributions from each supply reservoir are critical to controlling these branch pressures). To take full advantage of a given bypass configuration, it would be necessary to operate at higher suction pressures at the bypassed station and, as a result, portions of the main transmission pipeline would have to be designed for higher operating pressures.

For case 1, bypass flows are limited to about 100 mgd and Booster Station No.1 is bypassed while Booster Station No. 2 is maintained in operation. For case 2, flows are contributed from both Cedar Creek and Richland-Chambers (no contributory flows from Lake Palestine for this scenario). If Booster Station No. 1 is utilized and Booster Station No. 2 bypassed, flows are limited to about 100 mgd. Since both Cedar Creek and Richland-Chambers lake pumping stations are used to boost up the operating HGL, there is not a significant additional gain in head achieved with the first booster station operating and the second booster station off line, limiting the capacity of this configuration. However, if both of the intake stations are used to boost the HGLs up to the 250 psi limit and the first booster station is bypassed instead, the second booster station can operate much as a true booster pumping application and nearly doubles the delivery capacity over the alternate case 2 configuration (approximately 190 mgd).

Low Flow Pumping Considerations

Figure 4-10 depicts the operating HGL under half flow conditions (with the configuration discharging to a balancing reservoir at Crowley). Each supply reservoir is delivering half the flow shown in Figures 4-6 and 4-7. The represented flow condition approximately represents a transition point from multiple booster pumping operation to bypass and single booster operation (generally the same flow delivered to the Benbrook area for case 1 bypass, but considerably less than case 2 bypass with Booster Station No. 1 out of service).

Under lower flow rates from Lake Palestine (below 75 mgd), there may be need for a balancing reservoir near the highpoint in Segment A to maintain the HGL above the ground surface while conserving head at Booster Station No. 1. Alternatively, the balancing reservoir could serve also as the suction supply to Booster Station No. 1 (remote forebay) to avoid this concern. However, the same reservoir would need to be bypassed under high flow conditions out of Lake Palestine (defeating this advantage). The overall need/benefit for this reservoir may depend mostly on the anticipated mode of operations. Current operations planning indicate that withdrawals from Lake Palestine are rarely anticipated to drop below 75 mgd or the system will go into bypass mode at these lower flows. Therefore, at this time there appears to be little justification for a balancing reservoir near the highpoint in Segment A (approximately 550 ft msl).

Another potential concern is draining of raw water supply from the highpoints along segment A into the suction supply tank or reservoir at Booster Station No. 1 after routine shut down of the Segment A pipeline and Lake Palestine Intake pump station. The line would only drain for those portions of the Segment A line installed at a higher elevation than the overflow of the booster station supply tank (limited volume). There are several ways to solve this problem for either Booster Station site. Options include an automated valve to isolate the line ahead of the supply tank/reservoir, installation of a stand pipe with sufficient height (and isolation from the supply tank/reservoir), construction of a tank or reservoir with sufficient volume to receive the excess volume in the Segment A pipeline (easier to accommodate with a reservoir). Operational issues can be further explored during conceptual design, but should not present an issue for selection of either site for Booster Station No. 1.

Table 4-6 shows hydraulic power (no pump or electrical efficiency losses included) used for the half flow condition along with that for the full capacity conditions (with and without the tunnel under Benbrook highpoint).

4.3 Hydraulic Evaluation Criteria Matrix

In order to provide a comprehensive and consistent basis for comparing corridor alternatives for hydraulic performance, evaluation criteria were developed as shown in **Table 4-7**. For consistency, the scoring for corridors 1 and 5 (hybrid of both recommended in Report No. 2) is compared with corridor 7. Each evaluation criteria is designated either quantitative or qualitative. Quantitative criteria are scored on a number and qualitative criteria are scored on a scale of 'poor-fair-good-better-best'. The results in the table are generally based on evaluation under peak flows conditions.

4.4 Hydraulic Performance Summary

Updated findings and observations are summarized within specific categories below:

- The updated IPL configuration for corridor 7 is not substantially different in hydraulic performance from the previous corridor 1-5 performance. Net head requirements are generally equal when comparing the two corridors. Construction of a tunnel under the Benbrook high point (Crowley tunnel), would result in an average static head pump savings of 80 feet under virtually all delivery scenarios to the Lake Benbrook area. However, additional pumping to the Benbrook booster and for delivery to Rolling Hills water treatment plant may be necessary with this configuration. If, ultimately, the tunnel configurations at Crowley and Midlothian prove to be preferable, the corridor alignment should be altered somewhat to take full advantage of shortened length and lowered highpoints (See Section 2 for more discussion).
- Many bypass operating scenarios are possible and these have been examined further than in previous studies. While full bypass based on delivery of Lake Palestine (only) is limited to about 100 mgd, bypass pumping from Cedar Creek or Richland Chambers Reservoirs (or a combination) can take advantage of the ability to bypass either booster station. However, bypass of Booster Station No.1 and operation of Booster Station No. 2 has higher delivery potential (up to 190 mgd) over the alternate booster bypass configuration. Higher operating heads than under full capacity system delivery with both booster stations operating would be necessary from the intake pumping stations to take full advantage of this; portions of the intake delivery piping (segments E and F) as well as the main line IPL would have to be of higher pressure class as well.

Table 4-7. Hydraulic Evaluation Criteria Matrix - Main Corridors

Evaluation Criteria	Unit	2 Booster Stations		
		1	5	7
Hydraulics				
Minimize overall pumping (Peak Flow)	HP	100,879	98,030	100,306
Minimize RC and CC Pumping (Peak Flow)	HP	11,093	13,686	13,291
Diversion to Bachman w/o supplemental pumping	Yes/No	Yes	Yes	Yes
Ease of Operations	---	Best	Better	Good
Number of redundant power supply sources	#	2	2	2
Risk of total system shutdown	---	Best	Better	Better
Bypass capabilities (A through D)	Flow (mgd)	110	110	100
Delivery to Customers	---	Poor	Better	Fair
Maximize Storage (Bal R)	---	Good	Good	Good
Surge	---	Fair	Fair	Fair

- Preliminary pump selection screening has been completed for the booster pump stations as part of the design standardization process (being conducted by the IPL Conceptual Design Team) which indicates that high efficiency, high capacity/head units are available from multiple manufacturers. Preliminary evaluation also shows that these selections can be optimized to provide some additional run out while maintaining high mechanical efficiencies under potential variable (reduced) speed operations. Additional evaluation under numerous potential operating scenarios will be necessary during conceptual and final design phases to optimize final pump selection and configuration.

4.5 Next Steps

The tasks listed below will expand the hydraulic analysis during the Conceptual Design phase of the project. Much of the optimization modeling during this phase will be conducted using a fully integrated hydraulic network model which can take advantage of connectivity and simulation of the IPL with the existing transmission system.

- Develop hydraulic design basis for pipelines, appurtenances, outlet structures, connections, and terminal storage reservoirs. Also assess the impact of pipeline aging on loss of capacity.
- Use hydraulic and life-cycle cost analysis to further refine selection of lowest cost pipeline size for each segment of the IPL.

- Use hydraulic and life-cycle cost analysis to further refine selection of preferred pump station configuration (number of booster pump stations). Consider 2 or 3 booster pump station options.
- Further development of primary high capacity and bypass pumping potential for a range of pumping configurations and facility optimizations. Comparisons will be performed for bypass pumping associated with open cut pipeline vs. tunnels at Midlothian and Crowley with further life-cycle cost comparisons.
- Compare pumping from the Lake Benbrook area to the east towards the City of Ennis for open-cut and tunnel options at Midlothian and Crowley in terms of feasibility and flow volumes.
- Further refinement of hydraulic terminations at Longhorn Park to better characterize the recommended configuration including delivery to the Benbrook booster versus termination at the TRWD dechlorination facility.
- Hydraulic support analysis for evaluation of infrastructure phasing plans to ensure adequate delivery while optimizing deferment and capital investment of the IPL over time.
- Evaluate hydraulic delivery of flows from East Texas to Kennedale Balancing Reservoir (through Segment I) without delivery to Benbrook Lake through the IPL.
- Calculate the pressure and flow potential at interconnects to the existing TRWD system at the crossing of the Richland Chambers pipeline (TRWD segment 5) and the intersection of segment G.

Section 5
Costs

This section describes the project cost analysis and the current basis for the conceptual level opinion of probable capital cost and life cycle cost for the Integrated Pipeline route selection phase. Additional cost estimates will be generated and updated at project milestones such as conceptual, preliminary, and final design, each with greater detail so that estimates improve as project definition improves.

This section first describes parameters used in the cost analysis and its methodology. Next, capital cost estimates are summarized for each segment of the pipeline route and for each facility, followed by a life-cycle cost estimate of the recommended route. Detailed cost spreadsheets are included in Appendix F of this report.

The detailed cost spreadsheets and tables noted in this report have been validated by the 0% Value Engineering (VE) team. Most of the recommendations and cost estimating methodology suggestions were adopted and incorporated into this final report subsequent to the VE workshops held during the week of May 17, 2010. However, because some analyses were completed prior to the VE, many comparative cost estimates rely on older methodology. This is most evident in the appendices, which contain results from analyses completed prior to the VE. The costs in those sections will therefore not match the results in the main body of the report.

Because Dallas is reviewing multiple alternatives to bring water into their system from the IPL, this report does not analyze costs for connection between the IPL and Dallas' delivery point. Costs for many options are included in the Dallas Delivery Location Analysis Technical Memoranda and will be added to these overall project costs after a delivery point and path has been selected. The overall IPL capital cost estimate including the Dallas Delivery option selected in *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study, Report No. 2* is located in Appendix M of this report. **Figure 5-1** identifies the IPL segments and facilities for which costs were developed in this report.

5.1 Cost Parameters and Methodology

Cost opinions were prepared using spreadsheet models. The expected accuracy range, degree of preparation effort, typical estimating method and level of project definition were typical of a conceptual level Class 4 estimate (using AACE International Recommended Practice No. 17R-97 - Cost Estimate Classification System) based on primarily stochastic methods. The cost parameters were based on recent bid tabs from several large diameter pipeline and pump station projects constructed in the Dallas/Fort Worth area and local manufacturers' pipeline unit cost data.

For purposes of this cost analysis, the pipeline was divided into various pipeline segments based upon the potential ownership and cost allocations between TRWD and DWU. **Table 5-1** lists the various pipeline segments and design flow rates.

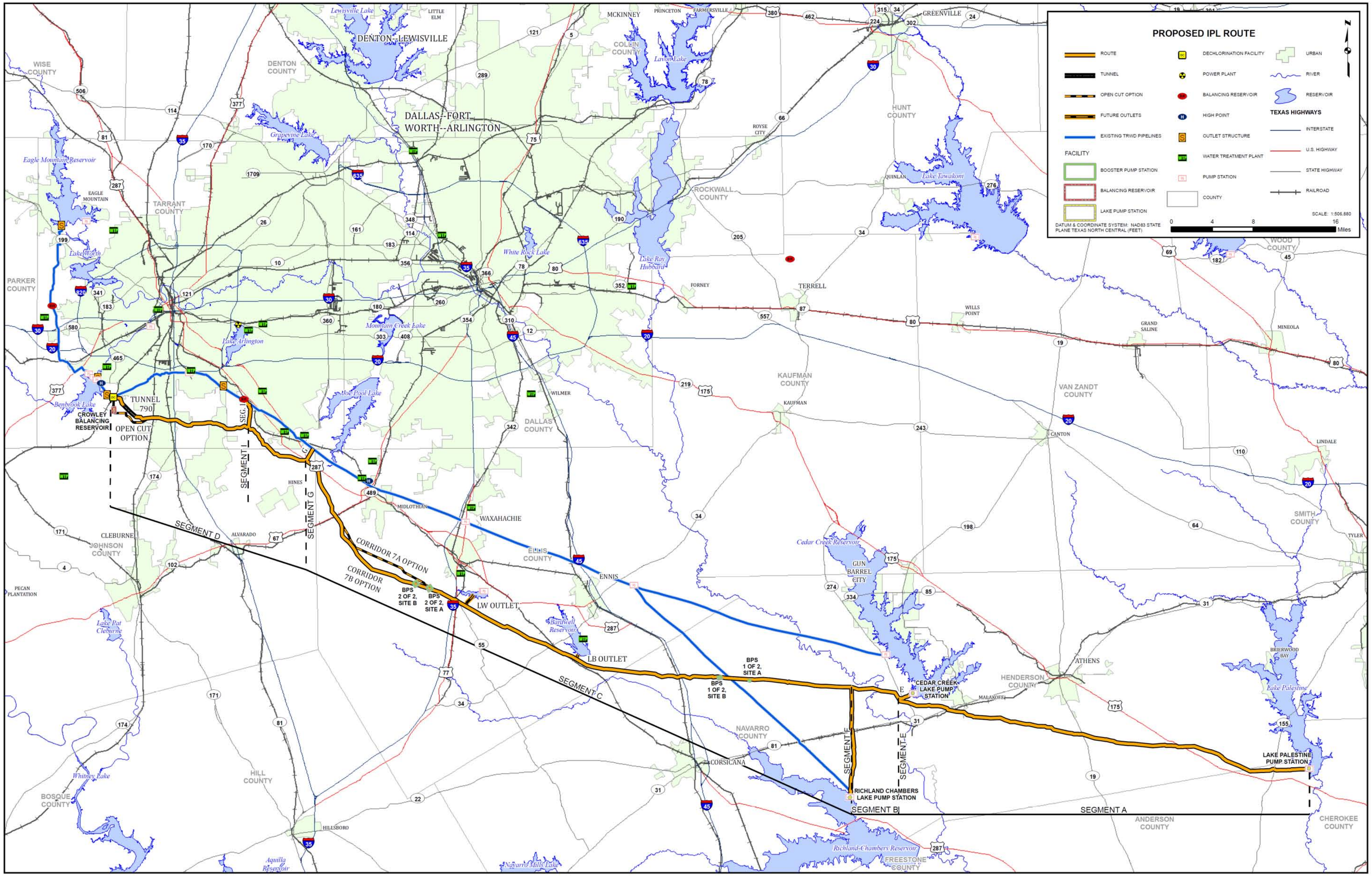

Figure 5-1 Integrated Pipeline Route

Table 5-1. Segment Descriptions

Segment	From	To	Design Flow (MGD)
A	Lake Palestine	Cedar Creek Connection	150
B	Cedar Creek Connection	Richland-Chambers Connection	277
C	Richland-Chambers Connection	Bachman Take-off Point	347
D	Bachman Take-off Point	Connection to Benbrook Pipeline	197
E	Cedar Creek Reservoir	Connection to the Main Proposed Pipeline	127
F	Richland Chambers	Connection to the Main Proposed Pipeline	70
G	Main Proposed Pipeline	Existing TRWD Lines	347
I	Main Proposed Pipeline	Kennedale Balancing Reservoir	197

5.1.1 Energy Cost Calculation Methodology

The energy costs for the transmission of flows through the Integrated Pipeline were determined using the IPL system simulation model (to generate flow time series) and TRWD's 'tariff spreadsheet' (to calculate energy usage and cost). The baseline integrated operating conditions of TRWD and Dallas sub-systems were defined and modeled using the STELLA program and are described in *Amendments 3 and 4 of the Raw Water Transmission System Integration Study, Report No. 1* (see Section 2 of that report). The STELLA model (the system simulation model) was used to calculate the flows transferred from Cedar Creek and Richland-Chambers Reservoirs (TRWD supply sources) and Lake Palestine (Dallas's supply source) through the three transmission pipelines (TRWD's existing CC and RC pipelines and the proposed integrated pipeline). As described in Report No. 1, model simulations were performed assuming no water sharing between TRWD and Dallas, using the hydrologic period-of-record extending from 1941-1986, and using demands representing the projected demand for each decade from 2010 to 2060.

TRWD currently uses a spreadsheet model to determine the energy costs incurred for pumping operations in their existing system. Because TRWD will control integrated system operations, this same model was used in this analysis. Few modifications were made to the spreadsheet model representing current system operations and to incorporate the Integrated Pipeline and the 3-booster and 2-booster pump stations modes of pumping operations. The flows generated by the system simulation model (STELLA) for each decade are put into the spreadsheet model, which then distributes the flows between the three pipelines based on pipeline hydraulics and the optimum flow distribution ratio that results in lowest energy costs for the entire system (existing TRWD pipelines and proposed IPL). Once the flows are distributed, the total dynamic head (TDH) and kilowatts (KW) required to transmit those flows through each pipeline segment between the pump stations are computed.

The total energy cost incurred by TRWD's system operations is comprised of generation costs (this is the cost required to move X amount of kWh through the system) and transmission and distribution costs. The generation costs are computed by multiplying the total kWh required for flow transmission with the costs/kWh factors developed and described in Appendix 5-C of *Amendments 3 and 4 of Phase 1 of the Raw Water Transmission System Integration Study -*

Report No. 1. The generation cost/kWh factors presented in that report were increased by $0.02 to make the generation costs/kWh factors comparable to TRWD's current contracted rates with the electricity providers. The transmission and distribution costs were computed using different distribution cost factors provided by TRWD.

The energy costs for intermediate years between each decade were linearly interpolated from the costs calculated at each decadal demand level. Because determination of the pipeline route was running on a parallel track to all of this cost estimating, it was not possible to determine which electricity provider would be supply to the pump stations. For this analysis, rates were based on current TRWD electricity providers.

The energy costs for different combinations of pipeline routes and pumping options are presented in Appendix A of this report. Demand projections on which these operating costs are based are presented in **Tables 5-2 and 5-3**. Demand values are based on TRWD estimates (using customer input) and Dallas's 2005 Long Range Water Supply Plan Update. Monthly adjustment factors and climate adjustment factors were applied, per direction from TRWD (same as RiverWare input) and Dallas.

Table 5-2. Demand Values (mgd) used for TRWD Customer Demand Nodes

	2010	***2020***	***2030***	***2040***	***2050***	***2060***
Holly WTP	48	50	47	43	39	35
Eagle Mountain WTP	50	65	80	95	110	127
JFK WTP	39	46	49	56	62	69
Pierce Burch WTP	38	38	47	53	59	66
Mansfield WTP	9	13	17	21	25	28
TRA Mosier Valley	38	48	59	69	80	90
Benbrook Local Use	3	4	6	7	8	9
Worth Local Use	4	4	4	4	4	4
Eagle Mountain Local use	2	2	3	3	4	4
Bridgeport Local Use	6	6	8	8	9	10
Arlington Local Use	2	2	2	3	3	3
Richland Chambers Local Use	3	4	4	5	5	5
Cedar Creek Local Use	4	4	5	6	7	8
Northwest WTP	10	13	21	30	41	53
Weatherford	4	4	4	4	4	4
BWSA	2	2	2	2	2	2
SW WTP	0	10	12	15	17	20
Rolling Hills WTP (removed SW WTP)	77	76	81	89	98	106
Ellis County Aggregated (Total Proposed Projections)	49	58	58	58	58	58
Total TRWD Demands	386	446	508	569	634	702

Table 5-3. Demand Values (mgd) used for Dallas Demand Nodes

Westside Lake Level Trigger	**When Lewisville is above 520 ft**						**When Lewisville is below 520 ft**					
Decade	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
Total Dallas Treated Water Demand	501	575	614	637	651	666	501	575	614	637	651	666
Westside System Demand [1, 3]	301	345	368	382	390	399	261	299	319	331	338	346
Elm Fork WTP [2]	195	224	239	249	254	260	169	194	207	215	220	225
Bachman WTP [2]	105	121	129	134	137	140	91	105	112	116	118	121
Eastside System Demand [1 3]	200	230	245	255	260	266	240	276	295	306	312	320
Eastside WTP	200	230	245	255	260	266	240	276	295	306	312	320
Westside System Raw Water Demand [4]	33	51	63	74	86	97	33	32	71	104	140	169
Eastside System Raw Water Demand [4]	3	3	3	3	3	3	3	3	3	3	3	3
Potential Customers [5]	2	2	2	3	3	4	2	2	2	3	3	4
Total Demand (including 5% treatment losses)	566	662	716	752	780	808	566	643	724	784	837	883

[1]Total Dallas Demand is distributed between Westside and Eastside systems in the ratio of 60:40 (When Lewisville >518 ft) and 52:48 (When Lewisville < 518 ft).
[2]Total Westside Demand is distributed between Elm Fork and Bachman WTP in the ratio of 65:35.
[3] Total Demand for each system (Westside and Eastside) is a total of Treated Water Demand, Raw Water Demand, and Demand for Potential Customers.
[4] Raw Water Demands are the demands supplied from Dallas system to other entities.
[5] Demand attributed to potential future demands for customer cities. Potential Demands are equally allocated to Eastside and Westside systems.

5.1.2 Capital Costs Calculation Methodology

Pipeline Costs

Pipeline costs are the most significant component of the overall IPL project estimate. Local pipeline manufacturers were consulted for budget estimates. Some of the assumptions used in the pipeline cost analysis include:

- Steel: Steel pipe will be manufactured and tested in accordance with AWWA C200. Steel grades of 36,000 psi, 42,000 psi, and 48,000 psi were utilized in determining the manufacture's pipeline unit cost estimate.
- Interior Lining: Pipeline will be cement mortar lined.
- Exterior Coating: Buried pipe will be polyurethane coated.
- Lengths: Standard lengths are 50 ft for steel.

Pipeline pressure classes were chosen based on the hydraulic grade lines developed for each pipeline segment as described in Section 4 of this report. **Figure 5-2** is an example of an HGL plot also showing pipe pressure class. Pipeline installation (excavation, bedding and backfill, appurtenances, etc.) costs were developed using recent data from large diameter pipeline installation projects constructed in the Dallas/Fort Worth and east Texas areas.

An itemized list of construction materials and labor used to generate the capital cost estimate is located in Appendix F of this report. **Table 5-4** shows steel pipe unit costs used in this analysis.

Table 5-4. Steel Pipe 2009 Material Unit Costs/Pressure Class

Pipe Diameter (inches)	Unit Cost (CL 150)	Unit Cost (CL 175)	Unit Cost (CL 200)	Unit Cost (CL 225)	Unit Cost (CL 250)
60	$189	$189	$189	$212	$236
66	$223	$223	$223	$250	$279
72	$259	$259	$259	$292	$324
78	$296	$296	$296	$334	$371
84	$339	$339	$344	$382	$425
90	$370	$370	$375	$417	$464
96	$410	$410	$415	$462	$513
102	$456	$456	$456	$513	$569
108	$510	$510	$510	$573	$637
120	$622	$627	$627	$705	$783

Pump Station Costs

Pump Station pricing was developed from bid tabs of similar size projects with similar pump and piping configurations (comparable type, size and number of pumps). Costs for pumps, motors, and drives were estimated based on current pricing provided by manufactures. Costs for pump suction and discharge piping (including headers and yard piping) and valves were estimated using bid tabs from past DWU and TRWD projects.

The use of horizontal split-case pumps was assumed at all booster pump stations. It was also assumed that all pumps at booster pump stations will be equipped with variable frequency drives (VFDs). Horizontal split-case pumps were assumed to be between 20,000 GPM to 30,000 GPM each (approximate pump suction and discharge size = 42" x 36"). For the purpose of estimating, the pump configuration was assumed to be four (4) units for firm capacity plus one (1) backup. Vertical turbine pumps were assumed at all lake intake pump stations, each equipped with a VFD. Vertical turbine pump sizes were assumed to be between 30,000 GPM to 40,000 GPM each. For the purpose of estimating, the pump configuration was assumed to be eight (8) units for firm capacity plus one (1) backup. An itemized list of construction materials and labor used to generate the capital cost estimate is located in Appendix F of this report.

Easement and Real Estate Costs

The easements and property costs were determined based on acquisition costs from recent Dallas Water Utilities and Tarrant Regional Water District large diameter pipeline projects. A 150 ft permanent easement width was assumed to accommodate a future second (and perhaps third) pipeline within the same right-of-way. The acquisition of the pump station sites were also included in the overall cost estimate.

5.1.3 Life Cycle Costs Calculation Methodology

In calculating the lifecycle cost, a 100-year project life was assumed, spanning from 2018 (project commissioning) through 2117, and annual costs were broken down into four categories: debt service, operations and maintenance, energy, and renewal and replacement.

Debt Service

Debt service represents the cost associated with the expected debt financing to pay for the capital costs of each project. For this project, the Dallas and TRWD costs of debt, 4.88% and 5.07%, respectively, were averaged together to yield 4.97%. These costs of debt were then applied to the capital cost of the appropriate scenario and a payment schedule was generated for a 30-year, fixed rate, level payment debt issue.

Operations and Maintenance

The operations and maintenance expenses (O&M) for each scenario were calculated based on historical itemized operation and maintenance information from Dallas Water Utilities.

Table 5-5. Pipeline O&M (not including energy)

Item	First year	Cost/ #year
Project Vehicles - 2 - 4x4 vehicles to drive ROW	$70,000	$0
Gas - Project Vehicles	$7,000	$3,500
Maintenance - Project Vehicles	$2,000	$2,000
ROW maintenance - mowing, clearing, etc.	$236,000	$236,000
CP - Annual Survey - 3 people 1 month	20,000	$20,000
Chemical Feed System	$5,400,000	$5,400,000
Valve Maintenance and replacement	0	$45,000
Labor - 2 people full time @ $34/hour including benefits	$141,000	$141,000

Assumptions:

1. Replace vehicles every 5 years
2. Assume 20k mileage per year @ 18 miles/gal. $3/gal gas
3. Assume tire replacement and fluid changes per year.
4. Mowing and clearing 130 miles of 150-foot wide pipeline ROW @ $100/acre. Mow once per year
5. Assume 3 people for annual survey, test station maintenance, and rectifier maintenance.
6. Based on 350 MGD @ $0.0426/1000 gal. Includes caustic, Chlorine, LAS, Power, Maintenance
7. Assume replacement of 0.5% of total valves per year - 130 miles of pipeline with a valve every 1500-feet.
8. Assume 2 people dedicated to pipeline O&M

Table 5-6. Pump Station O& M

Item	First Year	Cost/ #year
Pump Room HVAC Power	$100,000	$100,000
Pump Room Lighting Power	$10,000	$10,000
Pump Station Operator	$125,000	$125,000
Pump Station general maintenance employee	$80,000	$80,000
Yard and & Landscaping	$5,000	$5,000
Security Service	$100,000	$100,000
Pump Rebuild Maintenance (10-yr cycle)/pump	$15,000	$15,000
Roof Maintenance	$0	$30,000
Painting	$0	$15,000
Intake Screens	$3,000	$3,000
Motor Cooling System Maintenance	$3,000	$3,000
Bridge Crane Maintenance	$3,000	$3,000

Assumptions per pump station:

1. Including fringe benefits
2. Onsite guard service
3. Add cost every 10 years
4. Replace every 30 years
5. Repaint every 5 years

5.2 Cost Analysis Results

Based on the parameters and methodology described in Section 5.1, the following capital and life-cycle cost estimates were generated. **Table 5-7** summarizes the capital cost for the Integrated Pipeline route and facilities recommended in this report. **Table 5-8** contains energy cost estimates for each decade of operations based on the baseline operating conditions developed during this study. The full Operations Study that will be completed in the next phase of this IPL Project will define operating conditions more specifically and refine these operating costs. Using the values in Tables 5-7 and 5-8, the present worth of the 100-year life-cycle cost is **$3,053,000,000.**

Table 5-7 IPL Capital Costs

COST ESTIMATE SUMMARY

SCENARIO: VE validated w/o Dallas Delivery

2009 Prices	***INTEGRATED PIPELINE PROJECT***		Date: 6/25/2010
	Item		**Estimated Costs for Facilities**
Capital Costs			
Pipelines			
Segment A - Lake Palestine to Cedar Creek Reservoir		$	222,556,000
Segment B - Cedar Creek to Richland-Chambers Tie-in		$	43,597,000
Segment C - Richland-Chambers Tie-in to Segment G Connection		$	514,880,000
Segment D - Seg G Connection to Lake Benbrook		$	181,894,000
Segment E - Cedar Creek to Main Trunkline		$	8,040,000
Segment F - Richland-Chambers to Main Trunkline		$	45,388,000
Segment G - Main Trunkline to Existing TRWD Pipelines		$	11,790,000
Segment I - KBR Cross Connection		$	19,363,000
Pipelines Subtotal		$	1,047,508,000
Land Acquisition			
Segment A		$	34,811,000
Segment BCDE		$	83,482,000
Segment F		$	5,990,000
Segment G		$	1,505,000
Segment I		$	3,070,000
Land Subtotal		$	128,858,000
Pump Stations			
Lake Palestine Intake and PS			$51,627,000
Richland-Chambers Lake PS			$23,980,000
Cedar Creek Intake and PS			$47,285,000
Booster PS 1			$68,989,000
Booster PS 2			$68,989,000
Pump Stations Subtotal		$	260,870,000
Power Supply		$	30,000,000
Total Project Capital Cost		**$**	**1,467,236,000**
Escalation @ 3% to mid point of construction (2015)		**$**	**1,700,910,000**

CDM

Table 5-8 Energy Costs per Decade

IPL - Energy Costs Per Decade					
2010	2020	2030	2040	2050	2060
$21,106,000	$25,661,000	$39,091,000	$57,931,000	$79,921,000	$100,099,500

5.3 Integrated vs. Independent Project Development

From the beginning of this project, the Raw Water Transmission System Integration Study which later became known as the Integrated Pipeline Project, the question we sought to answer was: Should TRWD and DWU develop two independent water transmission projects or one integrated water transmission project? The technical aspects of this question were answered in previous reports and a definitive conclusion was reached that 'yes', integration should proceed. This decision rested in large part on the potential cost savings to both TRWD and Dallas in developing a joint project as opposed to two independent raw water conveyance systems.

Cost estimating methods and detail have continued to improve and project definition has improved. At this final stage of planning, it is prudent to again calculate the project cost for the TRWD and Dallas independent project development alternatives and compare them to the IPL configuration. **Table 5-9** contains the results of that comparison. It shows that **significant cost savings will be realized by developing an integrated raw water transmission system as compared to developing independent systems, savings in the range of $375 to $443 million in capital cost and roughly $1 to $1.5 billion in present worth 50-year life-cycle cost.**

Tabel 5-9 Integrated vs Independent Comparisons

COST ESTIMATE SUMMARY

SCENARIO: Comparison of Integrated and Baseline Alternatives

2009 Prices	*Integrated vs Independent*			Date:6/27/10
Parameter	**Project Alternative**			
	TRWD-Dallas Integrated Pipeline	***TRWD Independent Pipeline***	***Dallas Independent Pipeline - Pal to SE WTP***	***Dallas Independent Pipeline - Pal to Bachman WTP***
Pipeline Segments Included	A through I	B, C, D, E, F	A	A, B, C, G, H
Total Pipeline Length	933,808	522,322	466,021	717,859
Tunnel Length (i.e. deep tunnels, not crossings)	8,480	8,480	0	0
Pipeline Diameter	Segment A-84"; B-108"; C-108", D-84", E-72", F-66", G-108", H-84", I-84"	Segment B-72"; C-90"; D-90", E-72", F-66"	Segment A-84"	Segment A-84"; B-84"; C-90", G-84", H-84"
Number of Booster Pump Stations	2	2	2	2
Number of Intakes and Intake Pump Stations	3 PS, 2 new intakes	2 PS, 1 new intake	1 intake and PS	1 intake and PS
Design Flow	Segment A-150, B-277, C-347; D-197; E-127; F-70; G-197; H-150; I-197	B, E-127; C, D-197; F-70	All - 150	All - 150
Route	Follows Corridor 1/7 as finalized on xx/xx/2010. Runs between CC/RC, south of Lakes Bardwell and Wax., etc……	Follows same route as Integrated Pipeline alternative	-----	-----
Total Land Acquired (acres)	2681	1799	1605	2473
Number of Storage Facilities	1	1	1	1
Total Capital Cost (2009 $)	**$1,726,561,000**	**$977,845,000**	**$1,123,265,000**	**$1,192,079,000**
Energy Usage and Cost: 2010	$21,106,000	$18,709,000	$6,083,000	$8,216,000
Energy Usage and Cost: 2020	$25,661,000	$30,306,000	$10,701,000	$14,455,000
Energy Usage and Cost: 2030	$39,091,000	$46,594,000	$14,506,000	$19,596,000
Energy Usage and Cost: 2040	$57,931,000	$64,653,000	$18,218,000	$24,610,000
Energy Usage and Cost: 2050	$79,921,000	$82,450,000	$22,469,000	$30,351,000
Energy Usage and Cost: 2060	$100,100,000	$96,461,000	*$26,063,000*	$35,206,000
50-year Life-cycle Cost Present Worth	**$2,926,430,000**	**$2,170,296,000**	**$1,762,727,000**	**$1,917,380,000**

CDM

Section 6
Recommendations

This report section is meant to provide summary information about the recommended pipeline route in a tabular format. In the sections below are tables that describe the configuration of the recommended route.

In report Section 2, the configuration of the recommended Integrated Pipeline Project (IPL) route was described in specific detail. The IPL is divided into 8 parts that describe Segments A through I. The overall system configuration is shown in **Figure 6-1**. Detailed hydraulic analysis and cost estimating helped develop the optimum pipeline diameters for the IPL project. As a result of the analysis, there is a recommended deep tunnel in Segment D near Crowley. This tunnel is approximately 8,500 feet in length and has both hydraulic and social benefits to the project. This recommendation will also be refined and verified during the Conceptual Design and Operations Study phase. The recommended configuration of the pipeline is noted in **Table 6.1**.

Table 6-1. IPL Configuration

Segment	From	To	Pipeline Diameter	Flow Rate (MGD)	Pipeline Length
A	Lake Palestine	Cedar Creek Connection	84”	150	220,394’
B	Cedar Creek Connection	Richland-Chambers Connection	108”	277	26,159’
C	Richland-Chambers Connection	Bachman Take-off Point	108”	347	329,388’
D	Bachman Take-off Point	Connection to Benbrook Pipeline	84”	197	114,131’
E	Cedar Creek Reservoir	Connection to the Main Pipeline	72”	127	8,517’
F	Richland-Chambers	Connection to the Main Pipeline	66”	70	57,768’
G	Main Pipeline	Existing TRWD Lines	108”	347	7,120’
I	KBR Take-off Point from Main Pipeline	Kennedale Balancing Reservoir	84”	197	14,765’

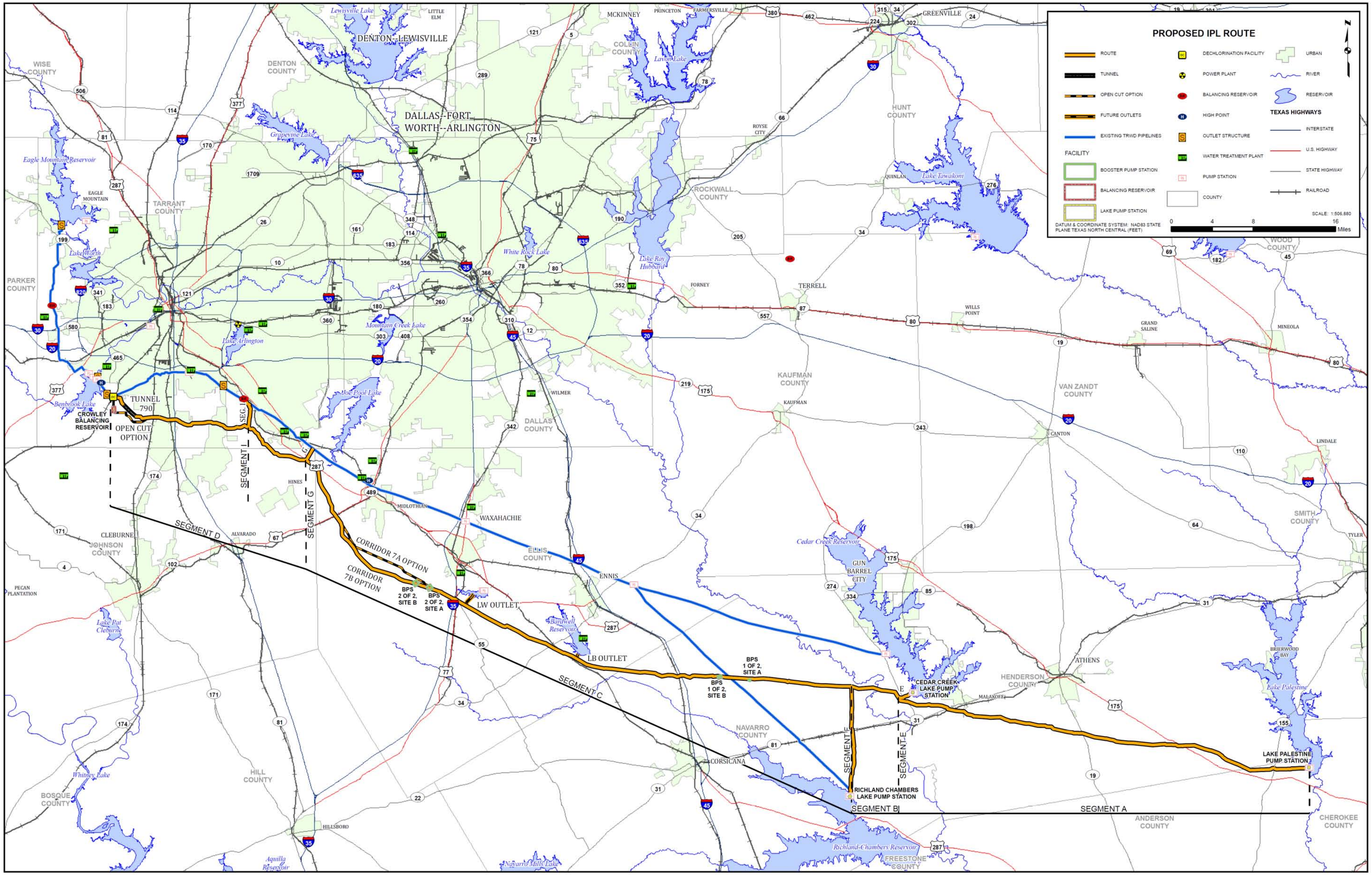

Figure 6-1. **Overall IPL Map**

The number of recommended facilities for the IPL project was studied in detail in this report and in previous studies. The recommended number of facilities and their locations were based on preliminary hydraulics calculations, capital costs, energy costs, and life cycle analyses. **Table 6-2** notes the number and of facilities and their pumping configuration.

Table 6-2. IPL Facilities

Facility	Flow Rate (MGD)	Operating Head Range	Number of Pumps
Lake Palestine Pump Station	150	210’ – 625’	4 + 1
Cedar Creek Pump Station	127	136’ – 378’	4 + 1
Richland-Chambers Pump Station	70	143’ – 396’	3 additional
Booster Pump Station No. 1	350	263’ – 577’	6 to 8 + 1
Booster Pump Station No. 2	350	152’ – 582’	6 to 8 + 1

In the previously submitted corridor selection report (*Amendment 3 and 4 Report No. 2*), there was a comparative analysis done for multiple corridors. The evaluation criteria used to differentiate the corridors has been used in this report to provide an overall and detailed view of the recommended route. **Table 6-3** is a criteria summary table for the IPL route.

Table 6-3. Evaluation Criteria Summary Table

Criteria	Unit	Quan/Qual
Number of Acquisitions (Parcels) - Total IPL	No.	877
Major Utility Xings/CCN Utility Bndry Xings	No.	26
State and US Highway Crossings	No.	19
Railroad Crossings	No.	6
Oil/Gas Line Crossings	No.	40
Pipeline Length (total IPL)	Ft	778,242
Urban Pipeline Length (Total IPL)	Ft	42,366
Major River Crossings (Total IPL)	No.	1
Stream Crossings	No.	210
Archeological and Historical Sites	No.	5
Lake and Pond Crossings	No.	42
Forested upland	ac	255
Forested Bottomland	ac	82
Native Grasslands	ac	626
Endangered Species Habitat	ac	207
USACE Property	ac	6
Pipeline Construction Costs (IPL Total)	$M	$1,047

Table 6-3(cont.). Evaluation Criteria Summary Table

Criteria	Unit	Quan/Qual
Easement Costs (IPL Total)	$M	$128
Energy Costs (IPL Total) Present Worth	$M	$895
Power Supply Costs	$M	$30
Fault Crossings	No.	5
Alluvial Soils	Ft	32,925
Terrace Soils	Ft	2,411
Native Soils	Ft	126,552
Tunnels (all are stream, highway, drainage crossings)	Ft	7,126
Deep Tunnels	Ft	8480
Rock Excavation	Ft	122,458
Levee Crossings (USACE)	No.	0
OH and UG power crossing	No.	41
Major Highway Crossings	No.	46
County Road/Local Street Crossings	No.	104
100-year Flood Plain	No.	56
Minimize Overall Pumping	Hp	100,306
Number of Redundant Power Supply Sources	No.	2

The detailed cost spreadsheets and tables noted in this report have been validated by the Program Manager's Value Engineering (VE) team. Most of the recommendations and cost estimating methodologies were adopted and incorporated into this final report after the VE workshops held through the week of May 17, 2010.

This report presents the preliminary capital and life cycle costs associated with the IPL project. Cost opinions were prepared using spreadsheet models. The expected accuracy range, degree of preparation effort, typical estimating method and level of project definition were typical of a conceptual level Class 4 estimate (using AACE International Recommended Practice No. 17R-97 - Cost Estimate Classification System) based on primarily stochastic methods. The cost parameters were based on recent bid tabs from several large diameter pipeline and pump station projects constructed in the Dallas/Fort Worth area and local manufacturers' pipeline unit cost data. Preliminary 2009 capital cost for the IPL project is approximately $1.47 B (escalated to 2015 construction mid-point this is $1.7 B). Detailed cost spreadsheets are located in Appendix F of this report. **Table 6-4** notes the capital costs for each pipeline segment and facility.

Table 6-4. IPL Capital Costs

Segment/Facility	Descriptions	Length (feet)	Design Flow	Capital Cost
Segment A	From Lake Palestine to Cedar Creek Lake	220,394	150	$222,556,000
Segment B	From Cedar Creek to Richand-Chambers tie-in connection	26,159	150	$43,597,000
Segment C	From Richland-Chambers tie-in connection to Bachman turn-out	329,388	347	$514,880,000
Segment D	From Bachman turn-out to Benbrook	114,131	197	$181,894,000
Segment E	From Cedar Creek to IPL	8,517	127	$8,040,000
Segment F	From Richand-Chambers to IPL	57,768	70	$45,388,000
Segment G	From main IPL to existing TRWD pipeline	7,120	347	$11,790,000
Segment I	From IPL to KBR	14,765	197	$19,363,000
Lake Palestine	Lake Intake Pump Station	n/a	150	$51,627,000
Cedar Creek Lake	Lake Intake Pump Station	n/a	127	$47,285,000
Richland-Chambers	Lake Intake Pump Station	n/a	70	$23,980,000
BPS1	Booster pump station 1	n/a	347	$68,989,000
BPS2	Booster pump station 2	n/a	347	$68,989,000
Land Acquisition	All pipeline and facilities (acres)	n/a	n/a	$128,858,000
Power Supply	Power connection to the pumping facilities	n/a	n/a	$30,000,000

Table 6-5 contains energy cost estimates for each decade of operations based on the baseline operating conditions developed during this study. The full Operations Study that will be completed in the next phase of this IPL Project will define operating conditions more specifically and refine these operating costs. Using the values in Tables 6-4 and 6-5, the present worth of the 100-year life-cycle cost is **$3,053,000,000.**

Table 6-5. IPL Energy Costs

IPL - Energy Costs Per Decade					
2010	2020	2030	2040	2050	2060
$21,106,000	$25,661,000	$39,091,000	$57,931,000	$79,921,000	$100,099,500

Section 7
References

Geologic mapping along the entire pipeline route is currently available from the Tyler Sheet and the Dallas Sheet of the Geologic Atlas of Texas at a scale of 1:250,000. This information has been used to develop the site geologic map in Figure 1-1.

Flawn, P.T. 1965. Geologic Atlas of Texas – Tyler Sheet. Bureau of Economic Geology, University of Texas at Austin. Scale: 1:250,000. March.

Fisher, W.L.. 1972. Geologic Atlas of Texas – Dallas Sheet. Bureau of Economic Geology, University of Texas at Austin. Scale: 1:250,000.

Thompson, G.L. 1969. Groundwater Resources of Johnson County, Texas. Texas Water Development Board Report 94. April.

Thompson, G.L. 1967. Groundwater Resources of Ellis County, Texas. Texas Water Development Board Report 62. October.

Thompson, G.L. 1972. Groundwater Resources of Navarro County, Texas. Texas Water Development Board Report 160. November.

Leggat, E.R.. 1957. Geology and Groundwater Resources of Johnson County, Texas. Texas Board of Water Engineers Bulletin 5709. April.

Guyton, W.F. and Associates. 1972. Groundwater Conditions in Anderson, Cherokee, Freestone and Henderson Counties, Texas. Texas Water Development boars. Report 150. August.

The Earth Technology Corporation (ETC). 1990. Geomechanical Characterization of the Eagle Ford Shale at the Superconducting Super Collider Site. Prepared for RTK a Joint Venture. GR-66. October.

The Earth Technology Corporation (ETC). 1990. Geomechanical Characterization of the Eagle Ford Shale at the Superconducting Super Collider Site. Prepared for RTK a Joint Venture. GR-67. November.

Texas Water Development Board (TWDB), Water Information Integration and Dissemination. Groundwater Database. Available on line at http://wiid.twdb.state.tx.us/. Accessed June 2009.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture (USDA) . Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. accessed [May 2009].