FINAL

TECHNICAL MEMORANDUM NO. 9
KARST AVOIDANCE AND IMPACT MITIGATION PLAN

Water Treatment Plant #4 – Jollyville Transmission Main — B&V Project 167760
Phase B – Final Design — B&V File D-1.2
CIP ID: 6935.016

To: Stacie Long, P.E. – Project Manager, City of Austin

From: Dennis Allen, P.E. – Project Manager, Black & Veatch

Date: May 12, 2011 (replaces all previous drafts)

1. Introduction

The purpose of Technical Memorandum (TM) No. 9 is to present a plan for avoidance and mitigation to limit the impact to karst subsurface conditions when encountered during the construction of the access shafts for the Jollyville Transmission Main (JTM). The JTM will convey finished water by tunnel from Water Treatment Plant No. 4 (WTP4) to the Jollyville Reservoir (JR) for distribution by the City of Austin (COA). This TM has been prepared by Black & Veatch, with technical review by Hicks & Company, and Zara Environmental LLC (Zara). Karst avoidance issues are also addressed in TM No. 12 (Shaft Site Recommendation).

2. Background and Objectives

Voids are common features of the karstic limestone and dolomite formations of the Edwards Group in Central Texas. Shaft locations are sited to avoid known karst features, however, when voids are encountered during shaft construction through the Edwards formation, the structural integrity and the hydrological function of the void may be impacted. This TM outlines the mitigation steps to reduce potential impacts to the Edwards karst formation and presents guidelines for preparation of the contract documents and the Geotechnical Baseline Report (GBR). Subsurface data collected is presented in the Geotechnical Data Report (GDR). Both the GBR and the GDR are contract documents.

The objective is to protect hydrologic characteristics of the karst formation and groundwater flow pathways so that there is no impact to karst springs and habitat, including the habitat of the Jollyville Plateau Salamander. This TM is intended to present techniques to avoid and/or preserve karst conduits that convey groundwater to springs or cave passages that are hydrologically connected within the Edwards Aquifer. These issues have been dealt with throughout the Environmental Commissioning (EC) planning process for years – not only from the beginning of this project, but earlier when the former WTP4 plant site was the focus. This TM represents a more detailed evolution of technical planning and approach with regard to karst and groundwater protection. This TM is based on information presented in the final Environmental Commissioning Plan (ECP) dated September 2010 and the subsequent list of project commitments documented in the Basis of Design Report.

A collaborative effort between the environmental and engineering teams will be necessary during both design and construction for a successful project. To this end, the following workshops and tasks were undertaken during design:

- A workshop was conducted on August 23, 2010 with the COA and EC Team to discuss strategies and best management practices for avoidance and mitigation of karst subsurface conditions during shaft construction. The workshop minutes are included in Appendix A.
- The EC Coordination Group met from January 3, 2011 to January 28, 2011 to discuss possible environmental impacts of the construction and operation of the transmission main. The Shaft Design Working Group met on several occasions to discuss environmental concerns regarding the construction and operation of the shafts. One key topic was the how will the shafts be designed to avoid and minimize possible harm to spring flows by limiting groundwater inflow and preserving groundwater flow paths. The discussions are summarized in a document entitled "Jollyville Transmission Main Environmental Commissioning Consensus" (a copy is included in Appendix S of the Basis of Design Report).
- Follow-up EC workgroup meetings were held to finalize elements of the shaft designs.

3. Tunnel Design Parameters and Requirements

This TM is based on the tunnel alignment from WTP4 to the JR as presented in the Preliminary Engineering Report and as presented in TM No. 11 (Evaluation of Alternative Tunneling Concepts), dated August 23, 2010. Figure 1 shows the proposed horizontal alignment and shaft locations. The alignment and shaft locations were confirmed during detailed design. Figure 2 shows the proposed vertical alignment and direction of tunneling that was presented as Alternative 2 in TM No. 11. This vertical alignment or tunnel profile was adjusted as additional geotechnical information was gathered and reviewed during detailed design. The tunnel was lowered approximately 50 feet to zones of lower permeability in the Glen Rose formation near the Parks and Recreation Department (PARD) shaft site and Jollyville Reservoir (JR) shaft site. Figure 3 shows the final tunnel profile. Locations of the completed borings are shown on Figure 1.

Other design parameters and requirements being used in the development of the TMs and Basis of Design Report, that were confirmed during detailed design, include the following:

Table 1
JTM Tunnel Design Parameters

No.	Design Parameter	Description and Rationale
1	Tunnel Horizontal Alignment	Alignment as presented in the PER and subsequent TM No. 11 (Evaluation of Alternative Tunneling Concepts). See Figure 1.
2	Design, Bid Documents, and Contract Execution Schedule	Design, sealed, and bid-ready 100% contract documents completed by April 29, 2011, with an anticipated notice to proceed for construction in Fall 2011.
3	Construction Schedule	The tunneled pipeline must be finished by Spring 2014 when WTP4 is scheduled to be operational. This schedule only allows a total of approximately 30 months for construction, requiring the need for two tunnel boring machines (TBMs).
4	Working Shafts	Working shafts approximately 40 feet excavated diameter will be located at Jollyville Reservoir (JR) and Four Points Area (FPA), and will be approximately 350 and 270 feet, deep respectively.
5	TBM Retrieval Shafts	TBM retrieval shafts approximately 20 to 30 feet excavated diameter will be located at the WTP4 and Parks and Recreation Department (PARD) sites, and will be approximately 200 feet and 125 feet deep, respectively. Construction Manager-at-Risk (CMAR) has requested that the WTP4 site be used as a retrieval shaft only to minimize congestion at the site with the planned construction work. Pipe installation and grouting will be undertaken at the WTP4 and PARD sites to achieve completion of the project within the required timeframe.
6	Tunnel Construction	The tunnel will be approximately 10 feet in excavated diameter and 34,600 feet in length. Tunneling will be advanced upgradient from the JR shaft to the PARD shaft and from the FPA shaft to the WTP4 shaft. Tunneling will be advanced downgradient from the FPA shaft to the

Table 1
JTM Tunnel Design Parameters

No.	Design Parameter	Description and Rationale
		PARD shaft.
7	Minimal Environmental Impacts	No or minimal construction and operations impact objectives must be targeted for sensitive environments, including protected endangered or threatened species, karst impacts, and other critical groundwater and surface water resources.
8	Ventilation Shafts	No ventilation shafts have been permitted or provided in the design.
9	Working hours	Acceptable working hours will be 12 hours per day from 7:00 a.m. to 7:00 p.m., Monday through Friday, excluding subterranean tunnel boring. Muck hauling outside the limits of the shaft sites will be 9:00 a.m. to 4:00 p.m. All muck hauling outside the limits of the PARD site will be 9:00 a.m. to 3:00 p.m. due to school drop-off and pickup times. Maintenance work will be allowed at the shaft sites from 8:00 a.m. to 5:00 p.m. on Saturdays, as approved by the COA. No work will be allowed on Sundays and major holidays.
10	Noise	Noise at the shaft sites will comply with the COA Code of Ordinances, Chapter 9-2-3 (General Restrictions),which prohibits (a) noise audible to an adjacent business or residence between 10:30 p.m. and 7:00 a.m. and (b) operation of a machine that separates, gathers, grades, loads, or unloads sand, rock, or gravel within 600 feet of a residence, church, hospital, hotel, or motel between 7:00 p.m. and 6:00 a.m., except for the installation of concrete as authorized under Section 9-2-15 (Permit for Concrete Installation During Non-Peak Hour Periods). Contractor will be required to prepare and implement a noise monitoring plan, and if necessary to conform to the noise ordinance, implement noise abatement.
11	Truck loads	Contractor may use maximum capacity trucks as allowed by the road limits for muck removal.

4.0 Project Area Geology and Hydrogeology

The JTM project area lies within the dissected edge of the Edwards Plateau physiographic province. The general geology of the JTM alignment corridor includes a thin veneer of soil overlying carbonate (limestone and dolomite) bedrock. Soils are generally comprised of clay and silty clay, and commonly contain gravel size fragments of the underlying bedrock. The bedrock is comprised of a series of Cretaceous carbonate rocks that have been divided into four geological formations. From top to bottom, or youngest to oldest, these formations are the Edwards, Comanche Peak, Walnut, and Glen Rose. Karst development in the Austin area is primarily in the Edwards, and is not widespread in the Walnut or Glen Rose formations.

There are two aquifers in the project area, the upper perched groundwater in the Edwards formation and the lower confined groundwater contained in the Glen Rose formation. The Jollyville Plateau represents a recharge area (Edwards Aquifer Recharge Zone) for the Edwards and possibly in the upper Walnut formation. Rainfall in this area passes down through the Edwards Limestone through conduits such as faults, sinkholes, vugs, and caves until it reaches the argillaceous limestone in the Walnut formation. This portion of the Walnut acts as an aquitard, so water moves laterally along the surface in the direction of dip (easterly to southeasterly). In the Balcones Canyonlands Preserve (BCP), where the Edwards and Walnut are exposed, groundwater daylights as spring water mostly from the Edwards and a few small springs along Bull Creek from the Walnut, and fewer places where it daylights as springs from the upper portion of the Glen Rose. Both the Walnut and the Glen Rose formations generally have low permeability. Based on geotechnical data collected for this project, groundwater in the Glen Rose is limited to discontinuities in the rock mass such as fractures and small solutional openings. A portion of the project area is located in geology characterized by the Jollyville Plateau Karst (Edwards formation), which is noted for numerous sinkholes, voids, and caves. Shaft excavations will avoid known sinkholes and caves but may encounter unknown voids in the subsurface.

5.0 Shaft Locations

Four access shafts are included in the JTM design and contract documents. These shafts will be utilized for tunnel and pipeline construction purposes, including removal of the tunnel spoils and tunnel water, installation and removal of TBMs, and installation of steel carrier pipe and backfill grouting. Table 2 below lists the general location and description for these shafts.

Table 2 JTM Tunnel Access Shafts		
Shaft Designation	**General Location**	**Description**
W-1	Four Points Area	Property recently purchased by the COA located at the northwest of intersection of RM 2222 and River Place Boulevard and southwest of Four Points Drive and River Place Boulevard.
W-2	Jollyville Reservoir (JR)	At the JR tank site on COA property
R-1	WTP4 Site	Near medium service pumping station on the west side of the COA property
R-2	Parks and Recreation Department (PARD) / Spicewood Springs Road	COA PARD property, on east side of Spicewood Springs Road where it turns to the south

The following section presents a description of shaft locations for tunnel construction.

5.1 Shaft W-1 Site (Four Points Area)

Shaft W-1 is located in the Four Points Area on property recently purchased by the COA just northeast of RM 2222. This shaft will be used as a working shaft to lower the tunnel boring machine and excavate the tunnel as well as for pipe installation and grouting. The immediate surrounding environment includes general commercial development and preserves.

5.2 Shaft W-2 Site (JR)

Shaft W-2 is located at the existing JR site and is bordered by Highway 183 (Research Boulevard), and McNeil Drive in Williamson County. It will also be used as a working shaft as well as for pipe installation and grouting. The shaft layout will need to be coordinated with ongoing site operations. The property is owned by the COA and is currently fenced and used as a finished water reservoir site. The surrounding environment is generally highway, commercial, and residential.

5.3 Shaft R-1 Site (WTP4)

Shaft R-1 is located at the WTP4 site and is bordered by RM 620 on the southeast and Bullick Hollow Road on the northeast. The shaft at this location will be used for a TBM retrieval shaft and also for pipe installation and grouting. The construction access will be coordinated with the plant construction. The specific shaft location is on the WTP4 plant site near the finished water pump station and will be located in coordination with the plant designer. This part of the plant site is located in an area covered by the Comanche Canyon 10(a) permit (Permit #TE004683).

5.4 Shaft R-2 Site (PARD)

Shaft R-2 is located on COA PARD Property on the south and east sides of Spicewood Springs Road where it changes direction from east-west bearing to north-south bearing. The shaft at this location will be used for a TBM retrieval shaft as well as for pipe installation and grouting. The property is currently used as open space and the surrounding environment is generally residential with a tributary to Bull Creek adjacent to the site on the east.

6.0 Shaft Excavation Methods

A separate TM (TM No. 2 - Excavation Methods Study) includes an evaluation of shaft construction methods for the project in detail. Shafts are typically excavated using a combination of mechanical equipment for soil excavation above the rock surface and blasting methods for rock excavation. Shaft diameters for the JTM project can vary from 20 to 40 feet. The shaft excavation has to be large enough for final functionality but must also fit within the constraints of the site and tunnel and pipeline construction. The final excavated size of the shaft will be determined by the contractor as part of his means and methods for construction in accordance with the contract documents.

While surface topography varies across the project area, the bedrock is relatively close to the surface along the tunnel alignment. Borings have been drilled at the shaft locations at the WTP4 (R-1), PARD (R-2), Four Points Area (W-1), and the JR (W-2) shaft sites. From these borings and other borings along the tunnel alignment, the soil thickness is likely less than 25 feet at these shaft locations (see the GDR for boring log information). At this shallow depth, large backhoes have sufficient reach to excavate soils from 20 feet diameter or smaller shafts from the ground surface. As the shaft diameter increases, the reach of the backhoe from the surface becomes a limiting factor in their use. In that case, cranes equipped with clamshell buckets or a small backhoe operating in the shaft can load materials into a muck box for hoisting from the shaft with a crane.

Based on the geological and geotechnical investigations (GDR) conducted, the water table is below the thin soil layer and groundwater encountered in the soil section is perched, localized pockets of minor quantity. Accordingly, any water encountered in the soils layer during shaft construction may be removed with the use of dewatering pumps and directed out of the shaft to the surface for treatment and disposal.

Drill and blast (D&B) is the most common shaft excavation method in rock. Shaft deepening is carried out in a series of vertical lifts or rounds. The shot rock is removed and ground support is installed as necessary for each lift. Use of the D&B method in the Edwards formation may require a variance from the Austin Land Development Code (ALDC). The

D&B is the most cost-effective and flexible method of shaft construction in rock while it is also possible to utilize hoe rams or roadheaders.

7.0 Environmental Commissioning Plan BMPs

The following best management practices (BMPs) will be used around the surrounding areas at the shaft sites to protect the environment and specific features such as caves, karst features, springs, and nature preserves:

- Protection by Distance
- Field investigations
- Mitigation Plan Development
- Contract Specifications
- Monitoring and Mitigation During Construction
- Contingency Plan

Other BMPs for storm water quality management including soil erosion and sedimentation controls will be implemented and checked throughout the construction and operational phases to protect karst and related recharge zones. Strategies such as routing runoff water from roads and parking areas away from karst feature catchment areas; limiting activities that disturb the natural vegetation within catchment areas; and restricting the use of pesticides, herbicides, fertilizers, and other potentially harmful substances should be used to protect recharge features.

Kurkjian Engineering Corporation, a subconsultant to Black & Veatch and a firm qualified in erosion and sediment control, is designing the BMPs. Baer Engineering and Environmental, Inc., a subconsultant to Black & Veatch, will prepare the Stormwater Pollution Prevention Plan (SW3P). The contractor will have a Certified Erosion Sediment Stormwater Inspector (CESSWI) or Certified Professional in Erosion and Sedimentation Control (CPESC) perform weekly inspections and within 24 hours after 0.5-inch (or greater) rain events.

The final Environmental Commissioning Plan (ECP) dated September 2010, states that a qualified geologist be on site at all times during construction for classification of karst features if encountered. The evaluation of voids for karst habitat is only pertinent at the WTP4 and JR shaft sites. Based on discussions from the January 2011 meetings and subsequent discussions, the following was decided to minimize environmental impacts from the shaft construction (as summarized in the Environmental Commissioning Consensus document):

- At the WTP4 shaft, a contractor geologist will be on-call for evaluation of karst voids (if encountered) for potential invertebrate habitat for compliance with the Comanche Canyon Section 10(a) permit. A City staff geologist will be on-call for evaluation of karst for groundwater flow or mitigation per City code.
- At the Four Points Area shaft, a City staff geologist or geologist's representative will visit the site after each lift is excavated (likely daily) to examine the exposed rock face for voids and possible groundwater flow zones to determine whether placement of permeable rings is warranted. An estimated maximum of five rings will be placed as the shaft is extended downward.
- At the PARD shaft, no geologist should be required.
- At the JR shaft, a contractor geologist will be on-call for evaluation of karst voids (if encountered) for potential invertebrate habitat for compliance with the TCEQ regulations for protection of the Edwards aquifer.

The contractor will be responsible for notifying the Environmental Compliance Manager (ECM) when voids are encountered. The ECM will notify USFWS and the CMAR's subcontractor (Zara) will look at the feature to determine whether or not it warrants biological investigation (baiting). Zara will prepare a report to submit to USFWS whether it requires baiting or not. The ECM will send the report to USFWS for their concurrence with the results. This determination will direct the proper mitigation effort.

The project specifications will include a section on void mitigation protocol that the contractor will be obligated to follow: Comanche Canyon 10(a) for WTP4 shaft site; City of Austin Environmental Criteria Manual (ECM) requirements of Section 1.12 Void and Water Flow Mitigation; and Standard Specification Item No. 658S Void and Water Flow Mitigation for the PARD site, and; the TCEQ Edwards Aquifer Protection Program for the JR shaft site. The specifications will also reflect additional criteria developed through the EC process as summarized in the Environmental Commissioning Consensus document.

The qualified geologist must be a Professional Geoscientist (P.G.) licensed under the Geology discipline by the Texas board of Professional Geoscientists (Title 22, Part 39, Chapter 850.1) and have documented local geologic and karst experience.

8.0 Karst Impact Mitigation Strategies During Shaft Excavations

The mitigation of the shaft excavation is completed in a step by step procedure with the assessment of the discovered void and the mitigation of the void encountered based on the site specific circumstances of its location, orientation, condition, and type.

Karst impact mitigation strategies for the JTM project include:

- Locate shafts as far as possible from known or suspected karst locations
- Keep tunnel vertical alignment in Glen Rose formation
- Implement applicable BMPs based on void with, or with evidence of, water flowing
- Follow through inspections, specifications, and action plans specified for construction
- Determine acceptable level of risks and prepare for contingency measures, i.e., prepare and implement contingency plan to further protect and restore karsts encountered. Refer to TM No. 2 Excavation Methods Study for additional information.

8.1 Void Assessment

The first step in karst impact mitigation is an assessment of voids encountered during investigations and construction. These criteria vary by shaft site. Generally, this information applies to one of three conditions for the reportable finding of a void during the investigation or construction and the related subsequent mitigation actions:

1. Void is greater than one square foot in total area, or
2. Void blows air from within the substrate, and/or
3. Void consistently receives water during any rain event.

If a void is encountered during construction and meets one of the three criteria above, then the void is reported (reportable void) by the on-site qualified geologist who will review the find and make an assessment for potential environmental impacts. In this manner, construction downtime (related to the WPD inspection and decision-making) is minimized. Note that the WTP4 shaft has additional USFWS requirements.

If a void contains filling; or is partially filled by leaf litter, modern soils, or other items that may be biologically significant; or airflow or channelized recharge of water; the void may be suitable for endangered karst habitat. In that case, a reconnaissance excavation by the geologist, will be used to determine whether invertebrate surveys should be conducted.

The voids will be generally characterized as one of three main types based on Section 1.12 of the ECM:

- Type I – void is less than 2 ft x 3 ft x 3 ft in volume and is hydrologically inactive.
- Type II – void is greater than 2 ft x 3 ft x 3 ft and is hydrologically active. Evidence includes water dripping from the ceiling or moving along the floor of the void or evidence of recent water flow but is an isolated feature lacking obvious connections to the water table, or a spring, or to other subsurface voids.

- Type III – void is greater than 2 ft x 3 ft x 3 ft and is hydrologically active and is probably connected to the water table or to a spring based on water quality, quantity, and movement observations.

The void terms used in this TM are based on the document SR-01-07 Karst Void Mitigation prepared by the COA Watershed Protection. The terms used in this TM are similar in meaning to the COA ECM.

8.2 Void Mitigation Process

If a reportable void is found during construction, the conditions will be documented in a report that will include the following:

- Description of the void
- Photographs of the void
- Sketches of the void, if helpful
- Maps or sketches of the void dimensions,
- Site plan showing underground expression, location, orientation, and footprint of the void, and
- Updated site plan drawing and cross section to document the location of the void(s) and the mitigation measure(s) used.

Based upon the results of the rock core borings in the Edwards formation that have been conducted on the project, the rock coring logs suggest that voids will likely be encountered during excavation at three of the four shafts for the project:

- Shaft W-1 (Four Points area)
- Shaft W-2 (JR site), and
- Shaft R-1 (WTP4 site)

Based on the rock core log descriptions of the rock in boring JT-120 and the fact that the bedrock portion of Shaft R-2 (PARD site) will be founded entirely in the Glen Rose formation, it is not anticipated that there will be any reportable voids during excavation of the shaft at this location.

8.3 Mitigation During Construction

Several approaches to void mitigation were discussed during the workshop on August 23, 2010 and the subsequent meetings in January 2011. The preliminary approach discussed in Section 8.3.1 was modified by the EC discussions held in 2011 and subsequent changes resulting from the Value Engineering (VE) Study. The final mitigation approach is summarized in Section 8.3.2.

8.3.1 Preliminary Mitigation Approach

From the discussions held during the workshop on August 23, 2010, a preliminary mitigation approach was developed. The entire length of the shaft in the Edwards and Walnut formations was required to be water-tight and lined with gasketed steel liner plates and steel ring beams as shown in the attached Figure TM9-1, or an equal system as approved by the Owner.

The cost of delays that result from determining whether a void in a shaft excavation is karst invertebrate habitat can be significant. Additionally, significant construction schedule delays associated with the karst invertebrate studies can be expected. Consequently, the design team will assume that Type II and Type III voids encountered in shaft excavations are karst invertebrate habitat and specify mitigation measures based on the void assessment and agreement with the onsite geologist who will still have to determine whether a void is hydrologically active.

From geologic literature and rock core borings to date, it is not anticipated that the Walnut formation is karst invertebrate habitat in the project area. However, the design will assume that the Walnut formation is potentially karst invertebrate habitat and will also specify mitigation measures to be in place accordingly. For sections of the shaft in the Edwards and Walnut formations that do not have voids according to the on-site and qualified geologist, the annular space will be backfilled with cementitious grout. As the Glen Rose formation is not recognized as karst invertebrate habitat in this area, no specific measures are required for mitigation in this formation.

8.3.2 Final Mitigation Approach

From the discussions held in 2011, the following final mitigation approach was developed:

1. To better protect karst features that are encountered in the shafts, protection will be included to prevent grout migration into significant voids regardless of the presence of water. Examples of acceptable protection include sandbags and geotextile fabric.

2. To prevent groundwater intrusion into the excavated shaft at elevations with environmentally significant groundwater flow as defined by best professional judgment of certified geologist on site, or where groundwater volume might interfere with construction, the proposed method for most shafts is to progressively install gasketed steel liner plates (within tolerance) around the circumference of the shaft

with impermeable grout filling the annular space between the gasketed liner plate and the wall of the shaft.

3. To preserve water flow pathways in sensitive Edwards karst formations, permeable rings will be created behind the steel plates (with no HDPE piping) at probable groundwater flow horizons as determined by the EC Team. Each ring will be filled with a maximum 1-inch sized crushed and washed limestone, with a less permeable layer above and below the gravel creating a conduit for water to flow around the perimeter of the shaft from one side to the other. This less permeable layer may be constructed from compacted clay and geosynthetic clay liner material or controlled low strength material (CLSM).

4. Placement of the gasketed liner plates and permeable rings will vary by shaft as described below.

   - WTP4 Shaft: The shaft will be designed with gasketed liner plates extending from the surface to below the Edwards/Walnut contact and with a single permeable ring at the Edwards/Walnut formation contact.
   - Four Points Area Shaft: This shaft will be designed with gasketed liner plates extending from the ground surface to below the Walnut/Glen Rose contact, and with an estimated maximum of five permeable rings at all horizons where significant groundwater flowpaths and/or indication of groundwater flowpaths are found, as determined by best professional judgment of certified geologist on site.
   - PARD Shaft: To limit inflow into the shaft, the fill will be excavated and the shaft design through the fill will consist of gasketed liner plates with grout placed behind the plates. Prior to excavation into the Glen Rose formation, the undisturbed rock will be pre-grouted at least 70 feet from the ground surface. This will address both constructability and environmental concerns. There are no permeable rings anticipated for the construction of this shaft.
   - JR Shaft: To preserve existing flow at the most likely groundwater flow horizons the shaft will be designed with gasketed liner plates from the surface to below the Edwards/Walnut contact. Permeable rings will be installed at the contact of the Edwards and Walnut formations and at the Edwards/ Comanche Peak formation contact for a total of two permeable rings.

Based on the results of the VE Study, the COA directed Black & Veatch to eliminate the permanent reinforced concrete liners in the Four Points Area and PARD shafts. In addition, the study recommended the following modifications:

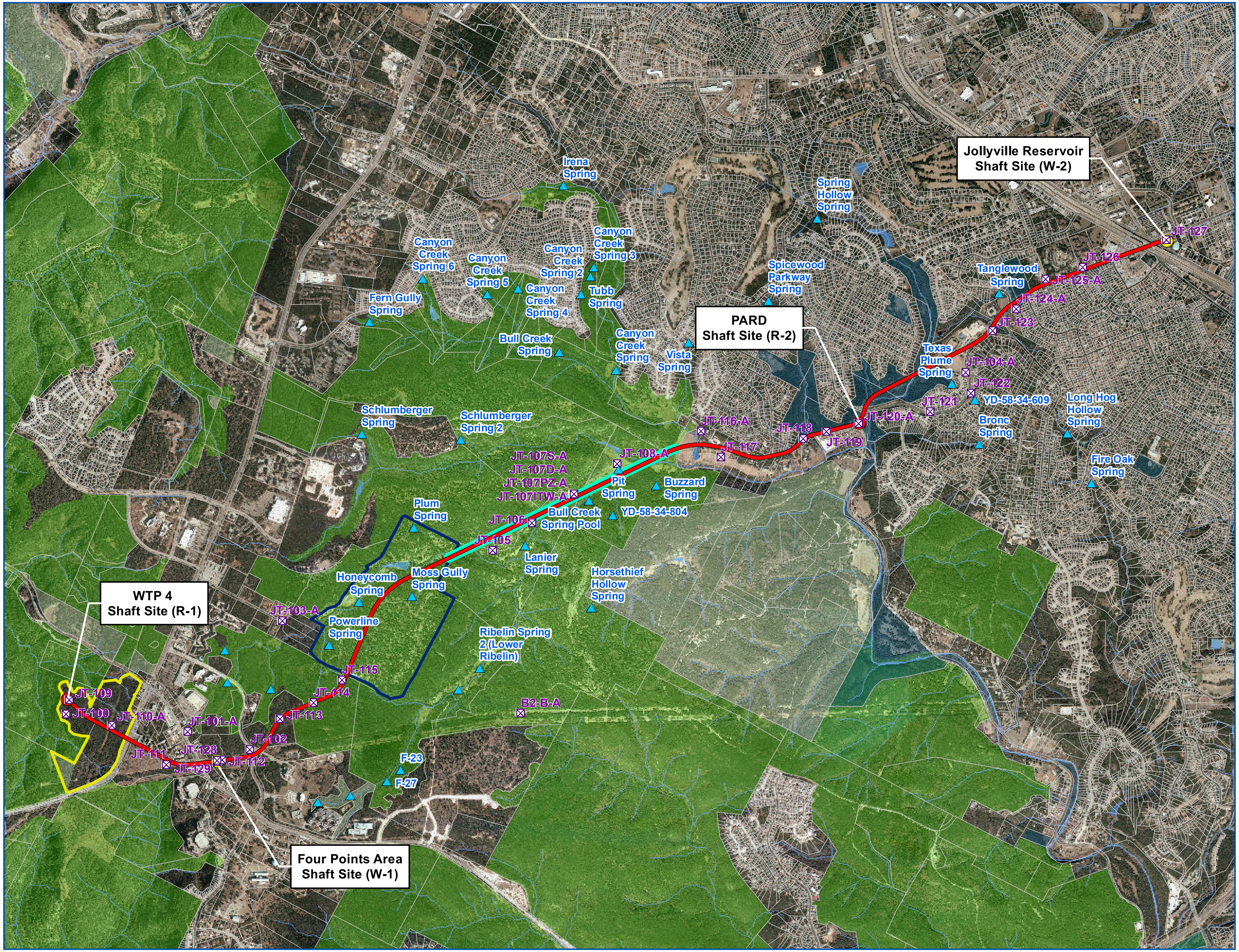
- The Four Points Area shaft will now be backfilled without a permanent access structure for maintenance. The contractor will be given the option of backfilling the shaft excavation (between the permeable rings and low permeable layers described above) with compacted tunnel spoils, compacted rock (ASTM C33, No. 57), or controlled low strength material.
- Future access to the tunnel at the PARD shaft will be accomplished by installation of 12-ft diameter pre-cast reinforced concrete sections of ASTM C76 pipe. The backfill options around the pipe will the same as those described above for the Four Points Area shaft excavation.

Refer to TM No. 3 (Shaft and Tunnel Liner Design) for additional information related to the shaft design. The final mitigation approach will be included in the Contract Documents.

9.0 Conclusions and Basis of Design

Black & Veatch will develop the Contract Documents and geotechnical baseline parameters for karst avoidance and impact mitigation consistent with strategies and processes outlined in this TM, the Environmental Commissioning Consensus document, and subsequent meetings.

The City's comments on the documents, including TMs, Contract Drawings and Specifications and geotechnical baseline parameters will be addressed in the final Basis of Design Report and the final Contract Documents.



City of Austin, Texas

Water Treatment Plant 4

Jollyville Transmission Main

March 04, 2011

LEGEND

- Monitoring Springs
- Retrieval Shafts
- Working Shafts
- Boreholes
- Proposed Alignment
- Infrastructure Corridor
- Reservoir and WTP 4
- Old WTP 4 Site
- BCP
- Potential Future BCP
- City of Austin Parks
- Creeks
- Water
- ROW/Property Lines

N W E S

0 1,250 2,500

Feet

1 inch = 2,500 feet

Figure 1

Proposed Horizontal Alignment

Austin Water

WTP 4 Water Treatment Plant 4

Data source: BV, City of Austin, CAPCOG, ESRI

Figure 2
Jollyville Transmission Main
Proposed Vertical Alignment

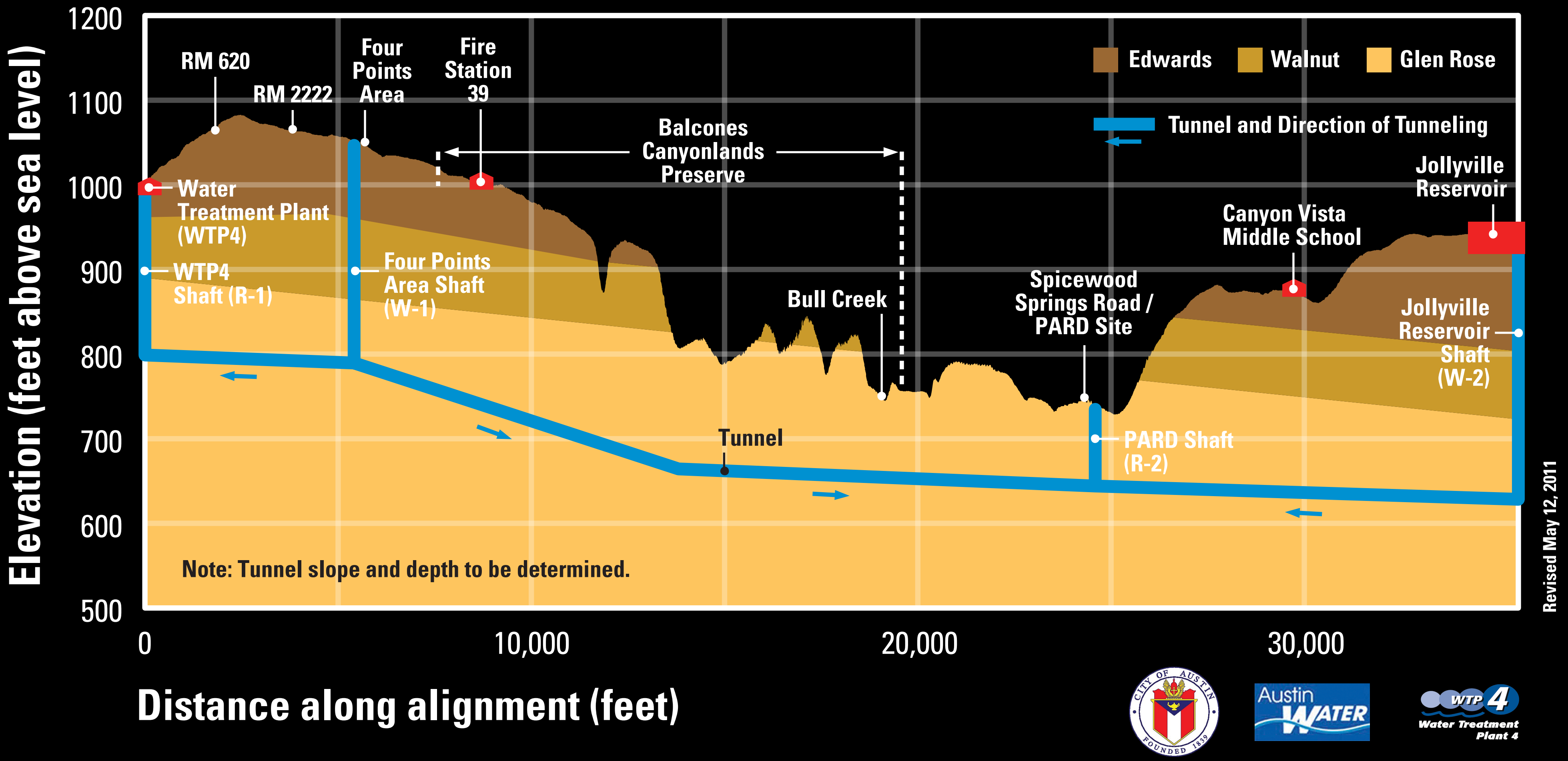
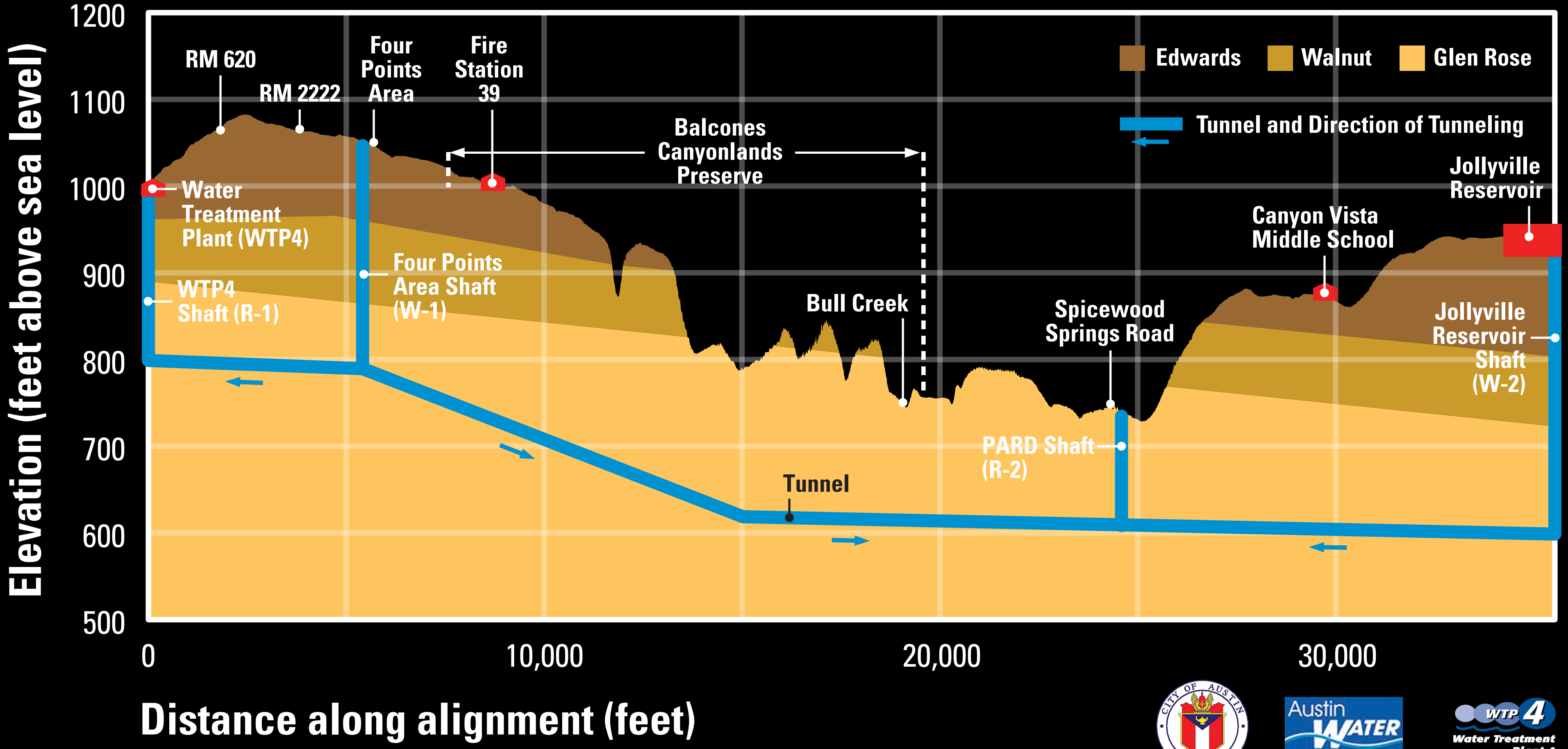


Figure 3
Jollyville Transmission Main
Final Tunnel Profile



Revised May 12, 2011

APPENDIX A

ENVIRONMENTAL COMMISSIONING WORKSHOP

KARST IMPACT AND GROUNDWATER INFLOW MITIGATION STRATEGIES

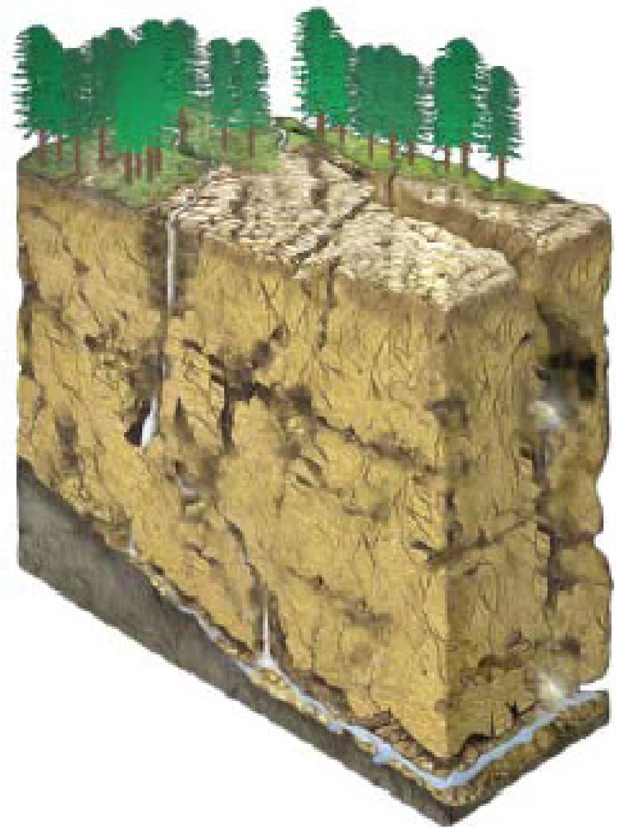
REVIEW FOR SHAFT AND TUNNEL CONSTRUCTION

BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH







Jollyville Transmission Main Karst Impact Mitigation and Tunnel Groundwater Inflow Management Workshop

August 23, 2010

Austin WATER

CITY OF AUSTIN FOUNDED 1839

WTP 4 Water Treatment Plant 4

DRAFT

Objectives of Workshop:

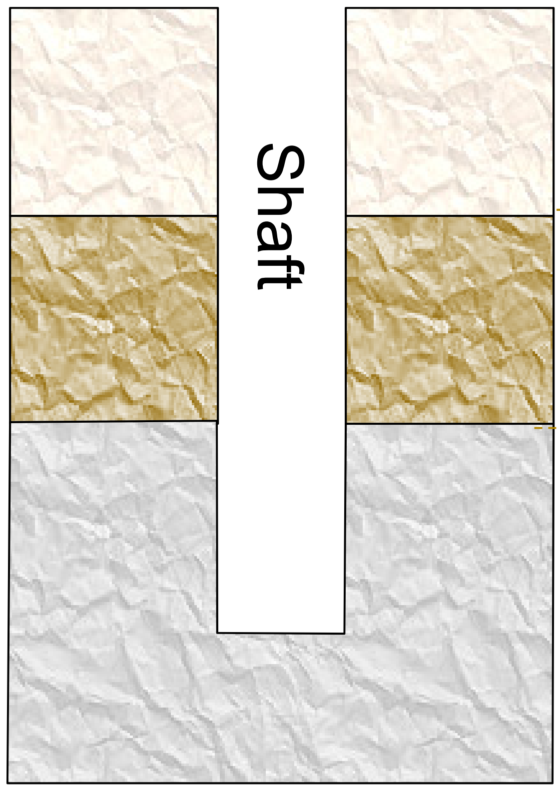
- Produce biddable and constructible contract documents while:
  - Protecting Springs and the Jollyville Plateau Salamander
  - Protecting cave invertebrates
  - Protecting Bull Creek and its tributaries
  - Protecting flora
  - Protecting groundwater resources

Purpose of Workshop

1. Understand how the geology and hydrogeology may impact springs, groundwater, cave life and surface water
2. Understand which regulatory agencies are involved, their restrictions, and permitting requirements
3. Understand the strategies for mitigating impacts
4. Discuss BMPs for mitigating impacts during shaft and tunnel construction
5. Discuss contracting strategies to ensure mitigation measures are taken into account, costs understood, and risk are appropriately shared between contractor and the owner

Shaft Geology

Ground Surface



Soil – very thin veneer (<5 ft), not shown

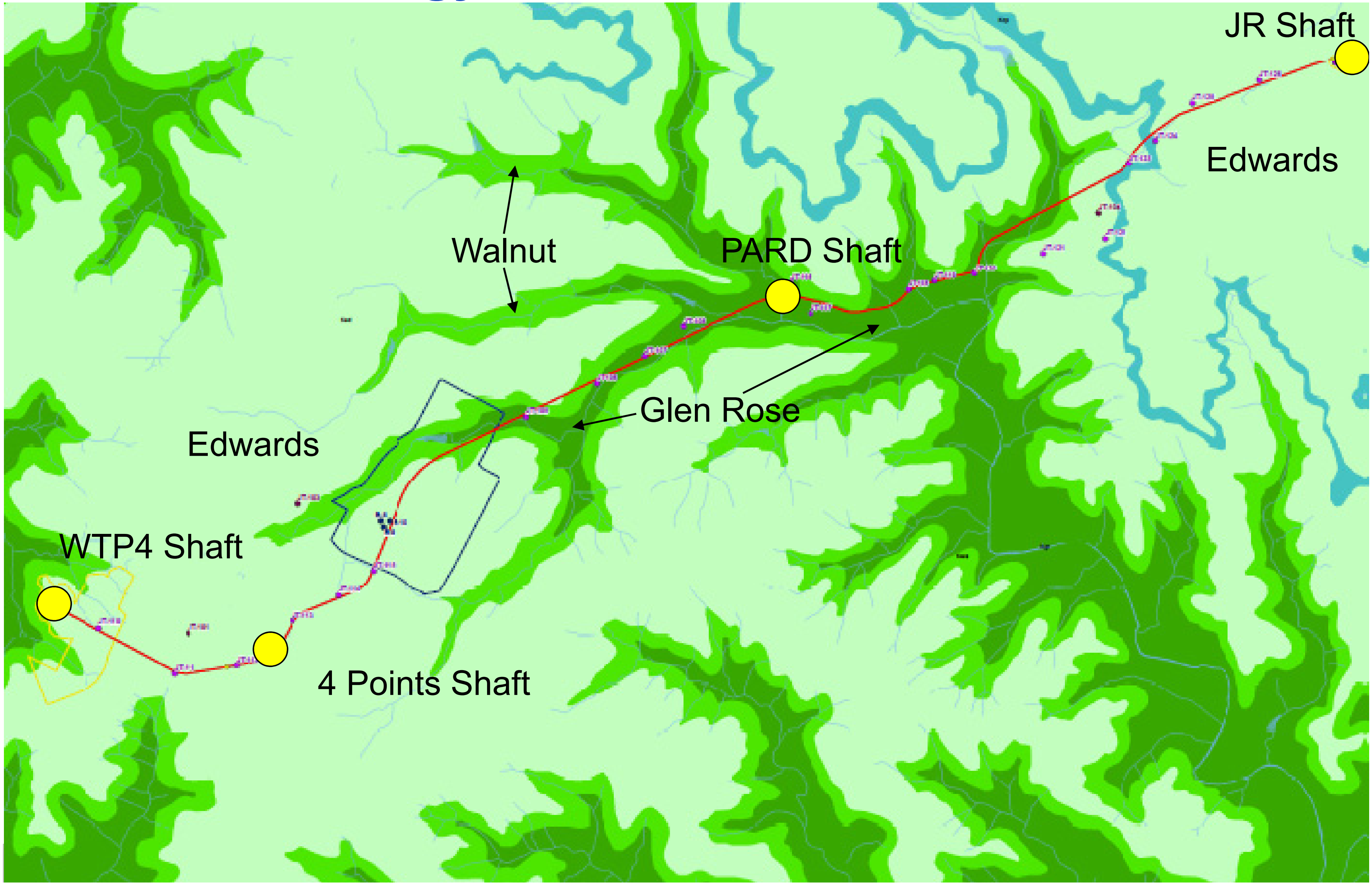
Edwards Formation – limestone and dolomite, karst features common

Walnut Formation – limestone and argillaceous limestone, extremely low hydraulic conductivity

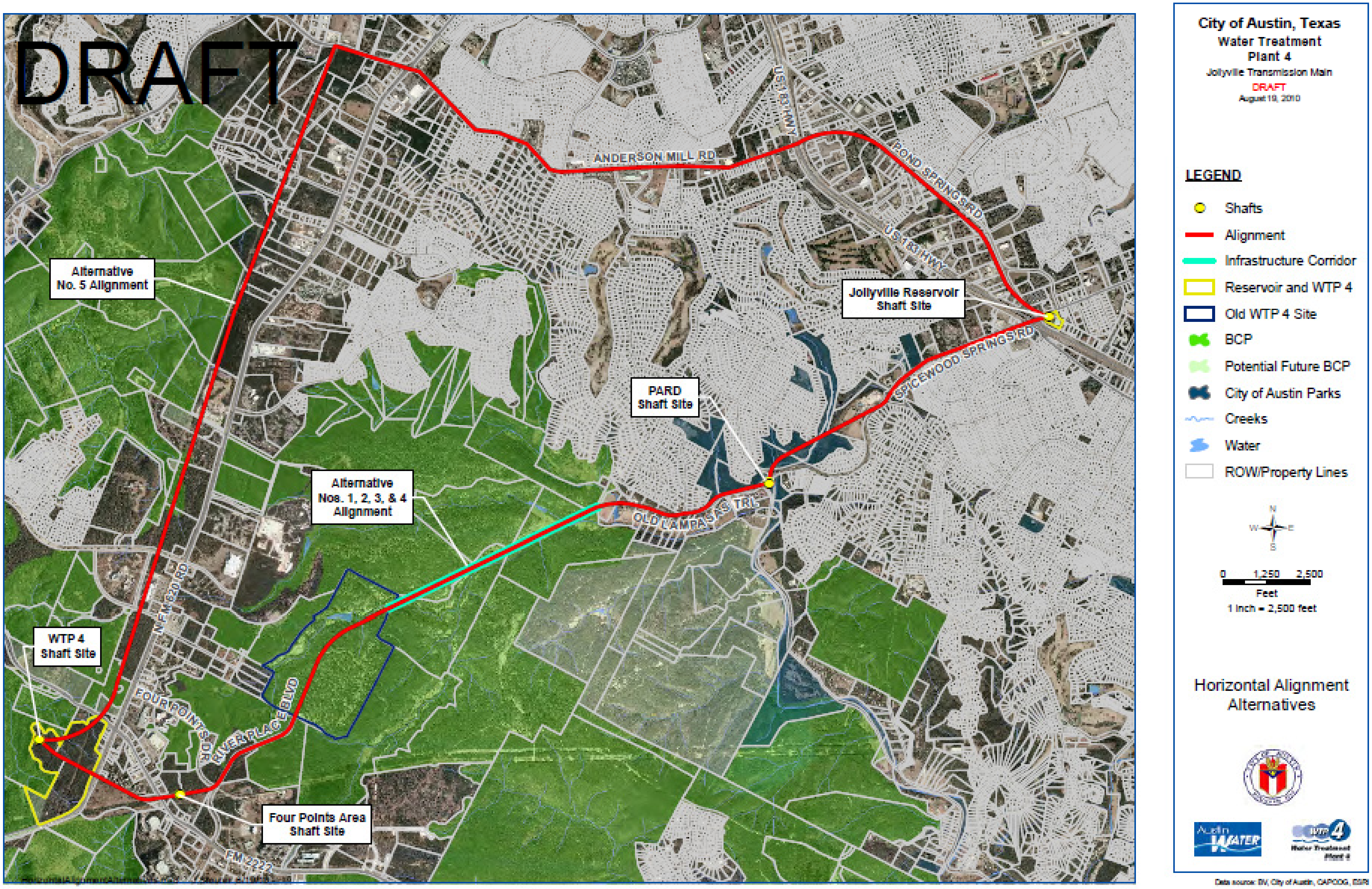
Glen Rose Formation – interbedded dolomite and limestone, vugs common, occasional zones of moderate to high hydraulic conductivity

Sketch is representative of the WTP4, Four Points and Jollyville Reservoir Shafts. The PARD shaft, begins in the Glen Rose.

Surface Geology



JTM Tunnel Alignment



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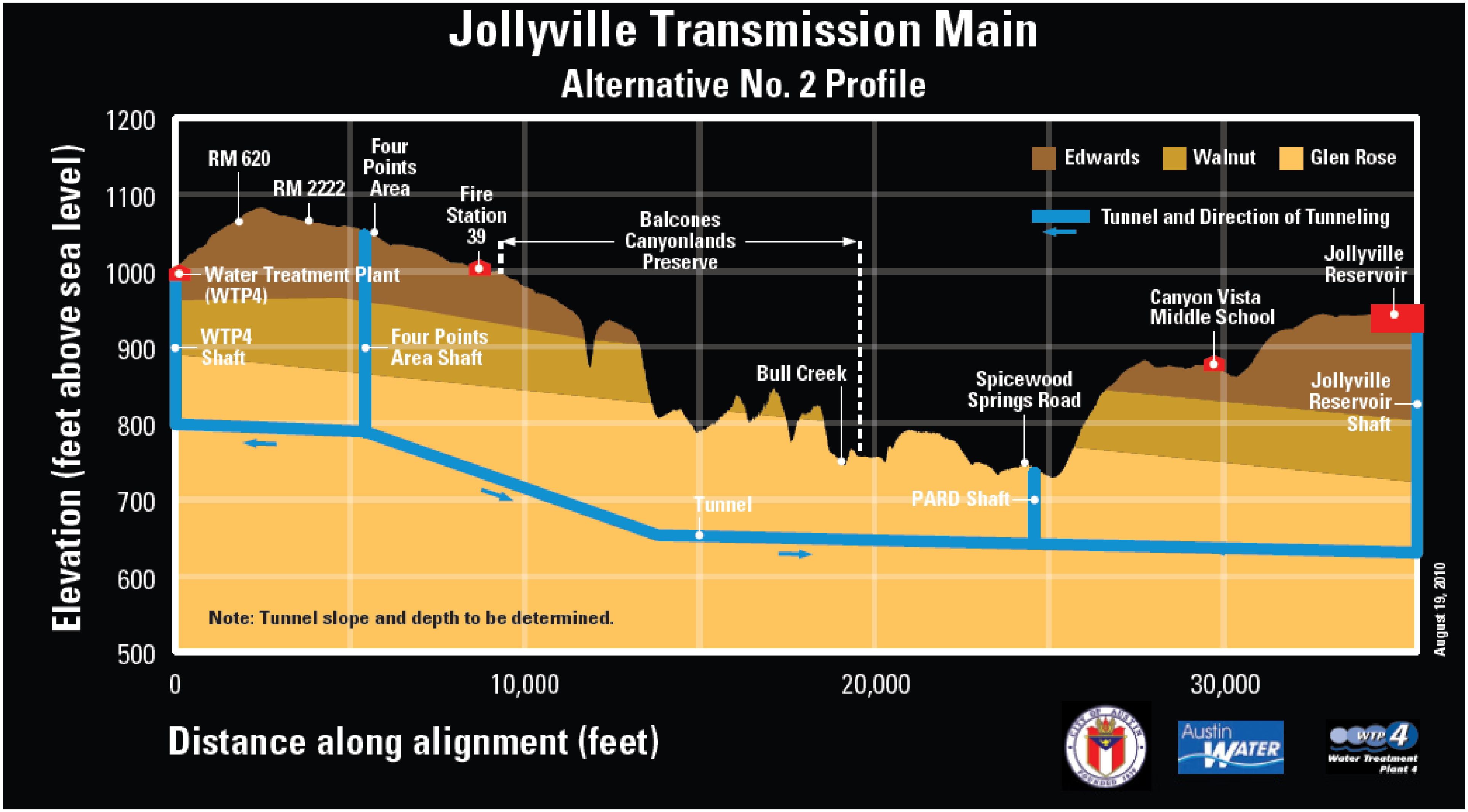
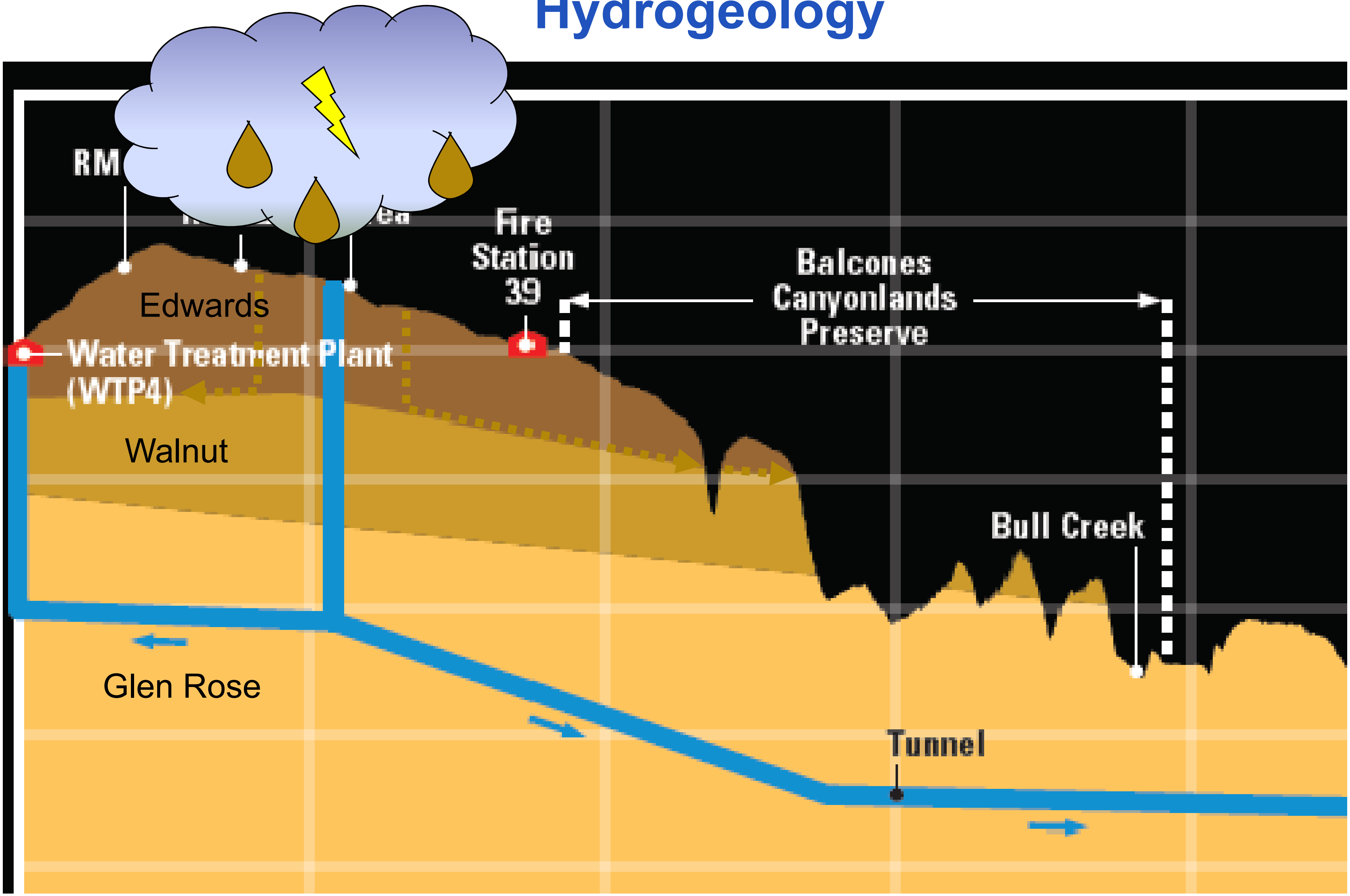
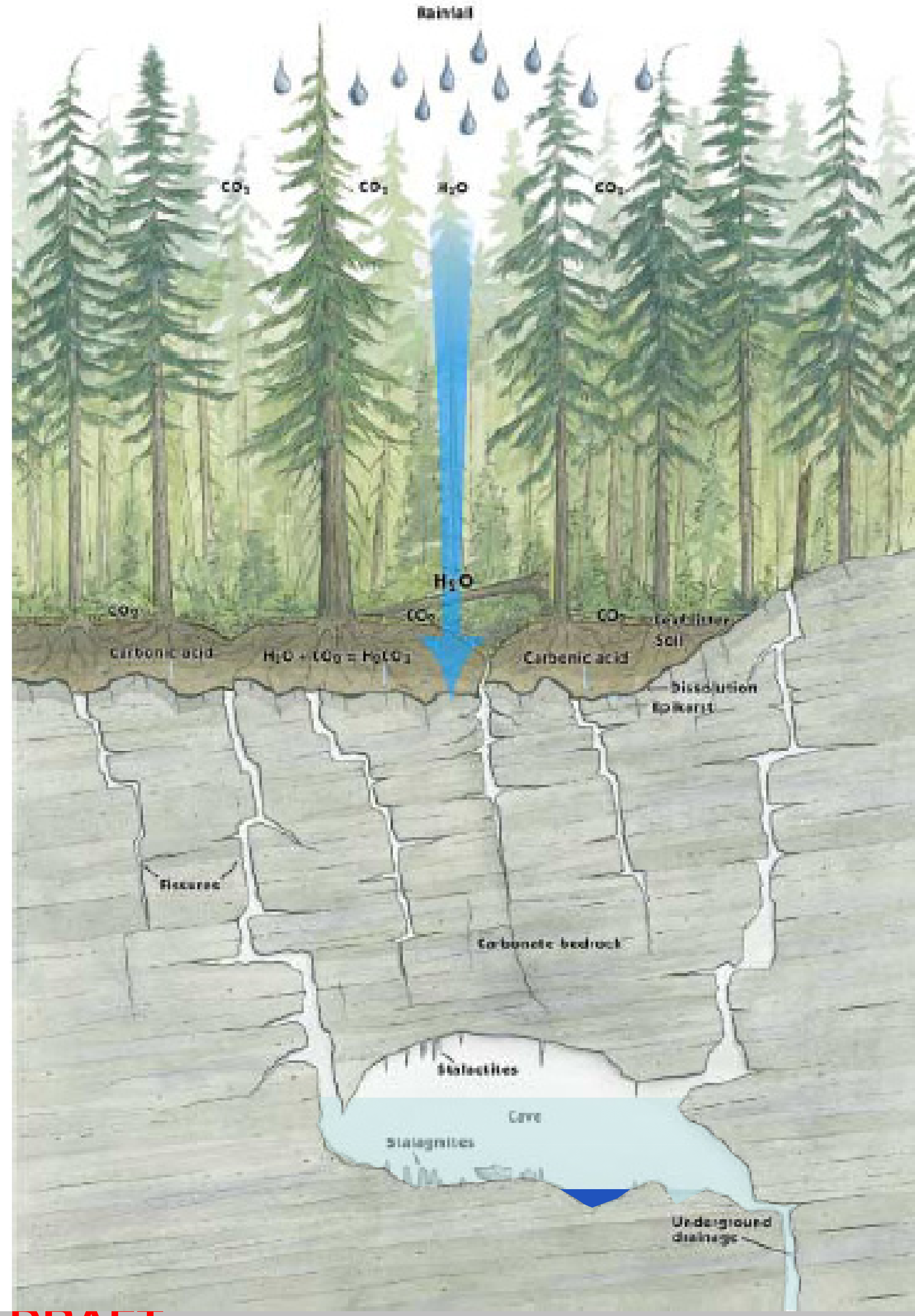
JTM Tunnel Profile (Alternative 2)



Hydrogeology



Water Movement Through Karst



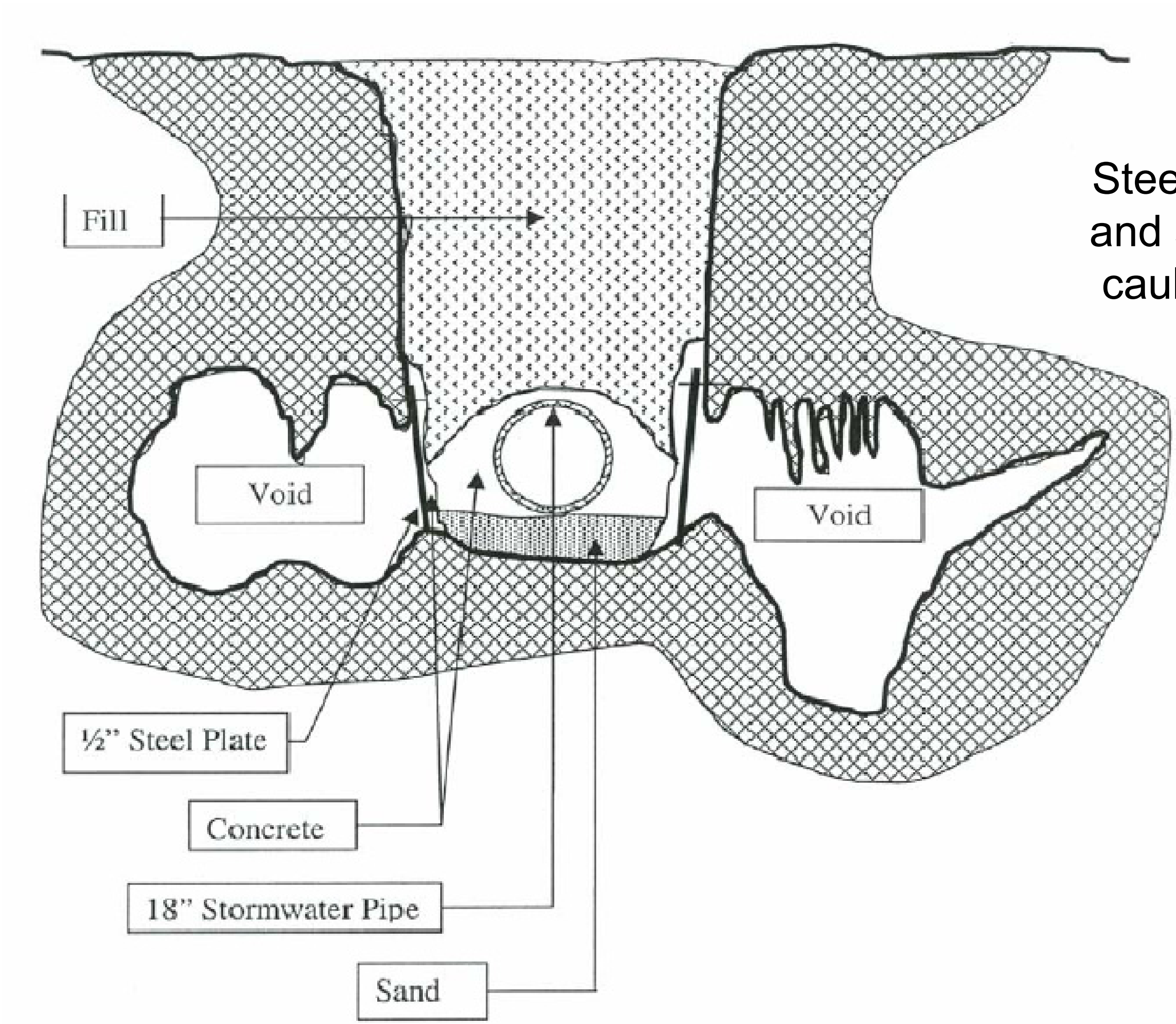
Regulatory Oversight

- City of Austin Watershed Protection Department
- Texas Commission on Environmental Quality (TCEQ)
- US Fish and Wildlife

Karst Void Characterization

- **Type 1**: <2 ft x 3 ft in volume and hydrologically inactive
- **Type 2**: >3 ft x 3 ft in volume and hydrologically active, but isolated and not connected to the water table
- **Type 3**: >2 ft x 3 ft in volume and hydrologically active and is probably connected to the water table or a spring

Four Points Fire Station

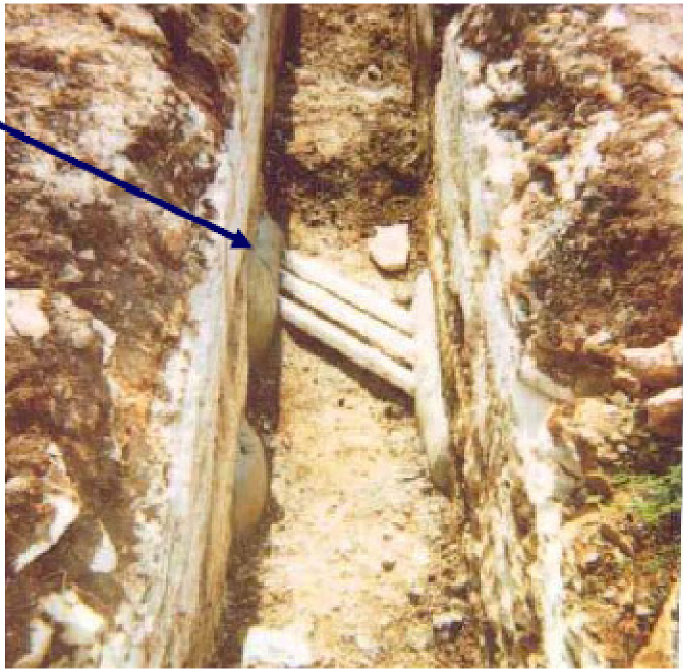


Type 2 Voids

Steel plates bolted to wall and sealed with grout and caulk, pipe encased with flowable fill

PVC pipe placed below natural gas pipeline to maintain hydrologic connection of void

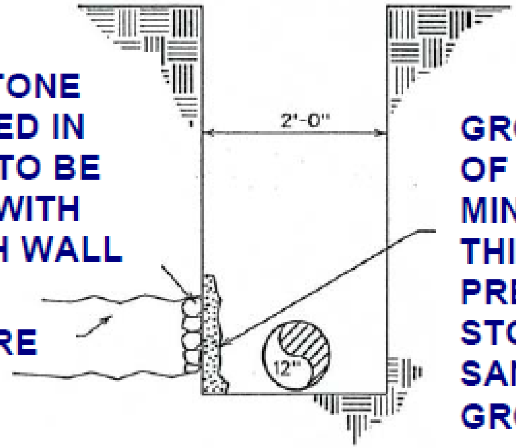
Void closure, Lonestar Gas Pipeline, Parmer Lane, Austin, Texas



Lone Star Gas Pipeline Parmer Lane

Type 3 Voids

Sealing cave entrances with rocks and grout; maintain air, water and fauna movement with PVC pipes if cave crossed trench excavation; encased pipeline in concrete



NOTE: GROUT SHALL BE 9 SACKS OF CEMENT PER CY MIX.

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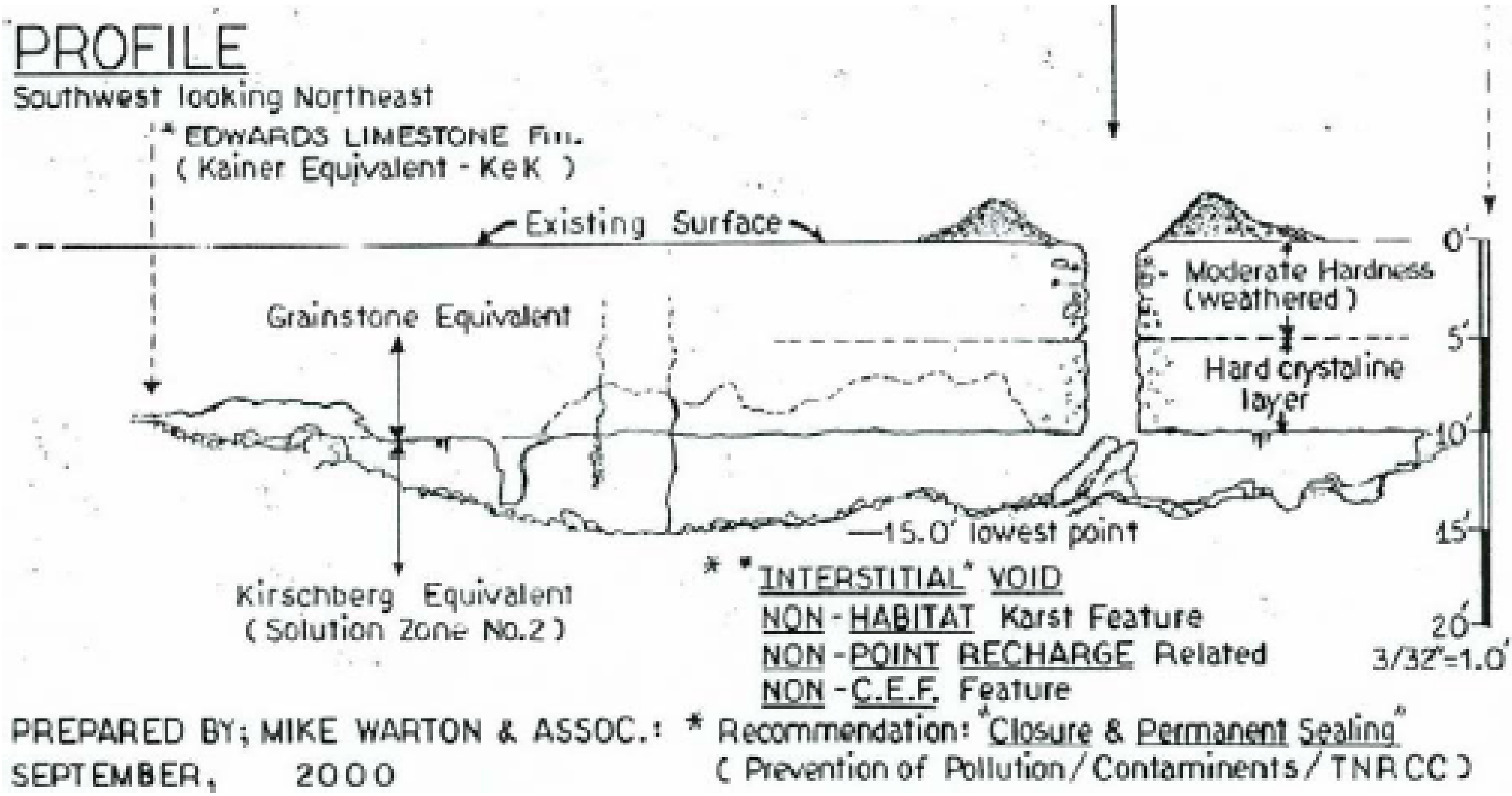
Lodge Cave Parmer Lane



Type 2 Void

1. Place 3-5 in dia rock to maintain water pathway between 2 sides of cave

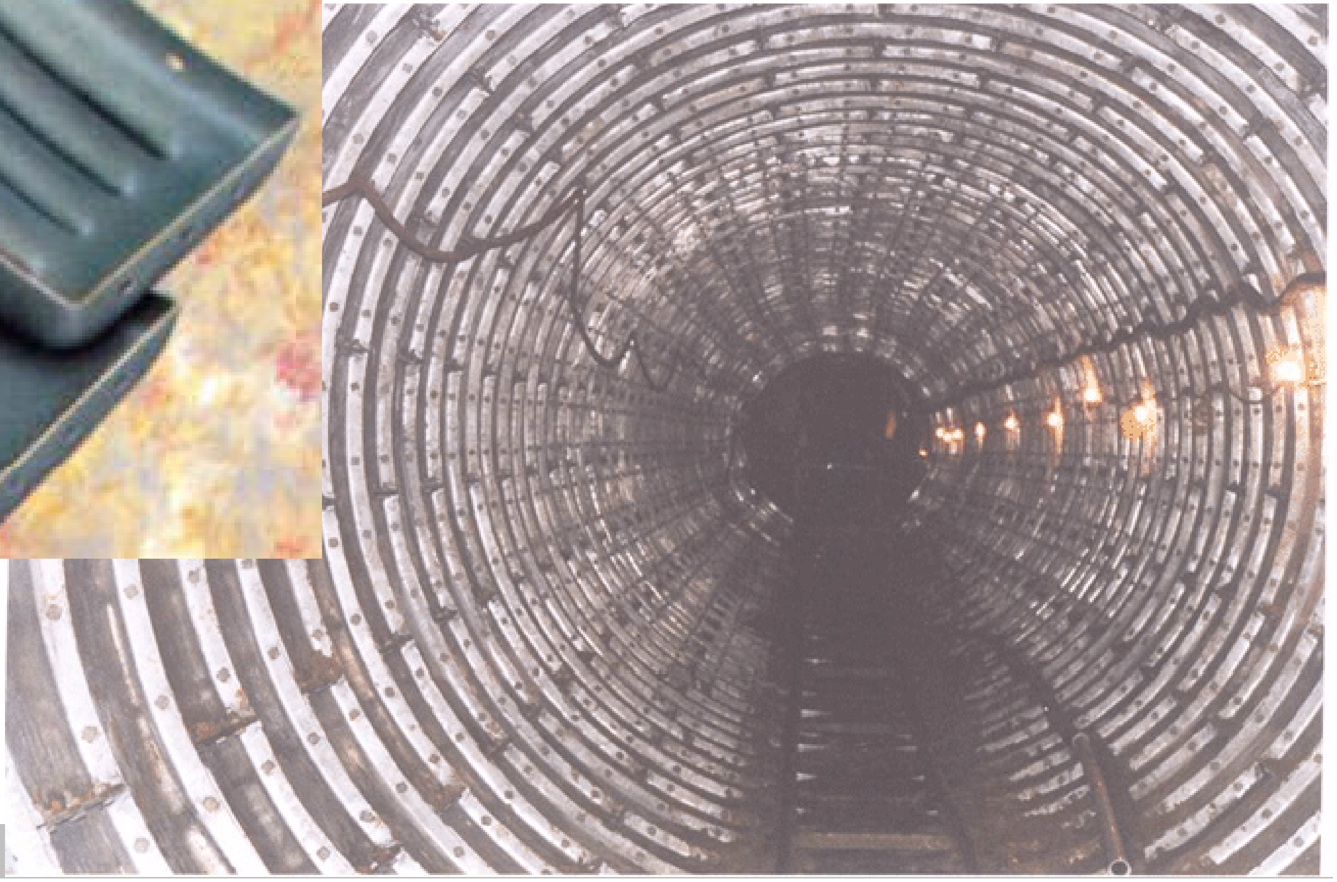
2. Place sandbags across remaining open cave entrance

3. Place grout seal between permeable rock fill and wastewater pipe that extends 5 ft above cave roof

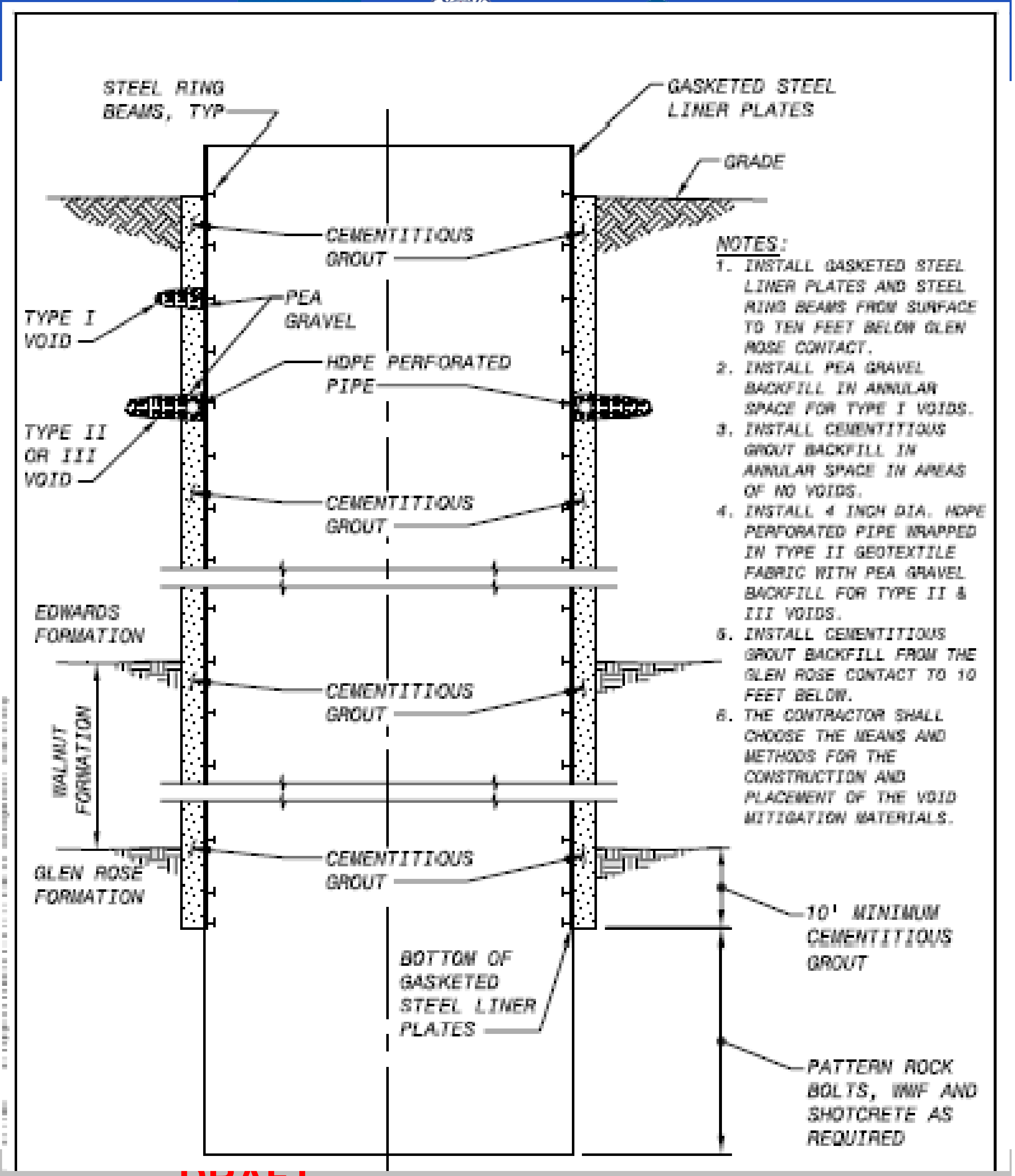
BMPs for Karst Mitigation

- Protection by Distance
- Investigations
- Mitigation Plan
- Contract Specifications
- Monitoring and Mitigation During Construction
- Contingency Plan

Liner Plates



Karst Mitigation in Shafts

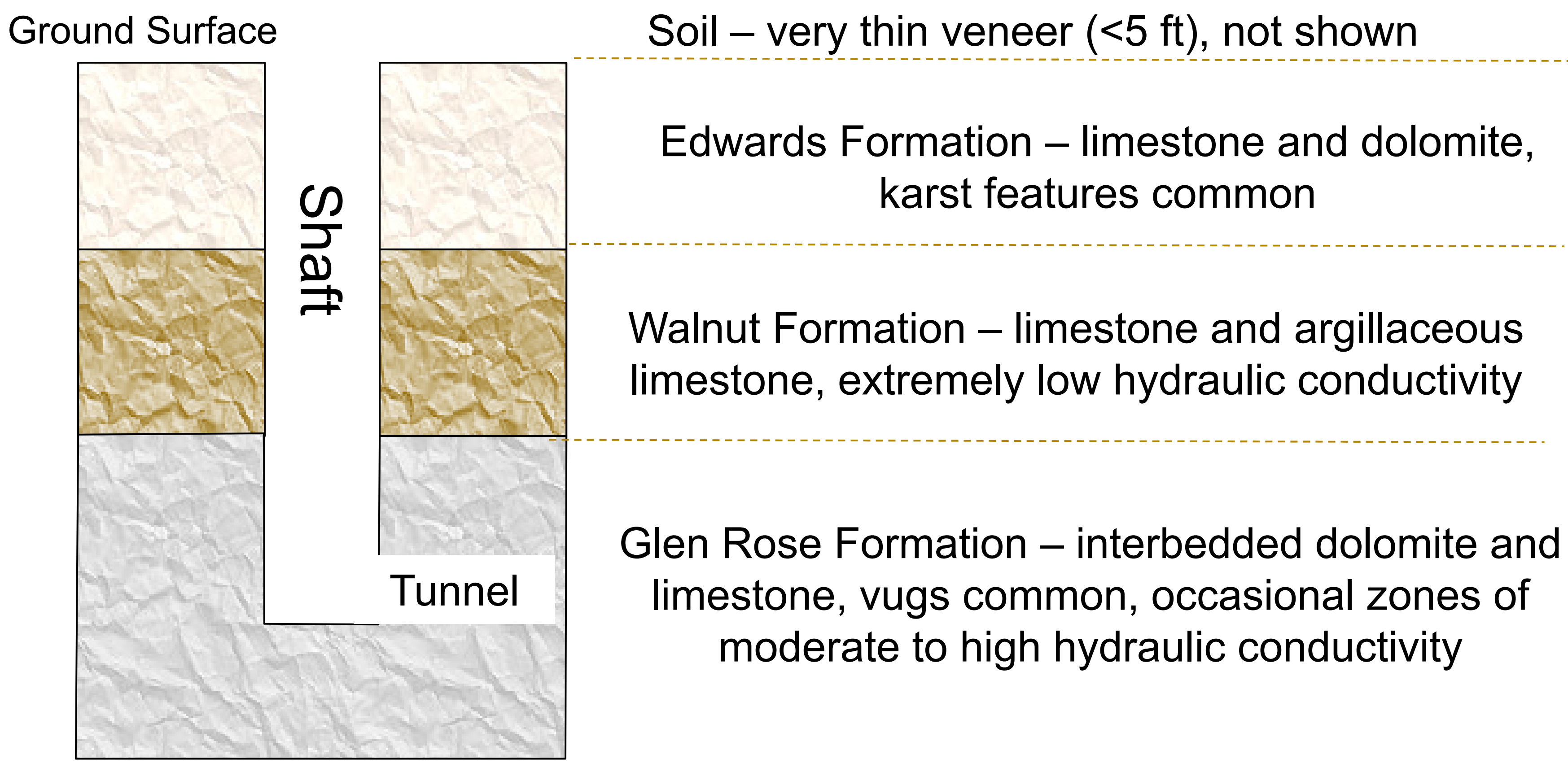


Notes (Shafts):

1. ..

Groundwater Inflow Management in Tunnels

Tunnel Geology



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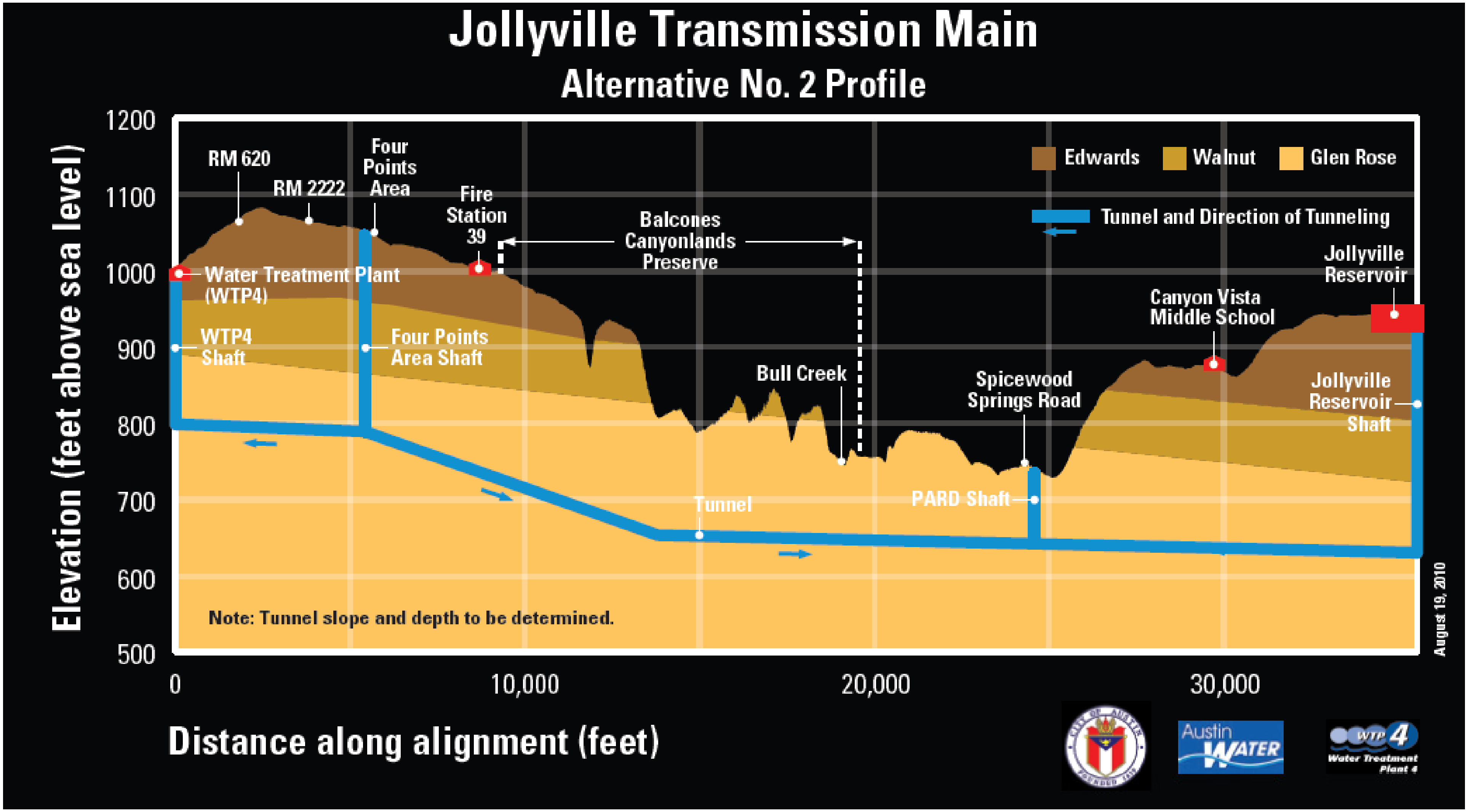
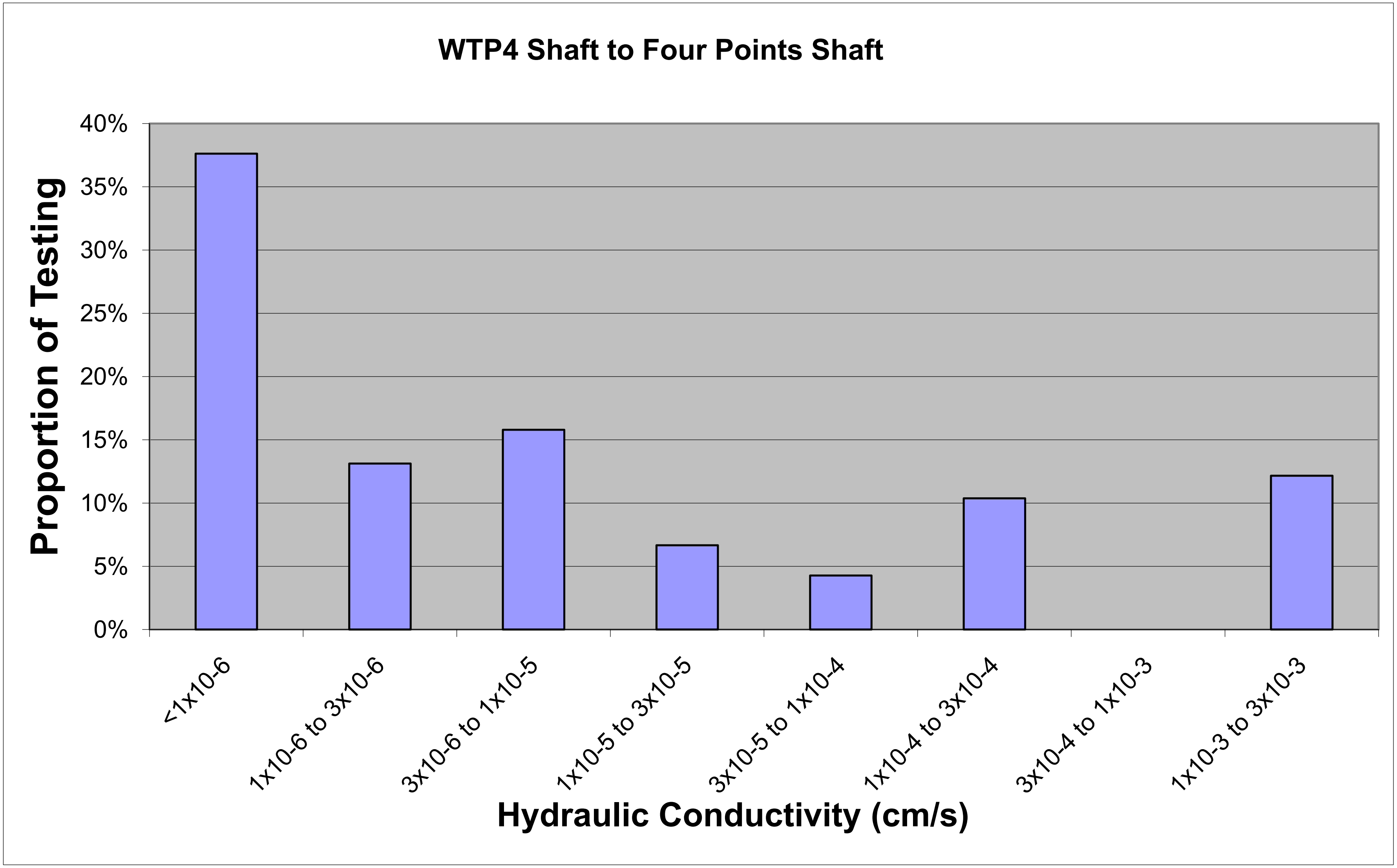
JTM Tunnel Profile (Alternative 2)



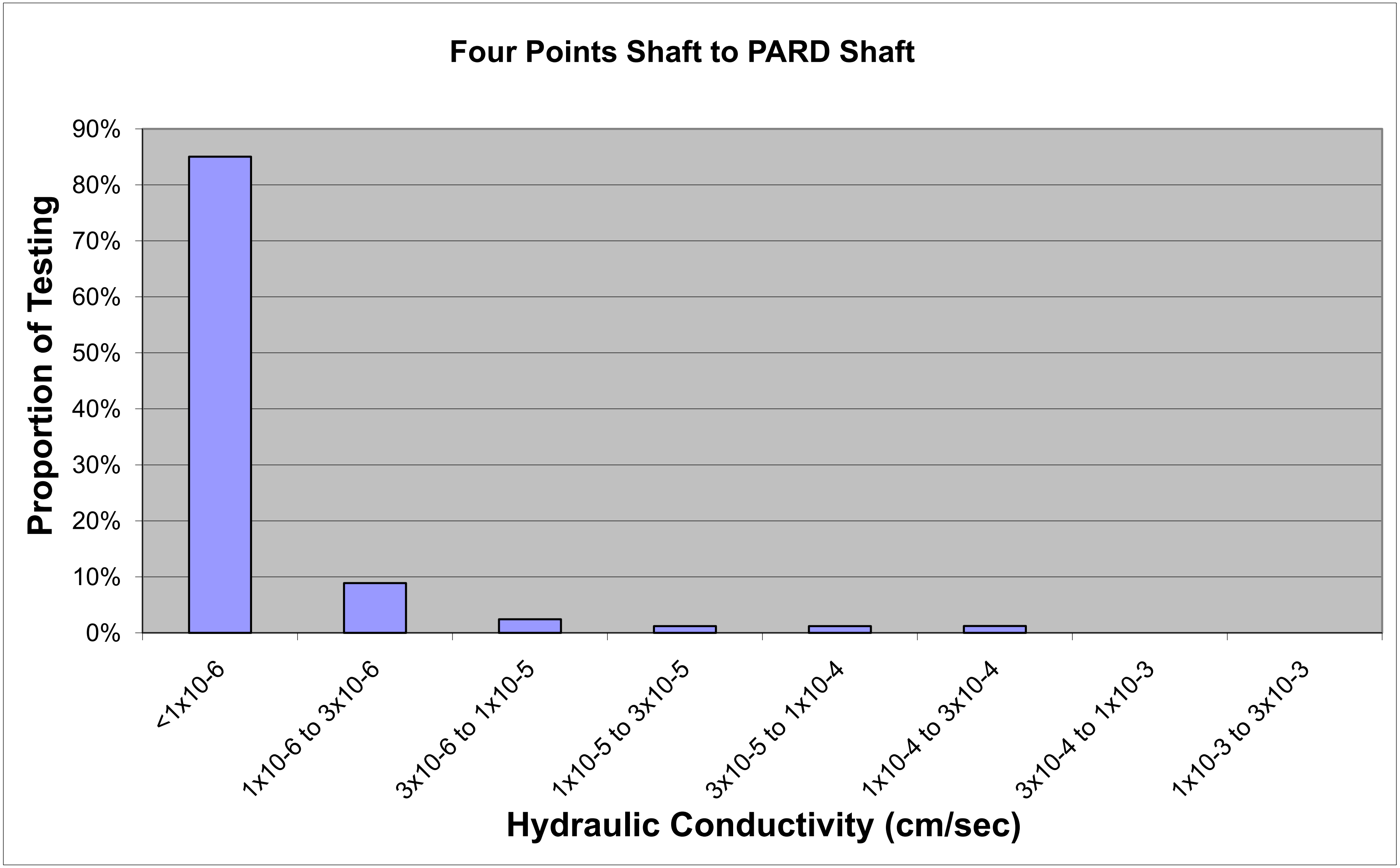
Groundwater Inflow Estimate and Handling

- Geology & Hydrogeology
- Field Investigations – Coring – Packer Testing, etc.
- Heuer's Method Using Packer Test Results
- Groundwater Modeling
- Tunnel Water Handling (Specs, GBR)

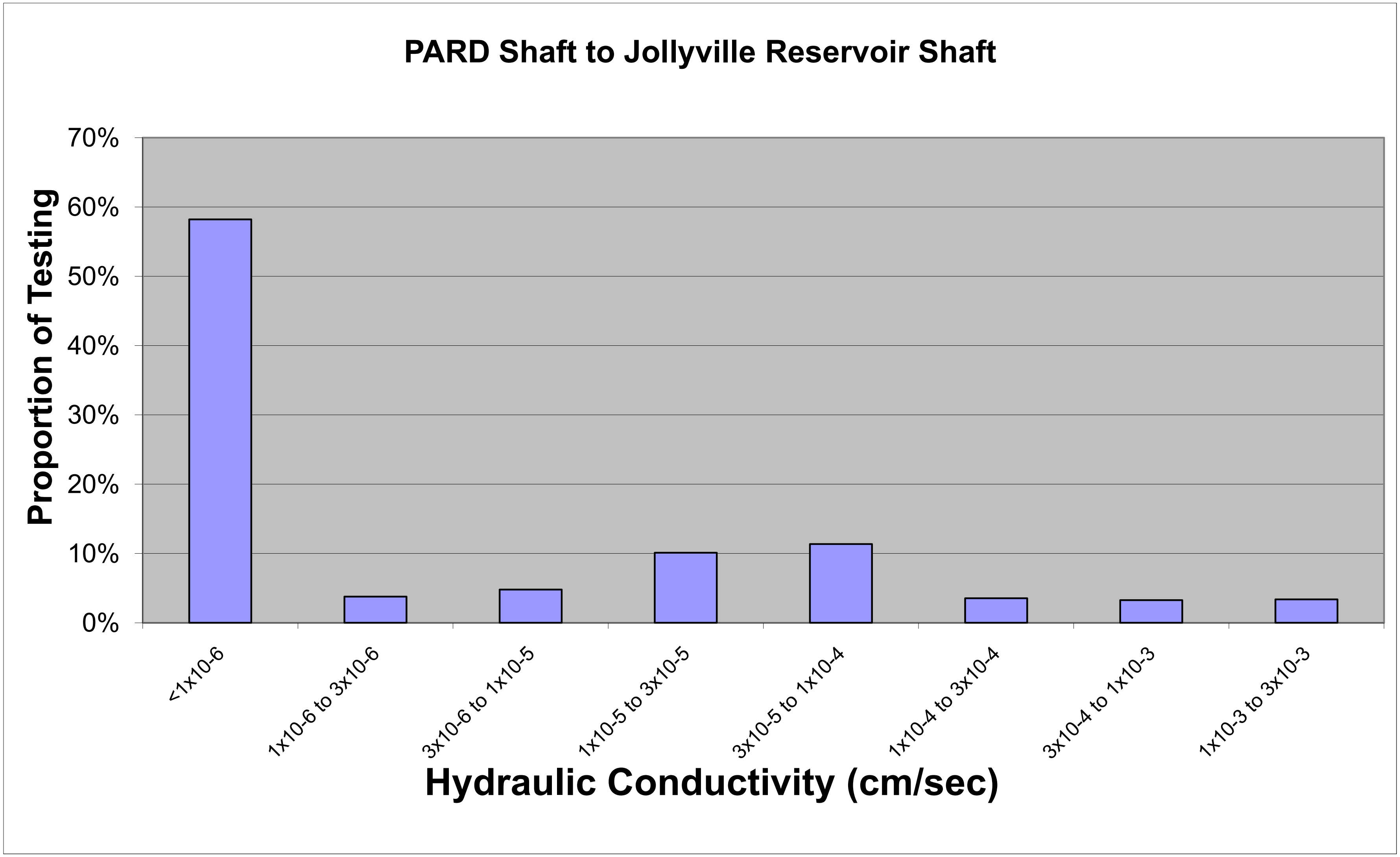
Packer Test Results - Preliminary



Packer Test Results - Preliminary



Packer Test Results - Preliminary



JT-109

Two 21 ft zones of $2x10^{-3}$ cm/s

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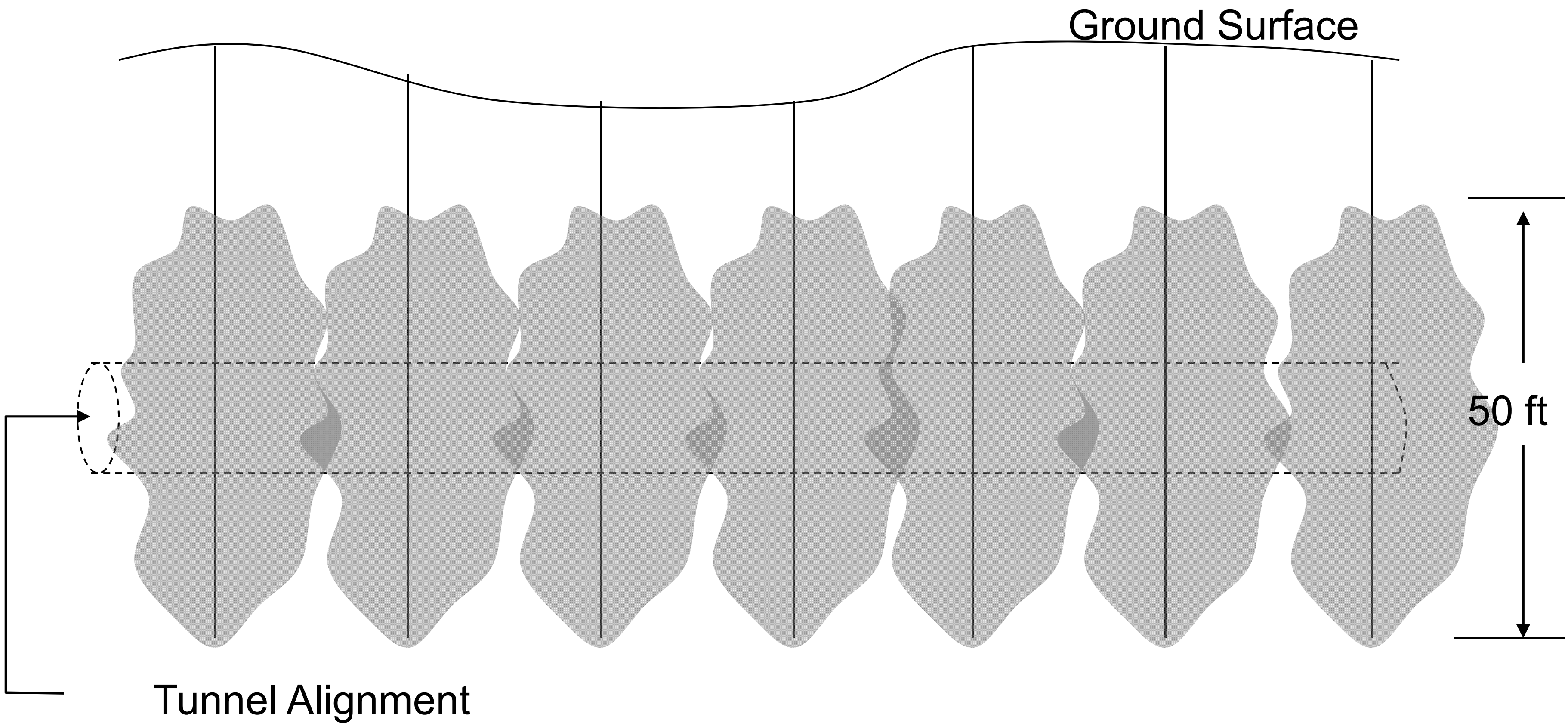
JT-123

1x10^{-2} cm/s

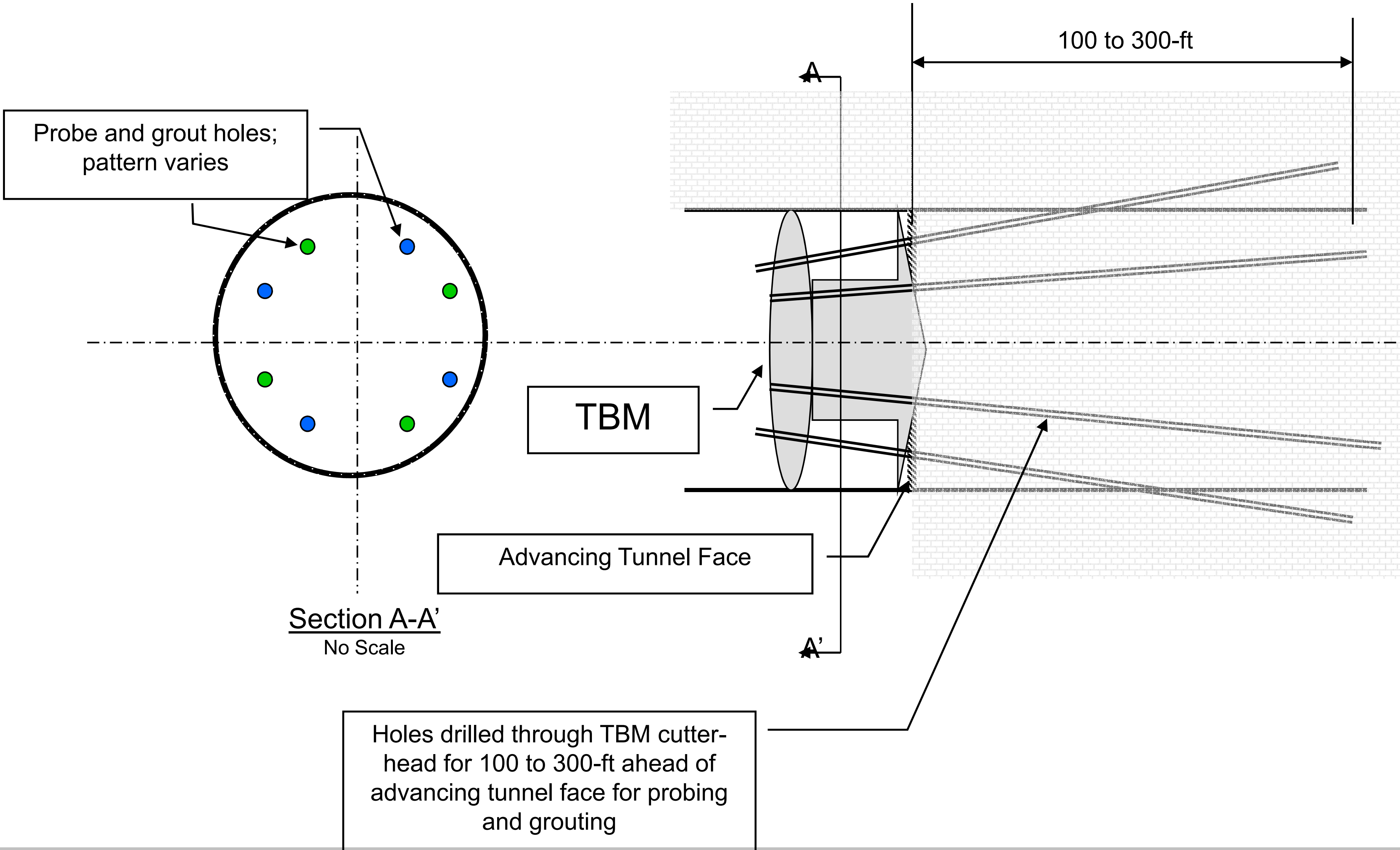
Typical Inflow Mitigation Techniques

- Probing (drilling ahead of advancing tunnel face)
- Pre-excavation grouting from the surface
- Pre-excavation grouting ahead of tunnel face
- Gasketed liner plates
- Bolted, gasketed, pre-cast concrete segments
- Cast-in-place concrete lining / carrier pipes
- Post-excavation grouting (contact and consolidation grouting)

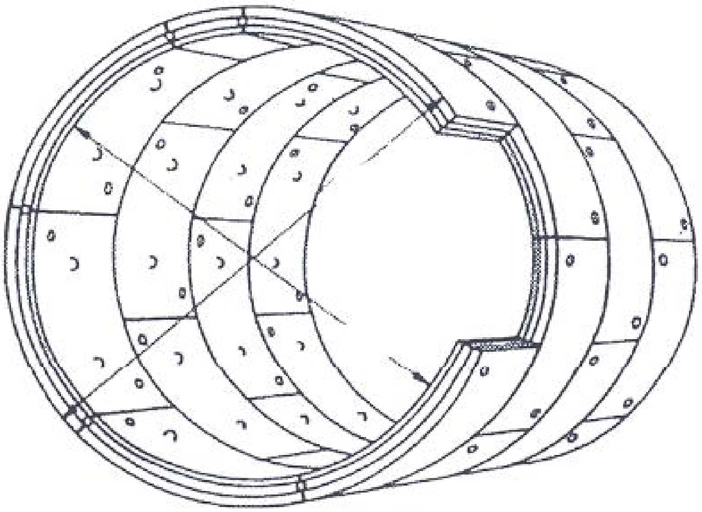
Pre-Excavation Grouting from the Surface

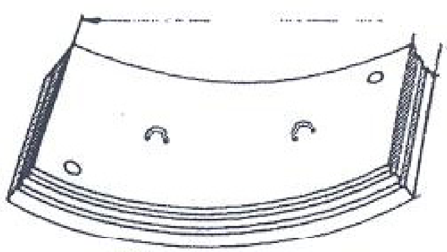


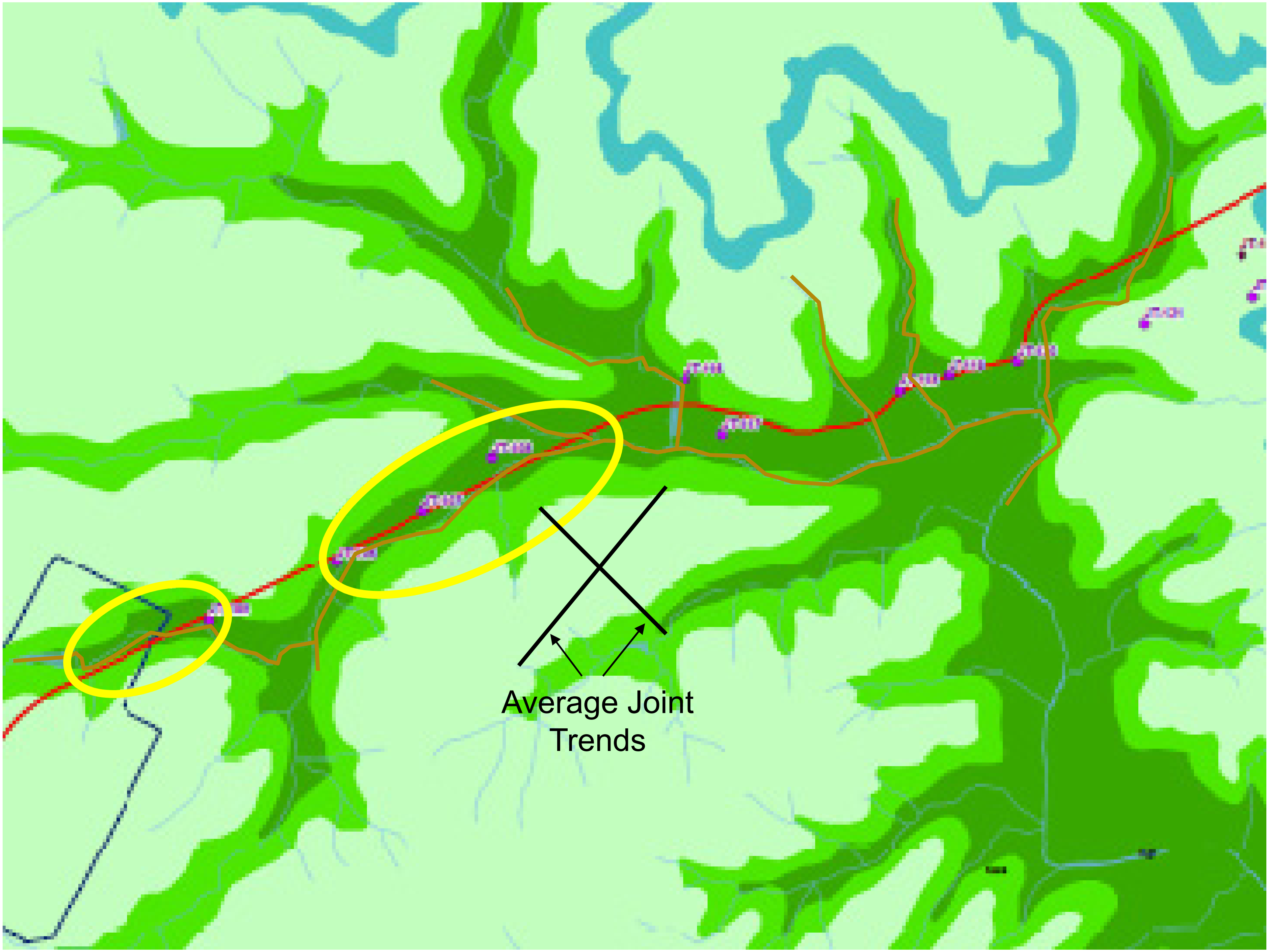
Pre-Excavation Grouting Ahead of TBM



Bolted, Gasketed, Pre-Cast Segmental Liner






Average Joint
Trends

Contract Documents

- Specifications:
  - Groundwater Monitoring Specification
  - Tunnel Excavation and Initial Support Specification
  - Tunnel Inflow Monitoring Specification
- Geotechnical Baseline Report
- Contingency Plans ?

Monitoring

- Monitoring wells already installed
- Additional monitoring wells to be installed by contractor prior to excavation as a result of groundwater modeling
- Bull Creek
- Key springs
- Tunnel inflow
- Flora?

Contractual Requirements

Objective	Performance Criteria	Triggers
Protect Springs	Interception and/or drainage of groundwater must not impact or diminish existing flow regime	•Flow exceeds target •Flow exceeds allowable maximum •Measureable effect on spring flow rate •Spring stops flowing

Specifications and Geotechnical Baseline Report

Trigger	Minimum Procedural Requirements
Flow exceeds target	Start probing ahead of TBM, flow exceeding defined limit requires grouting
Flow exceeds maximum allowable	TBM stopped, remedial grouting performed until inflow falls below maximum allowable
Measureable effect on spring flow rate	TBM stopped, remedial grouting performed until spring recovery starts
Spring stops flowing	TBM stopped, targeted remedial grouting commences, water added directly to spring

Tunnel Water Treatment and Discharge

- Permits – Treatment and Discharge Requirements
- Discharge to surface waters
- Discharge to sanitary sewer
- Other

Clarifier (and filter press, if needed) for total suspended solids removal

Notes:

1. ..