Sabal Trail Project

Best Drilling Practices Plan for the Sabal Trail Project

FERC Docket No. CP15-17-000

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TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 BEST AVAILABLE DRILLING PRACTICES 1

2.1 DESCRIPTION OF THE WORK 1
2.2 DRILLING FLUIDS 2
2.3 HDD WORKING PROCEDURES 3
2.4 HDD CONTINGENCY PLANS 3

3.0 MONITORING OF INADVERTENT RETURNS 5

3.1 PERSONNEL AND RESPONSIBILITIES 5
3.2 TRAINING 6
3.3 MONITORING & REPORTING 6
3.4 MAPPED SPRINGS 6
3.5 WELLS 14

4.0 RESPONSE TO INADVERTENT RETURNS 14

4.1 UPLAND LOCATIONS 18
4.2 WETLAND LOCATIONS 18
4.3 MAJOR WATERBODY LOCATIONS 18
4.4 MAPPED SPRINGS 19
4.5 WELLS 20

5.0 CLEAN-UP 20

LIST OF FIGURES

Figure 1. Close-Up View of the Location of the Proposed HDD Crossing of the Suwannee River. The Figure shows the Springs within a One Mile Radius of the Crossing 9
Figure 2. Close-Up View of the Proposed HDD Crossing of the Santa Fe River. The Figure shows the Springs within a One Mile Radius of the Crossing 9
Figure 3. Close-Up View of the Location of the Proposed HDD Crossing of the Withlacoochee River. The Figure shows there are no Springs within a One Mile Radius of the Crossing 10
Figure 4. Location of the Proposed HDD Crossing of the Flint River and Nearby Springs. 11
Figure 5. Location of the Proposed HDD Crossing of the Withlacoochee River (Georgia) and Nearby Springs 12
Figure 6. Location of the Proposed HDD Crossing of the Santa Fe River and Drinking Water Wells within a One Mile Radius 16
Figure 7. Location of the Proposed HDD Crossing of the Withlacoochee River (Citrus County) and Drinking Water Wells within a One mile radius 16

APPENDIX

Appendix A Information on Typical Drilling Fluid Additives

1.0 INTRODUCTION

Sabal Trail Transmission, LLC ("Sabal Trail"), a joint venture between affiliates of Spectra Energy Partners, LP and NextEra Energy, Inc., is seeking a Certificate of Public Convenience and Necessity from the Federal Energy Regulatory Commission ("FERC") pursuant to Section 7 (c) of the Natural Gas Act authorizing the construction and operation of the Sabal Trail Project ("Project").

The Project is a new natural gas transmission pipeline comprised of a combination of lease capacity and new greenfield pipeline construction that will provide approximately 1,075,000 dekatherms per day ("Dth/d") of new firm natural gas transportation capacity. Sabal Trail will acquire the capacity created by Transcontinental Gas Pipe Line Company, LLC's ("Transco") Hillabee Expansion Project (FERC Docket No. CP15-16-000) pursuant to a capacity lease, which extends from Transco's Compressor Station 85 in Choctaw County, Alabama to an interconnection with the new greenfield pipeline in Tallapoosa County, Alabama. Sabal Trail will construct, own and operate the greenfield pipeline, which will extend from Tallapoosa County, Alabama to a new interconnection hub ("the Central Florida Hub") in Osceola County, Florida. At the Central Florida Hub, the Project will connect with the Florida Southeast Connection Pipeline Project, currently being proposed by Florida Southeast Connection, LLC ("FSC") (FERC Docket No. CP14-554-000). In addition, at or near the Central Florida Hub, the Project will interconnect with Gulfstream Natural Gas System, LLC ("Gulfstream") and Florida Gas Transmission Company, LLC ("FGT"). The greenfield portion of the Project will have an initial capacity of 830,000 Dth/day with a proposed in-service date of May 1, 2017. Through a series of phased compressor station expansions to meet the future capacity needs of Sabal Trail's customers, the Project capacity will increase to approximately 999,000 Dth/day by 2020 and 1,075,000 Dth/day by 2021. References in this Resource Report to the Sabal Trail Project or Project are references to the greenfield portion of the Project only.

The construction of the Project will involve the use of the horizontal directional drilling ("HDD") installation technique for the purpose of avoiding environmentally sensitive resources or obstructions that occur along the Project pipeline route. This Best Drilling Practices Plan ("Plan") has been developed to minimize or quickly resolve possible inadvertent effects by identifying appropriate corrective actions for various potential scenarios that may be encountered during HDD operations. The purpose of this document is to provide a description of proposed HDD work activities, the HDD working procedures, monitoring of inadvertent returns of drilling fluid (including training and reporting), response to HDD operations, and proposed cleanup techniques in the event that inadvertent returns occur during HDD activities on the Project. The following sections of this Plan provide the processes and procedures to be implemented in the case of inadvertent returns or releases of drilling fluid during HDD activities.

2.0 BEST AVAILABLE DRILLING PRACTICES

2.1 Description of the Work

The HDD method requires establishing staging areas at both ends of the proposed crossing, typically known as the entry and exit points or workspaces. The process commences with the drilling of a pilot hole along a predetermined path beneath the obstruction, wetland or waterbody. Once the pilot hole has been completed, the drilled hole is enlarged with one or more passes of a reamer until the diameter of the hole is adequate to complete the pull-back (installation) of the pipeline. Once the reaming pass(s) are completed, prefabricated pipe segments are then pulled through the hole to complete the installation. Additional welding to join the prefabricated segments may be required during the pullback process. While the HDD method is a commonly used, proven technology, there is the potential for unintended effects that could occur as a result of the drilling. The proposed drilling program is expected to be initiated in 2016 during the Project construction period and will be completed in 2017.

2.2 Drilling Fluids

The HDD process uses drilling fluids to facilitate many of the HDD operations. Drilling fluid is a slurry composed of water and bentonite clay (typically 95 percent water) intended to maintain hole stability, lubricate the drilling head, remove cuttings and reduce soil friction. Bentonite clay (sodium montmorillonite) is a naturally occurring clay, usually mined in Wyoming, which is extremely hydrophilic and can absorb up to ten times its weight in water. Bentonite is non-toxic to the aquatic environment and is a non-hazardous substance. The composition of the drilling fluids and its engineering properties tested to ensure their suitability for the given subsurface conditions encountered along the alignment and at each individual HDD location

The slurry is designed to:

- Stabilize the hole against collapse;
- Lubricate, cool, and clean the cutters;
- Transport cuttings by suspension and flow to entry and exit points; and reduce soil friction and required pull loads during pilot hole, reaming, and carrier pipe installation.

Depending on subsurface conditions encountered, certain lost circulation materials (LCMs) and special polymers may also be introduced in the drilling fluid mixture. Lost circulation materials may be used during inadvertent return events and/or in certain cases when drilling fluid circulation seems to be diminishing. In the event that conduits intersect the HDD path, LCMs may be used in an attempt to seal around the borehole and prevent drilling fluid from escaping into the formation and allow for the reestablishment of drilling fluid returns to the entry and/or exit pits. Many types of LCMs are available for use during HDD operations that are inert and environmentally benign.

Sabal Trail is in the early phases of selecting pipeline and HDD construction contractors. Therefore, at this time, Sabal Trail is unable to identify the specific LCMs and polymers that may be used on the Project. For example, drilling fluid additives that may be used in clay will not likely be beneficial in rock. Consideration is also given to the varying geological formations the Project traverse. For example, drilling fluid additives that may be used in clay will not likely be beneficial in rock.

After contractor selection is completed and prior to the start of construction, the construction contractors will be required to submit a list of drilling fluid additives (e.g., polymers) proposed for use on the Project to Sabal Trail for review and approval. Sabal Trail will evaluate the contactor's list of proposed polymers, determine which of the proposed products will be authorized for Project use and provide that list to FERC staff. Sabal Trail will initially determine the products will be authorized for Project use based on compliance with NSF 60 standards. NSF 60 is a standard that establishes health and safety criteria for the chemical treatment of drinking water and consequently, drinking water well development ("NSF/ANSI Standard 60"). In addition to NSF 60 criteria, any other applicable federal or state requirements will also be considered during the review process. After this process has been completed, Sabal Trail will submit to FERC a list of specific additives planned to be used on the Project.

In lieu of specific polymer identification, at this time, Sabal Trail offers the following information on categories of polymers that may be used during HDD operations:

- Borehole stabilizers/viscosifiers: polymers used to increase viscosity and gel strength of water/bentonite drilling fluids.
- Lost circulation materials: can be polymers but sometimes other bio-degradable materials are used as LCMs (i.e. walnut shells, paper etc.).

Most drilling fluids, drilling fluid additives and polymers used in the HDD industry are NSF 60 compliant, as these products are also used in other rotary drilling applications such as water well drilling and completion. Therefore, if NSF 60 complaint products are used there will be no effects on water quality. Information on typical drilling fluid additives is found in Appendix A. Please note these or other similar products may be used on the Project.

Although intended to facilitate the HDD process, there is the potential for inadvertent migration or loss of drilling fluids from the bored hole. However, drilling fluids that are released will likely contain a lower concentration of bentonite when they surface because the mixture may be filtered and somewhat diluted as it passes through existing sediments of various types.

Inadvertent releases may occur as a result of rock fractures, low density soils, and unconsolidated geology, which were not foreseen during the design phase. Inadvertent returns are readily detected at the surface as seepage (pooling of drilling mud at the surface) or a loss of circulation of the drilling fluid. When the operator observes a loss of drilling fluid returning, it is an indicator that seepage may be occurring outside of the hole. Loss of drilling fluid returns is only an indicator as some loss of drilling fluid is expected, such as where loose sediments are encountered and more drilling fluid is required to be added to fill the voids.

2.3 HDD Working Procedures

Prior to the start of drilling operations, site-specific HDD Procedures will be reviewed with the HDD contractor. At a minimum, the HDD Procedures will address the following:

Return Circulation – Once it is indicated to the driller that drilling fluid circulation is dissipating or that a release has occurred, the driller has the following options (or any combination of these options):

- Decrease pump pressure;
- Decrease penetration rate;
- Retract the drill string a distance to restore circulation ("swab" the hole);
- Introduce additional drilling fluid flow along the hole using "weeper" subs; and
- Introduce lost circulation additives to the drilled hole.

Inadvertent Returns at In-accessible Locations - If inadvertent returns are observed on the ground surface along portions of the alignment that are inaccessible; the following procedures will be followed:

- Contractor will ensure all reasonable measures within the limitations of current technology have been taken to re-establish circulation; and
- Continue drilling utilizing a minimal amount of drilling fluid as required to penetrate the formation or to maintain a successful carrier pipe pull back.

Inadvertent Returns at Accessible Locations – If inadvertent returns are observed on the ground surface along portions of the alignment that are accessible, containment and recovery operations will be completed in accordance with the procedures discussed in Section 4.0.

2.4 HDD Contingency Plans

In the unlikely event the HDD crossing cannot be completed on the first attempt, the approved construction workspace and rights of way are sufficient to allow multiple attempts to install the HDD. In most cases, several attempts can be made within the permitted workspace by slightly modifying the HDD geometry to adjust either the depth of the drill profile and/or the horizontal alignment. Adjustments in the

alignment and profile depth can, often times, minimize contact with or completely avoid localized problematic formational zones.

If problems persist along the original drill alignment, including at alternate depths from the first attempt, the HDD rig can be offset left or right and a second pilot hole can be initiated along a new alignment designed with data collected during the first attempt. The drilling data collected along the first alignment will be utilized to create a new design that will, to the extent practical, minimize contact with problematic formational zones encountered during the initial attempt. If a first attempt along the new alignment is not successful, as described above, several attempts can be made at various depths along the new alignment. If all attempts fail along this new alignment, the HDD rig and equipment can again be moved left or right within the workspace and a third new pilot hole initiated along a new design alignment that minimizes contact with problematic formational zones encountered along both the initial and secondary attempts. If a first attempt at this location also proves unsuccessful, as described above, several attempts can be made at various depths along this alignment. In summary, the construction workspace contains sufficient room to allow numerous HDD attempts; therefore these techniques can be utilized until either the HDD is successfully installed or all possibilities of a successful HDD installation have been exhausted.

In the very unlikely event that an HDD cannot be successfully installed, the methods presented below and the associated required activities can be considered as potential options:

- Reroute Pipeline to Attempt HDD at an alternate location outside of the proposed pipeline construction ROW
    - Pipeline alignment will be altered and a new HDD crossing will be designed at a location that potentially will pose lesser installation challenges.
    - The proposed change in location will be selected via desktop analysis using existing aerial photography and other available data.
    - Survey permission will be required before the required civil, environmental and cultural surveys can be performed. Once survey permission has been obtained and the area is determined to be acceptable from a cultural and environmental perspective, geotechnical and geophysical investigations will be initiated to support design of a HDD at the new location.
    - Approvals from FERC, USACE and state agencies will be required before the HDD is attempted at the new location.
- Direct Pipe Installation;
    - Direct pipe installation would require mobilization and installation of the Direct Pipe Thruster and associated ancillary support equipment
    - Due to technical limits associated with 36” pipe diameter, in most cases, utilization of the Direct Pipe method would require the length of the crossing to be shortened. This reduction of crossing length would trigger the need for additional construction workspace and potentially additional environmental and cultural surveys between the river and the current HDD staging areas.
    - Approvals from FERC, USACE and state agencies will be required before the construction begins
- Aerial Crossing;

- Utilization of this crossing technique will require the pipeline span the river via large elevated frames, and their associated foundations and structural support members.
- Geological conditions may necessitate the need for piling supported foundations, columns and/or abutments, potentially adjacent to or in the water course.
- Installation of an aerial crossing may trigger the need for additional permanent easement, construction workspace and potentially additional environmental, cultural and geotechnical and/or geophysical surveys.
- Approvals from FERC, USACE and state agencies will be required before the construction begins

- Open cut river crossing;
  - This method involves the excavation of a trench through the river.
  - Additional armoring of the pipe in the river bottom could be required to protect the integrity of the pipe.
  - Equipment would have to work in the river and state mandated turbidity limits would apply.
  - Approvals from FERC, USACE and state agencies will be required before the construction begins
  - This type of crossing would also only be considered as last resort in the case when all other alternatives prove to be unfeasible.

3.0 MONITORING OF INADVERTENT RETURNS

3.1 Personnel and Responsibilities

The actions in this Plan are to be implemented by the following personnel:

Chief Inspector – Sabal Trail will designate a Chief Inspector ("CI") for the Project. The CI will have overall authority for construction activities that occur on their designated portion of the Project.

Environmental Inspector – At least one Environmental Inspector ("EI") will be designated by Sabal Trail to monitor the HDD activities. The EI will have peer status with all other craft inspectors and will report directly to the CI who has overall authority. The EI, along with all other inspectors and inspection personnel, will have the authority to stop activities that violate the environmental conditions of the FERC certificate (if applicable), other federal and state permits, or landowner requirements, and to order corrective action.

HDD Superintendent – The HDD Superintendent is the senior on-site representative of the HDD contractor. The HDD Superintendent has overall responsibility for implementing this Plan on behalf of the HDD contractor. The HDD Superintendent will be familiar with the aspects of the drilling activity, the contents of the Plan and the conditions of approval under which the activity is permitted to take place. The HDD Superintendent will make available a copy of this Plan to the appropriate construction personnel. The HDD Superintendent will ensure that workers are properly trained and familiar with the necessary procedures for response to an inadvertent release.

HDD Operator – The HDD Operator is the HDD contractor's driller operating the drilling rig and mud pumps. The HDD Operator is responsible for monitoring circulation back to the entry and exit locations. In the event of loss of circulation, the HDD Operator must communicate the event to the HDD

Superintendent and HDD contractor field crews. The HDD Operator is responsible for stoppage or changes to the drilling program in the event of observed inadvertent returns.

HDD Contractor Personnel – During HDD installation, field crews will be responsible for monitoring the HDD alignment along with Sabal Trail's field representatives'. Field crews, in coordination with the EI, are responsible for timely notifications and responses to observed releases in accordance with this Plan. The EI ultimately must approve the action plan for mitigating the release.

3.2 Training

Prior to drilling, the HDD Superintendent, CI, and the EI will verify that the HDD Operator and field crew receive the following site-specific training but not limited to:

- Project specific safety and environmental training;
- Review provisions of this Plan and site-specific permit requirements;
- Review location of sensitive environmental resources at the site;
- Review drilling procedures for release prevention;
- Review the site-specific monitoring requirements;
- Review the location and operation of release control equipment and materials; and
- Review protocols for reporting observed inadvertent returns.

3.3 Monitoring & Reporting

Appropriate Monitoring & Reporting actions will be:

- If the HDD Operator observes a loss of circulation, the Operator will notify the HDD Superintendent and field crews of the event and approximate position of the cutting head;
- Where practical, a member of the field crew will visually inspect the ground surface near the position of the cutting head. Surface waters, wells, and mapped springs within 2,000 feet of the HDD site will also be visually inspected.
- If an inadvertent release is observed:
    - Field crew will notify (via hand-held radio or cell phone) the HDD Operator;
    - The HDD Operator will temporarily cease pumping of the drilling fluid and notify the HDD Superintendent and CI;
    - The CI will notify and coordinate a response with the EI;
    - The EI will notify FERC and the appropriate permitting authorities as necessary of the event and proposed response and provide required documentation within 24 hours; and
- The CI will prepare a report that summarizes the incident.
- After the HDD installation is complete, perform final clean-up (*see* Section 5.0 below).

3.4 Mapped Springs

Drinking water wells and springs within 2,000 feet (downgradient) of proposed HDDs were located and confirmed using Floridan Aquifer potentiometric surface/water table maps. Figures 1, 2, and 3 show the springs within a one-mile radius of the Suwannee, Santa Fe, and Withlacoochee River (Citrus County) crossings, respectively. Figures 4 and 5 show the springs in the vicinity of the HDD crossings of the Flint

and Withlacoochee Rivers (Georgia). For both crossings, there are no springs within 2000 feet of the crossing.

The monitoring program proposed for mapped springs involves the establishment of a baseline turbidity level in springs that are 2,000 feet downgradient from the HDD activities proposed for the Project. Prior to the start of HDD activity, a baseline turbidity level will be established at the springs to be monitored by collecting samples at six hour intervals over a 24 hour period. This monitoring program will allow Sabal Trail to determine if drilling mud and/or sediments from construction activities have entered the spring system. Turbidity monitoring will be conducted in accordance with the schedule below, or as required in any permits issued by the United States Army Corps of Engineers ("USACE"), GAEPD, FDEP, and/or other state regulatory agencies.

Field sampling for turbidity will follow the Standard FDEP sampling protocols (FDEP, 2014). Water samples will be analyzed for turbidity using a portable turbidity meter. Turbidity readings, water levels, rainfall rates, seasonal and environmental changes, and water appearance will be recorded during every sampling event. Water samples will be collected from large springs using a Van Dorn sample bottle deployed from the bank or boat/canoe. All necessary safety precautions will be taken. The turbidity meter will be calibrated daily in accordance with FDEP (FDEP, 2014) calibration standards. Rainfall rates will be recorded from the nearest weather station with available data.

The monitoring program will address only one mapped spring that has been identified as occurring within 2,000 feet and downstream of Project HDDs. Monitoring of this spring is subject to granting of access permission and safety of the access point at the time of monitoring. Sabal Trail will work with the landowners where applicable to gain access to springs for monitoring.

Proposed Spring Monitoring Locations								
Spring ID	**Location**	**Nearest Distance From Pipeline (feet)**	**Nearest Milepost**	**Magnitude**	**HDD Crossing Milepost**	**HDD Crossing Name**	**Distance from HDD Crossing**	**Access**
Suw923972 (Suwannee)	Lat 30 24 15.92, Long 83 09 27.76	1,040	TBD	4	TBD	Suwannee River	1,040 feet downstream of crossing	Owner: Trustees of the Internal Improvement Trust Fund, Suwannee River State Park

Source: FDEP. 2011. Spring Locations in Florida – 2011. Florida Geographic Data Library.

If an inadvertent release is reported, this spring will be sampled twice per day (morning and afternoon) until the turbidity returns to background levels or until the turbidity levels are below the 29 NTUs above background in accordance with the Florida Department of Environmental Protection ("FDEP") Surface Water Criteria for Class III, Predominantly Fresh Waters (Florida Administrative Code 62-302.530).

Figure 1. Close-Up View of the Location of the Proposed HDD Crossing of the Suwannee River. The Figure shows the Springs within a One Mile Radius of the Crossing

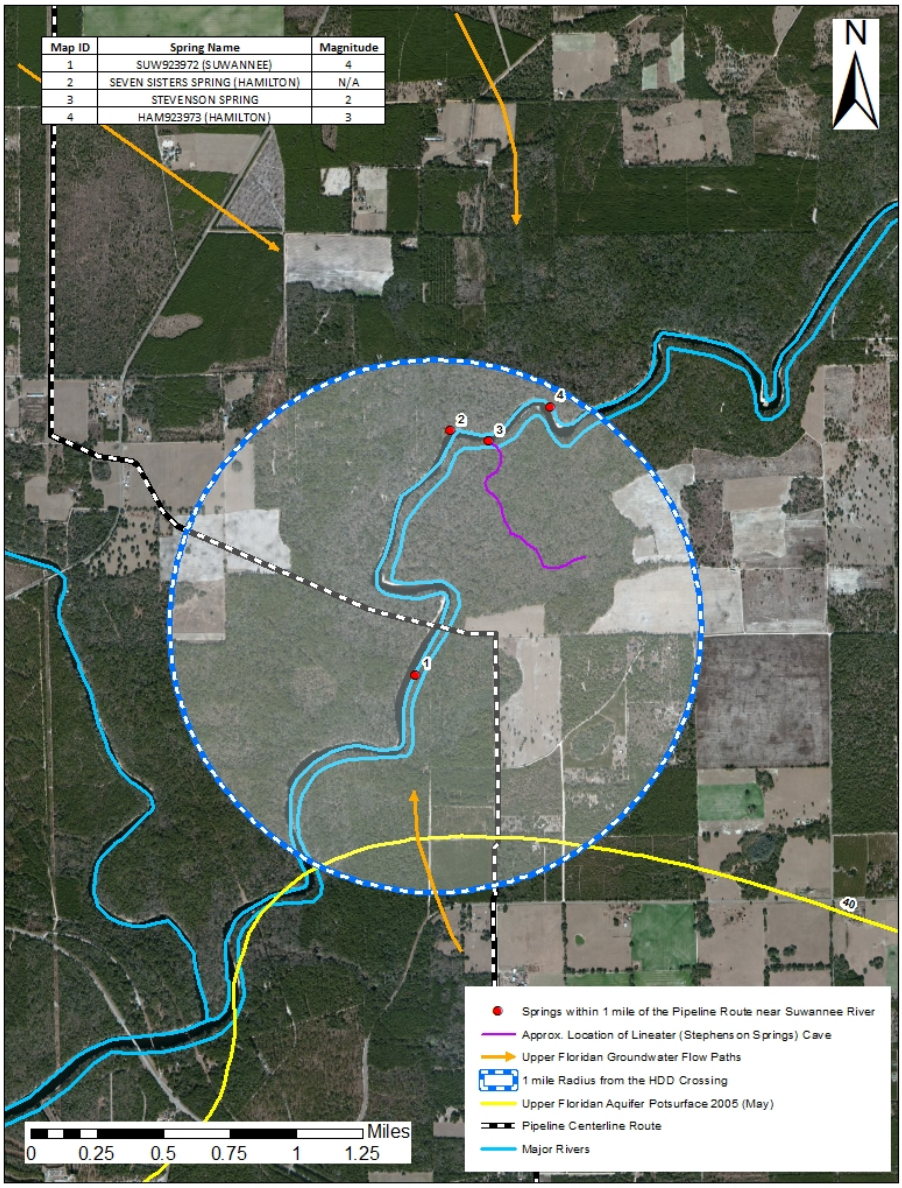


Figure 2. Close-Up View of the Proposed HDD Crossing of the Santa Fe River. The Figure shows the Springs within a One Mile Radius of the Crossing

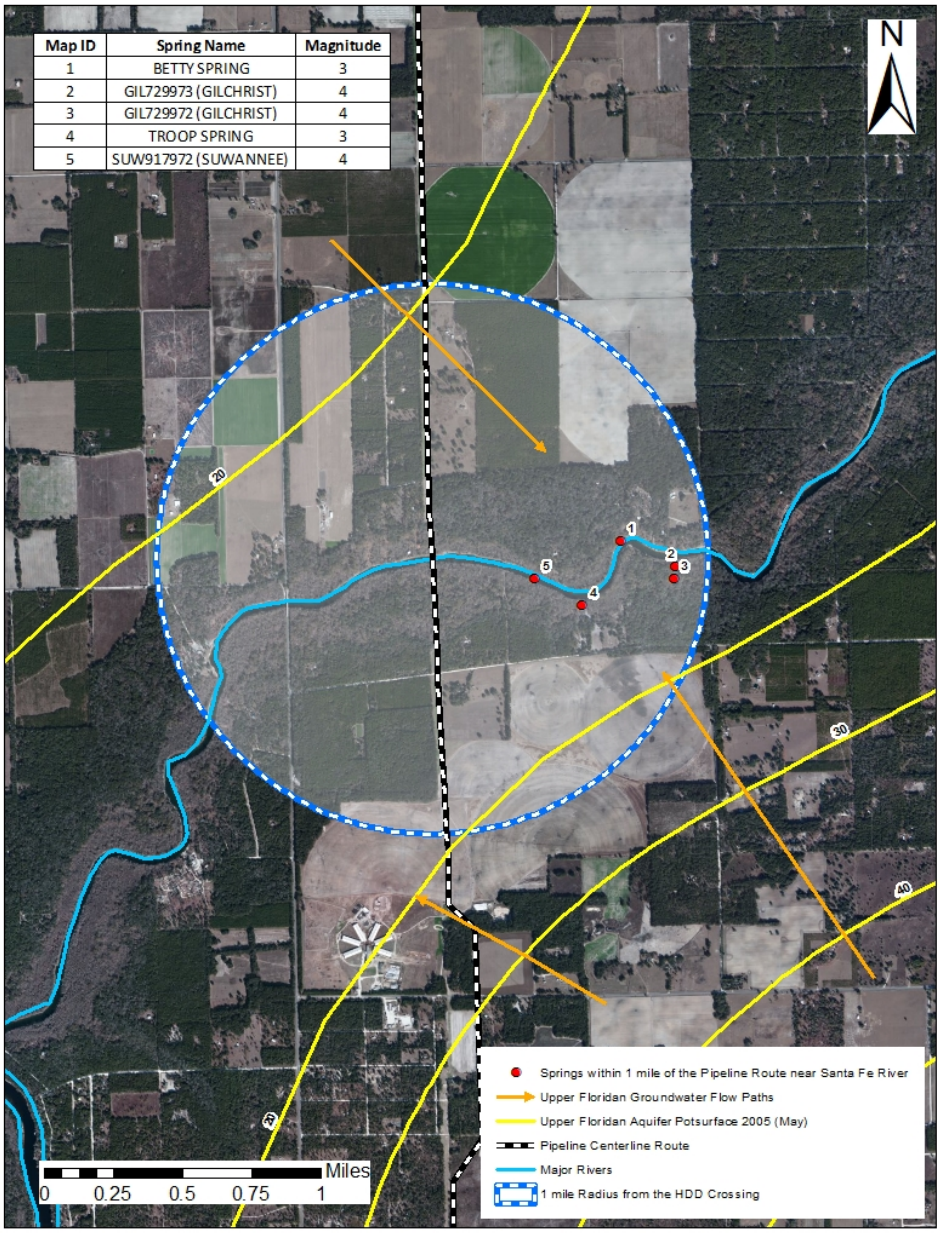


Figure 3. Close-Up View of the Location of the Proposed HDD Crossing of the Withlacoochee River. The Figure shows there are no Springs within a One Mile Radius of the Crossing

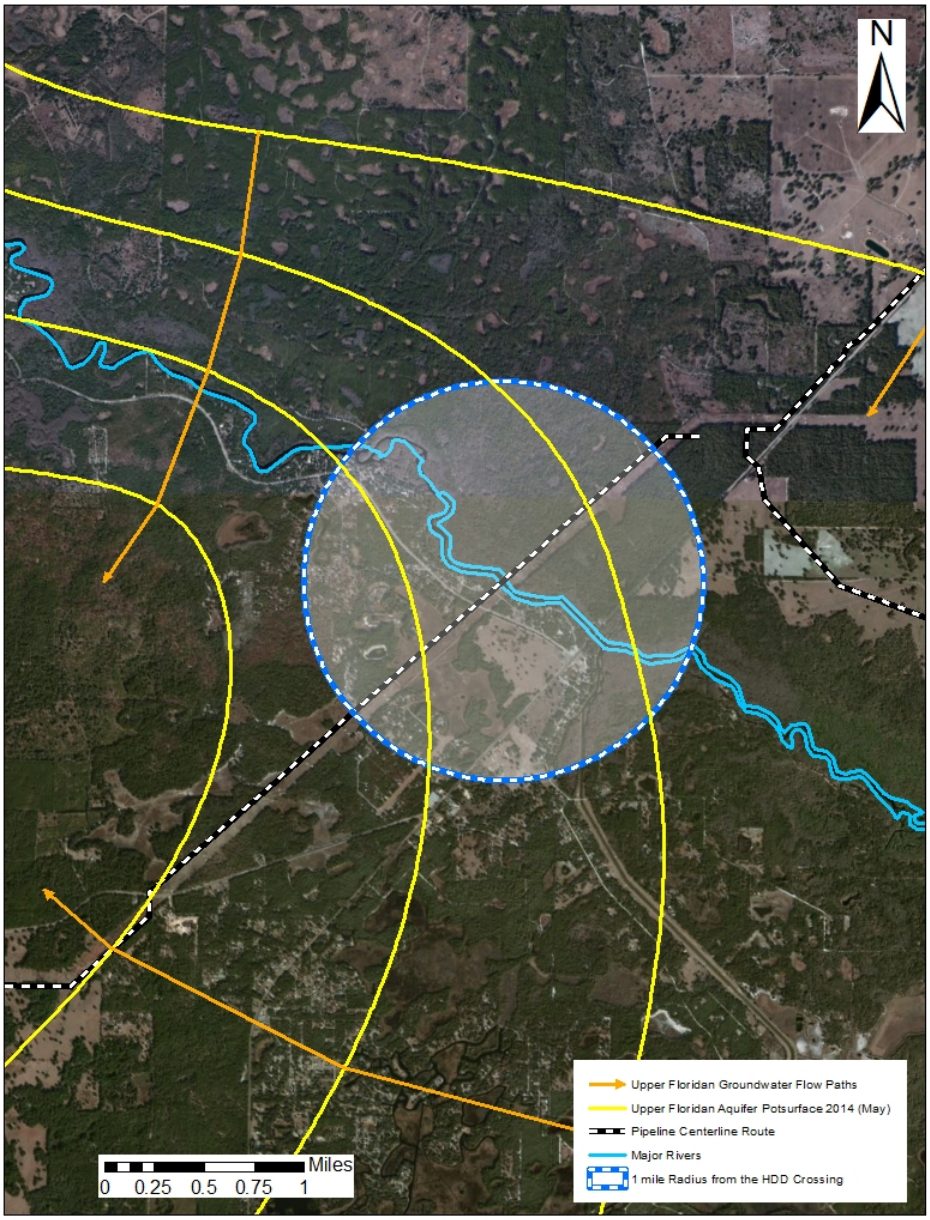
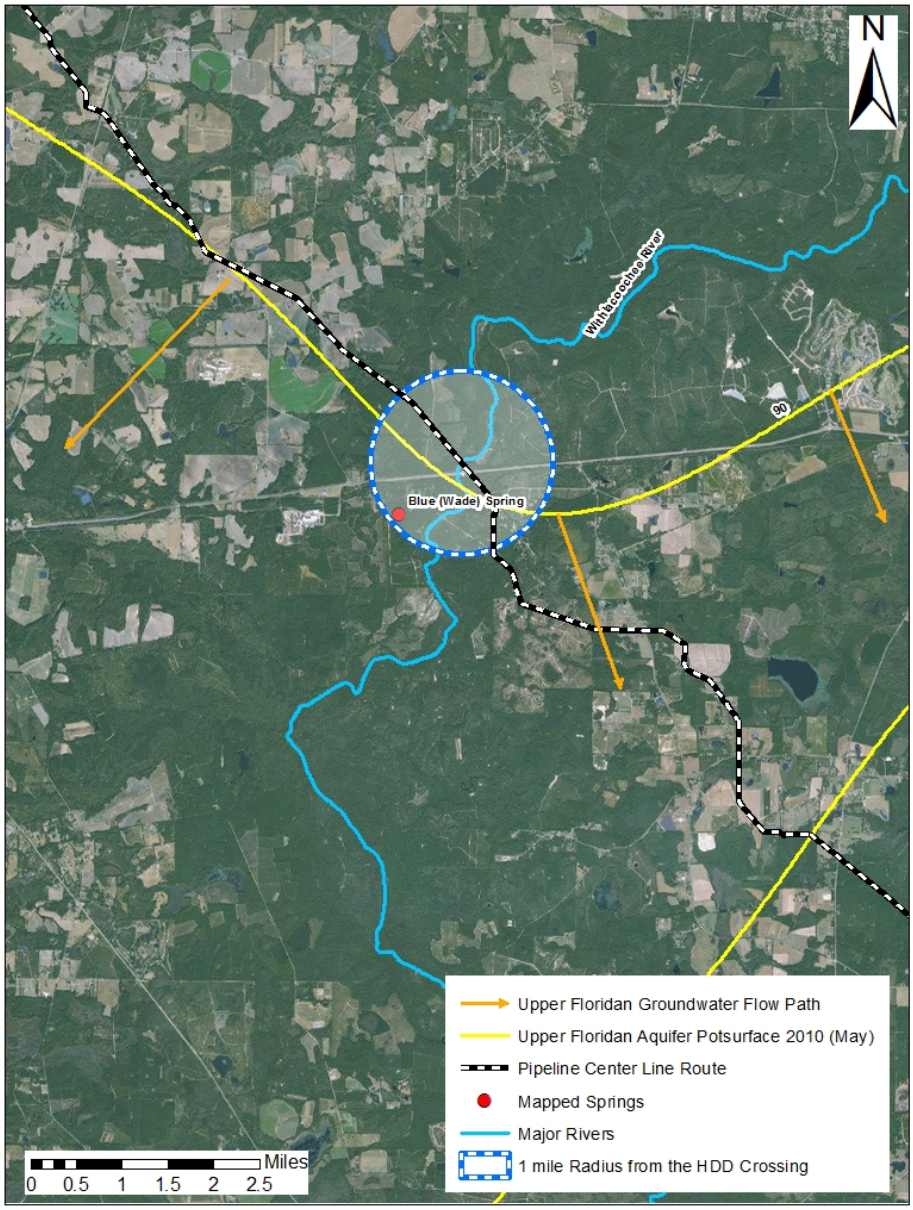


Figure 4. Location of the Proposed HDD Crossing of the Flint River and Nearby Springs.

Figure 5. Location of the Proposed HDD Crossing of the Withlacoochee River (Georgia) and Nearby Springs



3.5 Wells

Turbidity sampling, using the portable turbidity meter noted above and following the same testing and calibration protocols, will be conducted at drinking water wells within 150 feet of the HDD activity prior to initiating the HDD activity, where access is permitted and in coordination with the landowner. This sampling will establish baseline turbidity levels for these wells. A table of drinking water wells within 150 feet of the Sabal Trail HDD activities is provided below. This table will be updated as additional drinking water wells are identified during preconstruction surveys. If an inadvertent release from the HDD activity is confirmed, water samples will be taken from these drinking water wells and tested for turbidity on a daily basis until the turbidity levels return to the baseline levels.

Publicly available data from various agencies was used to provide the location of domestic supply wells within 2000 feet of HDD crossings and work areas. The distance of the wells in Figures 6 and 7 are provided in the tables below. Sabal Trail will choose a subset of these wells to sample during HDD operations. The subset will be based on a number of criteria that include the location of the well within the groundwater flow system, distance of the well from HDD operations, ability to obtain landowner permission, and confirmation of the precise well locations. In the event of an inadvertent release during the HDD activity and a change in water quality is identified from the sampling of the drinking water wells within 150 feet of the HDD activity, additional turbidity sampling will be extended to these drinking water wells (2,000 feet of the HDD activity and for which a baseline turbidity level had been established). Sampling of these wells will continue daily until the turbidity levels return to baseline levels.

Proposed Well Monitoring Locations				
Milepost	**Distance from Centerline (feet)**	**Distance from Construction Work Area (feet)**	**HDD Crossing Name**	**Drinking Water (Y/N)**
464.57	85	80	US Highway 27	Yes
308.1	875	840	Santa Fe River	Yes
308.2	1,177	1,141	Santa Fe River	Yes
CCL 1.5	731	472	Withlacoochee River	Yes
CCL 1.4	609	417	Withlacoochee River	Yes
CCL 1.4	465	350	Withlacoochee River	Yes
CCL 1.3	617	581	Withlacoochee River	Yes
CCL 1.2	754	675	Withlacoochee River	Yes

Figures 6 and 7 show the drinking water wells within a one mile radius of the Santa Fe, and Withlacoochee River (Citrus County) crossings in Florida, respectively. There are no drinking water wells within a one-mile radius of the Suwannee River HDD crossing. Regarding drinking water wells in Georgia, the state public health websites and Georgia Department of Natural Resources website were searched and no domestic drinking water information was available.

4.0 RESPONSE TO INADVERTENT RETURNS

Typically, inadvertent releases are most often detected in the area near the entry or exit points of the drill alignment where the HDD path is at shallow depths, above bedrock, and in permeable/porous soils. In these occurrences the release will be assessed by the HDD Superintendent, EI, and CI to determine an estimated volume of the release. They will also assess the potential of the release to reach adjacent waterbodies, wetlands, or other types of infrastructure (e.g., wells). The HDD Superintendent will assess

the drilling parameters (depth, type of formation, fluid flow rate, and drilling fluid characteristics) and incorporate appropriate changes.

The HDD Superintendent, EI, and CI will coordinate installation of appropriate containment structures and implement additional response measures. Site topography in conjunction with access for personnel and equipment to the release site are major factors in determining the methods used for containment and disposal. Typically, containment is achieved by excavating a small sump pit (approximately 5 cubic yards) at the site of the release and/or surrounding the release with hay bales, silt fence and/or sand bags. Once contained, the drilling fluid is either collected by vacuum trucks or pumped to a location where vacuum trucks can be accessed. The fluids are then transported either back to the HDD Drilling Rig or to a disposal site.

Figure 6. Location of the Proposed HDD Crossing of the Santa Fe River and Drinking Water Wells within a One Mile Radius

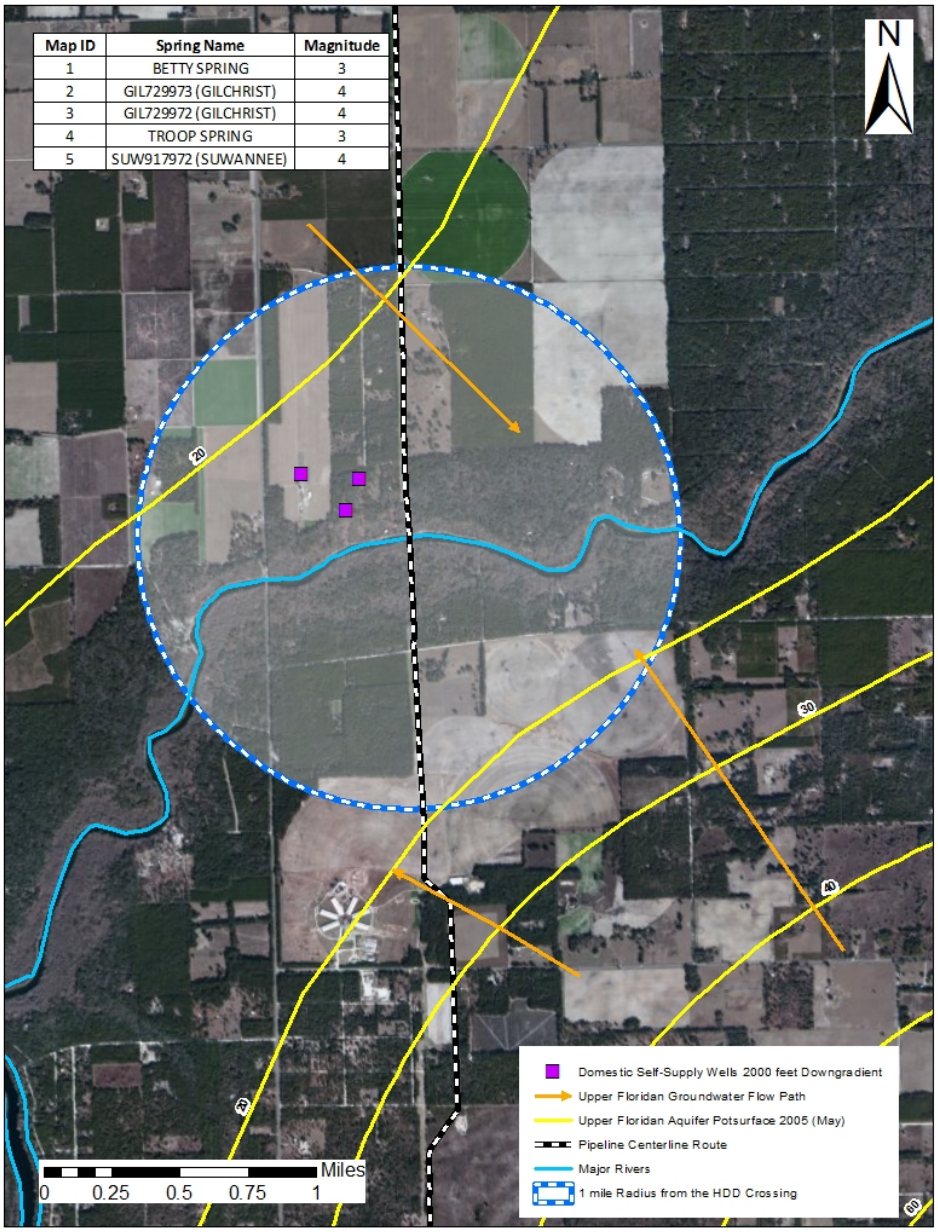
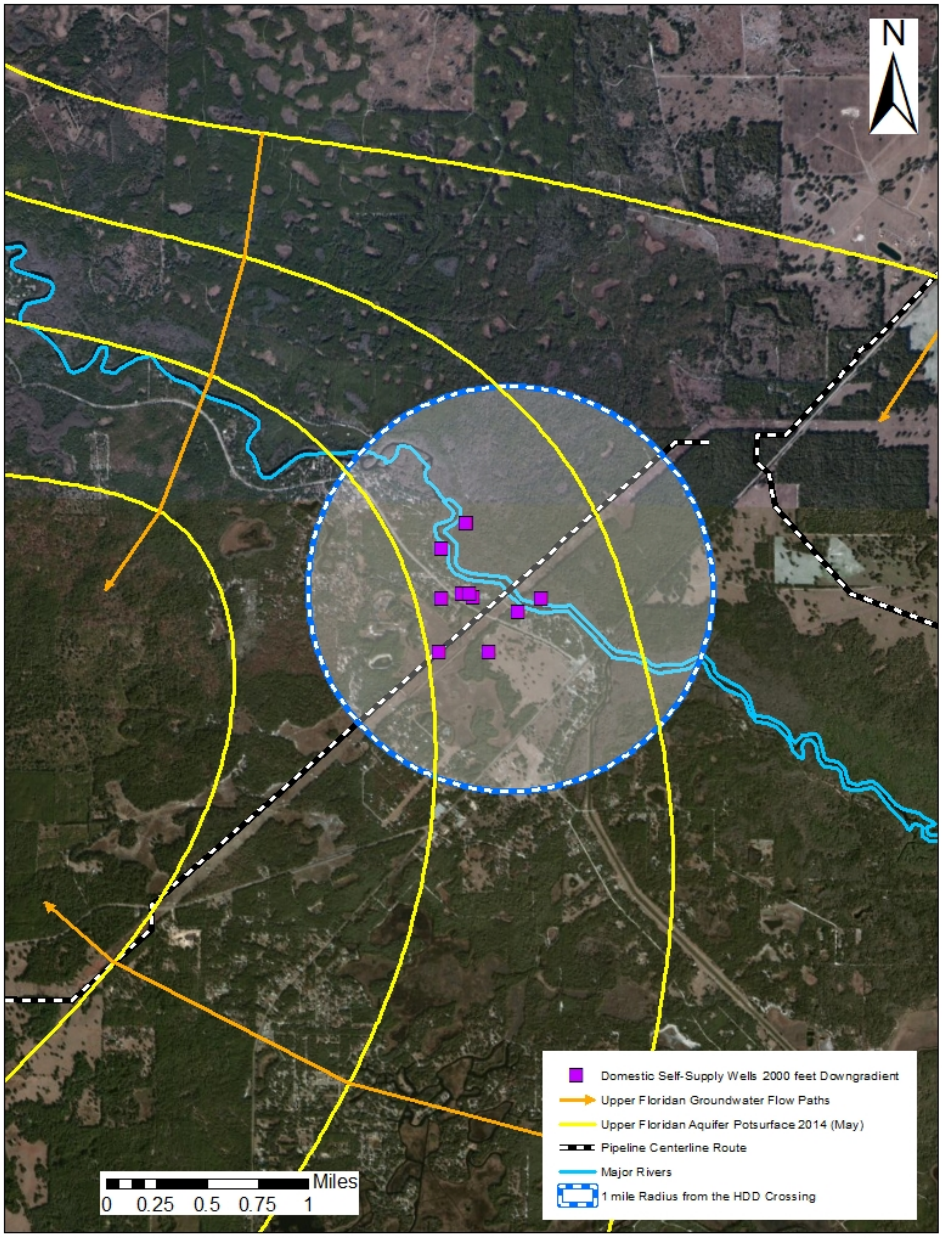


Figure 7. Location of the Proposed HDD Crossing of the Withlacoochee River (Citrus County) and Drinking Water Wells within a One mile radius



The EI in coordination with the HDD Superintendent and CI will determine when drilling operations can resume.

The site-specific response will follow the guidelines provided in the following sections.

4.1 Upland Locations

- Evaluate the amount of release to determine if containment structures are warranted and if they will effectively contain the release.
- Promptly implement appropriate containment measures as needed to contain and recover the slurry.
- If the release is within 50-foot of a wetland or waterbody, silt fence and/or hay bales will be installed between the release site and the wetland or waterbody.
- If the release cannot be contained, then the operator must suspend drilling operations until appropriate containment is in place.
- Remove the fluids using either a vacuum truck or by pumping to a location where a vacuum truck is accessible.
- After the HDD installation is complete, perform final clean-up (*see* Section 5.0 herein).

4.2 Wetland Locations

- Evaluate the amount of release to determine if containment structures are warranted and if they will effectively contain the release.
- Promptly implement appropriate containment measures to contain and recover the slurry;
    - Efforts to contain and recover slurry in wetlands may result in further disturbance by equipment and personnel, and possibly offset the benefit gained in removing the slurry.
    - If the amount of the slurry is too small to allow the practical collection from the affected area, the fluid will be diluted with fresh water or allowed to dry and dissipate naturally.
- If the release cannot be controlled or contained, immediately suspend drilling operations until appropriate containment is in place.
- Remove the fluids using either a vacuum truck or by pumping to a location where a vacuum truck is accessible.

4.3 Major Waterbody Locations

Sabal Trail's proposed HDDs are being designed to minimize the potential for inadvertent releases. Sabal Trail's Contractor(s) may also employee the techniques described below to reduce the probability of inadvertent returns.

Surface Casing – If deemed necessary, surface casing may be installed in certain instances. Surface casing provides a conduit to allow drilling fluids to return from the drill path back to the surface. Additionally, surface casing helps isolate the drill path from regions of unstable overburden material.

Intersect Method – Sabal Trail's Contractor(s) may drill some of the pilot holes from both sides of the crossing and perform and intersect near a predetermined point, usually near the middle of the crossing. The intersect method is widely used in long, large diameter HDDs. The intersect method reduces the length that must be drilled from each end and thereby decreases the distance that drilling fluids need to be pumped in order to return to surface at the entry/exit points. Utilization of this method is particularly

advantageous in longer crossings because the reduced distance that drilling fluid must be pumped subsequently decreases the fluid pressure required for the drilling fluid to travel back to the entry/exit points.

In the event of an inadvertent release in a flowing waterbody, the following approach will generally be followed after the inadvertent release has been isolated and the flow has stopped. Due to the unpredictable nature of the locations and environment in which inadvertent releases may appear, this description cannot encompass all possible approaches to clean-up under all conditions.

Agency staff and other experts will be consulted to the extent practicable in the development of remedial clean up techniques, as required. The following are standard response techniques that may be applied:

- If the bentonite material flows overland prior to entering the waterbody, installation of silt fencing or sandbag dams at the point of entry will be used to reduce or stop the flow; if the vent is directly into the waterbody, other means to isolate the vent site from the flowing waterbody will be used.
- Using a vacuum truck or pump(s), with a sufficient hose, personnel will remove the bentonite, working from downstream to upstream, to allow maximum visibility. Hand tools may be used to scarify the sediments and ensure removal to the maximum extent practicable.
- If necessary, water may be diverted using temporary barriers to isolate the impact area. Only a portion of the stream will be diverted to minimize dewatering impacts. Water will be able to pass through the site in its natural condition.
- If it is impracticable to remove the drill fluid from the surface water, a clear written explanation will be submitted to the applicable regulatory agencies.
- Any disturbed soils will be stabilized immediately.
- Exposed soils will have temporary erosion control measures established as soon as practical with permanent erosion controls established as soon as possible as described in the Project E&SCP.
- Disturbance of vegetation will be kept to a minimum and all disturbed vegetation will be restored.

In the event of an inadvertent release of drilling mud under pressure into dry ephemeral streams, a response plan similar to the above described will be implemented.

4.4 Mapped Springs

Specific emergency procedures will be addressed through the appropriate regulatory agency permitting process. It is important to understand that any significant rise or fall in water levels in the spring directly attributed to nearby river discharge or rainfall can dramatically alter water quality conditions. In the event of a suspected or confirmed inadvertent release, the site-specific response will follow measures outlined for surface waters in Section 4.3, to the extent practical.

Agency staff and other experts will be consulted to the extent practicable in the development of remedial clean up techniques, as required. The following are standard response techniques that may be applied:

- If there is a potential for bentonite material to flow overland and reach a spring, installation of silt fencing or sandbag dams will be used to reduce or stop the flow.
- If practical, bentonite entering the spring overland will be removed using a vacuum truck or pump. Hand tools may be used to scarify the sediments and ensure removal to the maximum extent practicable.

- Any disturbed soils will be stabilized immediately.
- Exposed soils will have temporary erosion control measures established as soon as practical with permanent erosion controls established as soon as possible as described in the Project E&SCP.
- Disturbance of vegetation will be kept to a minimum and all disturbed vegetation will be restored.

4.5 Wells

In the event an inadvertent release results in a change in the quality of the water within the drinking water wells sampled as described above in Section 3.5, Sabal Trail will provide an alternate source of water to the landowner until the well water quality returns to pre-construction conditions. If the well water quality does not return to pre-construction conditions after a suitable length of time, Sabal Trail will compensate the landowner for the installation of a new well or otherwise arrange for provision of a suitable water supply.

5.0 CLEAN-UP

After completion of the HDD installation, site-specific clean-up measures will be developed by the CI and the HDD Superintendent for approval by the EI. Potential for secondary impact from the clean-up process will be evaluated, as well as the benefits of clean-up activities.

The following measures may be used:

- Drilling mud will be cleaned up by hand using hand shovels, buckets and soft bristled brooms minimizing damage to existing vegetation.
- Fresh water washes may be employed if deemed beneficial and feasible.
- Containment structures will be pumped out and the ground surface scraped to bare topsoil minimizing loss of topsoil or damage to adjacent vegetation.
- The recovered drilling fluid will be recycled or disposed of at an approved upland location or disposal facility. Recovered drilling fluid will not be disposed of in streams or storm drains.
- All containment structures will be removed.
- Recovered materials will be collected in containers for temporary storage prior to removal from the site.

Appendix A

Information on Typical Drilling Fluid Additives

BAROFIBRE®

Seepage Loss Additive

Description

BAROFIBRE, fibrous cellulosic material, is designed to effectively seal the borehole wall in sands and fractured zones. To stop the loss of drilling fluid, the voids must be plugged so a filter cake can be formed on or in the porous rock. BAROFIBRE can be used in all types of water-based and oil-based drilling fluids. BAROFIBRE is available in two grades: regular and coarse.

Applications/Functions

- Reduce wallcake permeability and seepage loss
- Seal and bridge depleted sands and microfractures

Advantages

- Is compatible with most water-based and oil-based muds
- Has no adverse effects on rheological and filtration control properties of drilling fluids
- Will not plug drilling equipment
- Is biodegradable and nontoxic

Typical Properties

- Appearance, regular — Brown-powdered material
  Appearance, coarse — Granulated material
- Bulk density, lb/ft^3 — 31
- pH (1% aqueous solution) — 4.9
- Dry sieve analysis

	Regular	*Coarse*
Sieve size, mesh	*% through*	*% through*
5	95 min	95 min
16	85 min	60-80
20	80 min	43-63
80	41-61	7-27
200	23-43	20 max

Continued on the back

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Because the conditions of use of this product are beyond the seller's control, the product is sold without warranty either express or implied and upon condition that purchaser make its own test to determine the suitability for purchaser's application. Purchaser assumes all risk of use and handling of this product. This product will be replaced if defective in manufacture or packaging or if damaged. Except for such replacement, seller is not liable for any damages caused by this product or its use. The statements and recommendations made herein are believed to be accurate. No guarantee of their accuracy is made, however.

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Recommended Treatment

1. As a preventive treatment, add 2-10 lb/bbl (5.7-28.5 kg/m^3).
2. As a slug treatment, add 30-50 lb/bbl (85.6-142.7 kg/m^3).

Notes:

- Water-based fluids treated with BAROFIBRE should be supplemented with a biocide such as ALDACIDE® G microbiocide to control or eliminate potential bacterial contamination.
- Treatments in excess of 20 lb/bbl (57.1 kg/m^3) may cause reduction in electrical stability measurements in oil-based systems.

Packaging

BAROFIBRE regular is packaged in 25-lb (11.3-kg) sacks.

BAROFIBRE coarse is packaged in 40-lb (18.1-kg) sacks.

BARO-SEAL™

Lost Circulation Material

Description

BARO-SEAL, a combination of granules, flakes, and fibers, can be used with most water-based drilling fluids in a wide range of formations to seal loss zones. The particles are tough and retain their shape under pressure and temperature.
BARO-SEAL is specifically designed not to plug drilling equipment. It is available in coarse, medium, and fine grades.

Applications/Functions

- Seal permeable zones
- Reduce loss of whole mud

Advantages

- Mixes easily with standard rig equipment and can be pumped with the rig pumps
- Can be used with most water-based fluids
- Will not plug conventional drilling equipment

Typical Properties

- Appearance — Brown, white, and gray particles and fibers
- Specific gravity — 1.1

Recommended Treatment

1. As a slug treatment, add 30-50 lb/bbl (85.59-142.65 kg/m^3).
2. As a preventative treatment, add 5-20 lb/bbl (14.27-57.06 kg/m^3).

Notes:

- BARO-SEAL will be screened from the active drilling fluid system by shale shakers or mud cleaner. These pieces of equipment must be bypassed if BARO-SEAL is to be maintained as a preventative treatment.
- BARO-SEAL should not be used in an oil-based mud because water wetting of the solids can occur.
- Downhole tools with small tolerances may become plugged.

Packaging

BARO-SEAL coarse, medium, and fine grades are packaged in 40-lb (18.1-kg) sacks.

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FORM-A-SET™

FORM-A-SET is a one-sack blend of polymers, crosslinking agents and fibrous lost-circulation materials designed to plug matrix, and naturally fractured or vugular zones. When activated with time and temperature, FORM-A-SET produces a rubbery, ductile, spongy, soft-set gel that effectively prevents loss of fluid to the formation. The lost-circulation material in the FORM-A-SET package is a fibrous cellulose containing a wide variation of particle sizes.

TYPICAL PHYSICAL PROPERTIES

Physical appearance	Light tan powder
Specific gravity	1.20
Bulk density	32.6 lb/ft^3 (523 kg/m^3)

APPLICATIONS

FORM-A-SET, which can be used in any application where a squeeze plug would be beneficial, is particularly advantageous in areas where loss of whole mud is prevalent. FORM-A-SET may also be employed to shut off water flows and stabilize gravel sections. Equally effective in vertical and horizontal wellbores, FORM-A-SET can be weighted with M-I BAR® or FER-OX.® FORM-A-SET can be used to shut off losses to depleted sands and isolate gas/water zones. It may even eliminate the requirement for additional casing string.

FORM-A-SET may be blended with either freshwater, seawater or saltwater up to saturation. Seawater and sodium chloride tend to retard the crosslink set time. FORM-A-SET may be used to stop losses occurring with any water- and non-aqueous-base fluid systems.

RETARDER/ ACCELERATOR

Two products are available with the material to help control the setting times: FORM-A-SET RET and FORM-A-SET ACC. A retarder, FORM-A-SET RET is designed for situations requiring longer setting or pumping times and higher squeeze temperatures. FORM-A-SET ACC (accelerator) is engineered for situations where set conditions are faster and lower water temperatures will not allow the polymers to hydrate.

FORM-A-SET RET should be used with all applications above 70 to 80°F. A retarder is required when bottom-hole temperature and pumping time increase. Add the retarder to the water before adding the FORM-A-SET material. As a guideline, the typical concentration of retarder is as follows:

Bottom-Hole Temperature (°F)	FORM-A-SET RET (lb/bbl) (per makeup water)
70 - 80	—
80 - 120	4
120 - 150	6
150 - 200	10
200 - 250	16
250 - 300	18
300 - 350	20

It is important to pilot test the retarder to investigate whether the time and temperature will keep the slurry from crosslinking prematurely.

The FORM-A-SET ACC should be used to speed up the setting time of the slurry. It is used when ambient temperatures or makeup water are below 60°F. To avoid over-treatment, caution must be exercised when adding the accelerator. Suggested concentrations of 0.3 lb/bbl should be used as colder conditions demand. The FORM-A-SET ACC should be added after the dry material has been added to the water. Allow the dry material to blend thoroughly, then add the FORM-A-SET ACC to the slurry slowly to assure that it is well dispersed. It is suggested that the accelerator be diluted in 5 to 10 gal of water before adding to the FORM-A-SET slurry.

Physical Properties:

	FORM-A-SET RET	FORM-A-SET ACC
Physical appearance	Clear liquid	Dark green liquid
Specific gravity	1.323	1.4
Solubility in water	Soluble	Soluble

ADVANTAGES

Since FORM-A-SET contains crosslinking agents and polymers in the same package, FORM-A-SET RET is not required at lower temperatures. However, at increased temperature and longer pumping times, it is recommended to use a minimum concentration of 6 lb/bbl. At temperatures of 200 to 350°F, it is recommended to use 10 to 16 lb/bbl of FORM-A-SET RET. Pilot testing is suggested before pumping to obtain an estimate of time needed to create a well-set plug.

LIMITATIONS

The FORM-A-SET plug will not degrade due to bacteria or time in the wellbore, and should be used with caution in or near producing zones.

MIXING/PUMPING INSTRUCTIONS

To mix a pill of FORM-A-SET, use a clean pit or blending tank to mix the FORM-A-SET and water. Allow the mixture to stir until the entire pill has been well-dispersed. If the retarder is to be used, add it to the water before mixing the polymer, but add the accelerator after the FORM-A-SET product has been mixed.

WEIGHTED SLURRIES

Table 1 should be followed to mix FORM-A-SET slurries heavier than freshwater. Mixing order should be:

- Add the retarder before the FORM-A-SET. The retarder concentration should be proportioned to the water volume.
- Add one-half of the FORM-A-SET material.
- Add the barite.
- Add the remaining FORM-A-SET.
- Add the accelerator concentration in proportion to the water volume.

NOTE: The defoamer may be added at any time air entrapment is observed.

For unweighted slurries, add one sack (40 lb) to one bbl of water.

Density (lb/gal)	Water (bbl)	FORM-A-SET (lb/bbl)	M-I BAR (lb/bbl)
8.47	0.913	36.52	0.00
9.0	0.896	35.83	27.72
10.0	0.861	34.45	83.17
11.0	0.827	33.08	138.62
12.0	0.792	31.70	194.07
13.0	0.758	30.32	249.52
14.0	0.724	28.94	304.97
15.0	0.689	27.56	360.42
16.0	0.655	26.19	415.87
17.0	0.620	24.81	471.32
18.0	0.586	23.43	526.77

Table 1

Typical viscosities range from 120 to 160 sec/qt funnel viscosity directly after initial mixing. A defoamer, such as DEFOAM A®, should be available in case any aeration causes foaming. Avoid using any defoamer containing glycol or stearate as they might cause changes in the crosslinking mechanism.

Use approximately 20 to 30 bbl of viscosified water or mud as a spacer both ahead of and behind the pill.

Pump the pill to the annulus at the depth of loss, pull above the loss zone, being careful not to leave any pill in the pipe even if losses have stopped or slowed. *Do not shut down pumping while the pill is in the drillstring.* Watch for any sign of the pill reaching the loss zone, such as pressure increase or the return flow improving.

Pull above pill, and close annular preventer to begin squeezing. If pressure is noted, hold for at least 3 hr to obtain a firm set of the pill. Allow about 4 hr for pill to obtain maximum strength.

Total time for the job, including blending, pumping and squeezing is about 6 hr.

TECHNICAL DATA

Figure 1
FORM-A-SET Gelation Time (70°F)

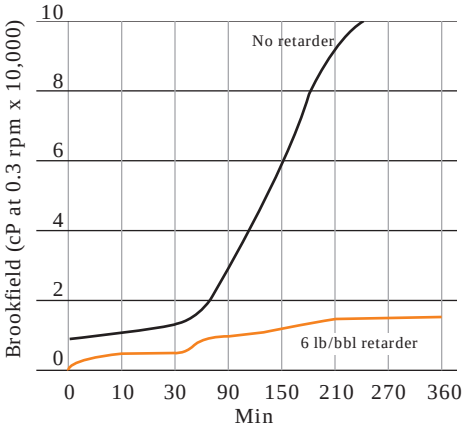
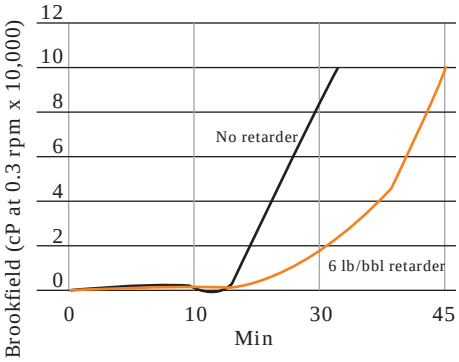


Figure 2
FORM-A-SET Gelation Time (120°F)



TOXICITY AND HANDLING

Bioassay information is available upon request.

Handle as an industrial chemical, wearing protective equipment and observing the precautions as described on the Material Safety Data Sheet (MSDS).

The use of eye and respiration protection is recommended. To remove airborne particulates, it should be used in areas with sufficient ventilation. Avoid breathing vapors.

PACKAGING AND STORAGE

FORM-A-SET is packaged in 40-lb (18.1-kg) sacks. FORM-A-SET should be stored in a dry location.

FORM-A-SET RET is packaged in 5-gal (0.019-m^3) cans. Use in a well-ventilated area and avoid breathing vapors. Store in a dry, ventilated place. Avoid breathing vapors.

FORM-A-SET ACC is packaged in 1-qt (0.946-l) containers. Use in a well-ventilated area and avoid breathing vapors. Store in a clean, dry location.

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G-SEAL®

G-SEAL graphite is a coarse-sized plugging agent used to bridge and seal permeable formations in water-, oil- or synthetic-base mud systems. When drilling depleted zones where high differential pressures exist, the bridging and plugging capabilities of G-SEAL reduce differential-pressure sticking tendencies. It can be used to control seepage in partial to severe lost-circulation zones. G-SEAL is completely inert and does not affect rheological properties. G-SEAL reduces torque and drag by increasing the lubricity. G-SEAL lowers the spurt and total filtrate loss values in PPT and sandbed laboratory studies.

TYPICAL PHYSICAL PROPERTIES

Physical appearance · · · · · · · · · · · · Dark, gray to black powder
Specific gravity · · · · · · · · · · · · · · · · 2.19 - 2.26
Solubility in water @ 68°F (20°C) · · · Insoluble

Typical Particle Size Analysis (Standard Dry Sieve Analysis)

Micron Size Range*	Weight Percent in Range	Undersize Mesh	Weight Percent Undersized
2,000 - 840	0	Finer than 20 mesh	100
840 - 420	8.7	Finer than 40 mesh	91.3
420 - 250	39.7	Finer than 60 mesh	51.6
250 - 177	34.0	Finer than 80 mesh	17.6
177 - 149	12.0	Finer than 100 mesh	5.6
149 - 73.7	5.0	Finer than 200 mesh	0.6
73.7 - 44.5	0.1	Finer than 325 mesh	0.5
44.5 - 38.1	0.1	Finer than 400 mesh	0.4

*Median (microns) = ± 250.

APPLICATIONS

G-SEAL is designed to bridge and seal permeable formations, reducing the possibility of differential sticking, controlling lost circulation and increasing lubricity.

The recommended treatment for seepage losses (<10 bbl/hr) is 15 to 20 lb/bbl (43 to 57 kg/m^3) in spotted pills. The pills can be incorporated into the entire system for a total concentration of 5 to 10 lb/bbl (14 to 29 kg/m^3). However, when the pill returns to the surface, the shaker screens must be monitored for losses and changed if possible. If changing shaker screens is not practical, the pill can be diverted to a standby pit when it returns to the surface, reconditioned and used again as a spot or sweep.

The recommended treatment for partial losses (20 to 50 bbl/hr) is 20 to 50 lb/bbl (57 to 143 kg/m^3) in spotted pills. G-SEAL can be used in combination with other lost-circulation materials to control partial to severe losses. Very high permeability formations such as fractured carbonates and conglomerate zones may require additional spots in conjunction with a variety of lost-circulation materials of varied particle size distribution.

APPLICATIONS (CONTINUED)

Torque and drag may be reduced by incorporating G-SEAL spots and sweeps into the active system up to a total concentration of 10 lb/bbl (29 kg/m^3). Initial treatments for the active system may be added at 2 lb/bbl (5.7 kg/m^3) increments while monitoring torque and drag.

G-SEAL may require additional wetting agent when used in an oil- or synthetic-base mud system.

ADVANTAGES

- Effective bridging and sealing agent for a wide range of formations and severity of losses.
- Controls seepage losses, thereby reducing the possibility of differential sticking.
- Increases lubricity to reduce torque and drag in all mud systems.
- Inert material with no adverse effects on mud rheology and compatible with all mud systems.
- One-sack product with no other additive requirements and easily mixed and dispersed into the system.
- Temperature-stable to more than 500°F (260°C).

LIMITATIONS

- Can be removed from the circulating system by shale shakers and other solids-control equipment. Requires close monitoring of the shale shakers.
- Non-acid soluble material may not be suited for open hole completions where acid solubility is required.

TOXICITY AND HANDLING

Bioassay information is available upon request.

Handle as an industrial chemical, wearing protective equipment and observing the precautions as described on the Material Safety Data Sheet (MSDS).

PACKAGING AND STORAGE

G-SEAL is packaged in 50-lb (22.7-kg), multi-wall, paper sacks and needs no special storage requirements.

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HY-SEAL®

Lost Circulation Material

Description

HY-SEAL, shredded cellulosic fiber, can be used to reduce lost circulation in water-based fluids. When combined with lost circulation materials made of coarser fibers, HY-SEAL rapidly bridges between the coarser fibers and speeds formation of the seal when larger openings in the formation are taking fluid.

Applications/Functions

HY-SEAL can be used to reduce lost circulation in porous sands and fine gravels.

Advantages

- Disperses rapidly
- Does not separate out of or float in clear-water fluids
- Quickly seals porous formations

Typical Properties

• Appearance	Gray fiber
• Specific gravity	1.4

Recommended Treatment

1. For normal treatment, add 5-15 lb/bbl (14.27-42.80 kg/m^3) of HY-SEAL.
2. As a pill, add 20-40 lb/bbl (57.06-114.12 kg/m^3) of HY-SEAL.

Packaging

HY-SEAL is packaged in 40-lb (18.1-kg) sacks.

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LOST CIRCULATION MATERIALS

CEDAR FIBER

Cedar Fiber is a specially processed blend of fibers of controlled length, giving proper size distribution for regaining circulation.

- Non fermenting
- Amounts used vary from 1% to 35% by volume.

PACKAGING
40 pound bags (18 Kg.)

MICA

Mica is a selected, non-abrasive mineral available in fine and coarse grades. Mica has no adverse effect on mud properties. Mica is used to prevent and regain lost returns. Fine Mica will pass through a 20 mesh screen.

APPLICATION
Lubricity: 1-5 pounds (.45-2.25 Kg.) Lost circulation: 5-15 pounds (2.25-6.75 Kg.)

PACKAGING
50 Lb. sacks (22.68 Kg.)

DRILL PAPER

Drilling paper is a blend of variable-sized particles of ground paper that is applicable for use in all water base mud systems.

Drilling paper can be used in concentrations of up to 20 lb./bbl (57 Kg/m^3) in slug treatments or as an additive to the entire system. In areas of known lost circulation zones, it is advisable to pre-treat the system before drilling into the zone of loss. Drilling paper can be mixed through the mud hopper or added directly to the pits and gunned into the mud.

The most important aspect of combating lost circulation is utilizing the correct particle size. Consequently, it is recommended that a combination of materials be added to ensure a good particle size distribution. If left in the mud for an extended period of time, Drilling paper may be susceptible to bacterial degradation. To prevent fermentation, a bactericide may be necessary.

PACKAGING
40 pound plastic sacks (18 Kg.)

COTTONSEED HULLS

Cottonseed Hulls are fibrous, biodegradable materials that are excellent bridging agents when large particle-size materials are needed. They may be used in any water base mud system.

Cottonseed Hulls are used in concentrations of up to 20 Lb./bbl (57 Kg/m^3) as slug treatments or as an additive to the entire system. In areas of known lost circulation zones, it is advisable to pre-treat the system before drilling into the zone of loss. Cottonseed Hulls can be mixed through the mud hopper or added directly to the pits and gunned into the mud. The most important aspect of combating lost circulation is utilizing the correct particle size. Consequently, it is recommended that a combination of materials be added to ensure a good particle size distribution. If left in the mud for extended periods of time, Cottonseed hulls may be susceptible to bacterial degradation, resulting in the release of H_2S and CO_2 into the mud. To prevent fermentation, a bactericide may be necessary.

PACKAGING
50 pound (22.68 Kg.) and 100 pound (45.37 Kg.) burlap or paper sacks

MULTISEAL

MultiSeal is an engineered lost circulation material containing an optimum blend of granular, fibrous and flake materials. MultiSeal is available in three grinds (coarse, medium and fine) covering a wide range of lost circulation problems. MultiSeal is normally recommended in concentrations of 20-30 Lb./bbl (57-86 Kg/m^3) mixed in a slug of 100-200 barrels and spotted at the zone of loss, displacing the slurry at a reduced pumping rate with either large nozzles or open ended. MultiSeal can be added to either the water based mud being used at the time of loss or in any special purpose slurry prepared for squeeze applications. MultiSeal has been used for preventative measures or as a "filler" because the fine grade will pass through 20 mesh shaker screens in concentrations of 2-10 Lb./bbl (6-28 Kg/m^3).

LIMITATIONS
Do not mix in oil muds

PACKAGING
40 Lb. (18 Kg.) multi-walled paper sacks

TOXICITY
Bioassay information available upon request.

MACRO-FILL™

SOLIDIFICATION AND LOSS CIRCULATION MATERIAL

DESCRIPTION

MACRO-FILL is a granular, advanced super-absorbent material that rapidly absorbs and retains large volumes of water from aqueous solutions. MACRO-FILL will absorb 7 to 10 times its weight but only expand 1% in volume.

RECOMMENDED USE

MACRO-FILL is ideally suited for solidification and stabilization of drilling fluids, wastewater, and sludge. MACRO-FILL is also a superior lost circulation material.

CHARACTERISTICS

- Seals large and fine fractures and highly permeable and porous formations.
- Absorbs 100 times its own weight in water.

MIXING AND APPLICATIONS

Solidification Aid	Add 4-5 lbs per 100 gallons liquid.
Loss Circulation	Pre-mix 8-12 lbs in thinned fluid on surface and pump quickly to discrete depth via tremie pipe. Allow time for MACRO-FILL to expand before proceeding with drilling.

PACKAGING

14 lb pail, per pallet or 55 lb bag, 36 per pallet. All pallets are plastic-wrapped.

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All weights are approximate. The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information. REV 1/09

MAGMA FIBER™

DESCRIPTION

MAGMA FIBER is a specially formulated, extrusion spun mineral fiber. This coarse, long flexible fiber will give increased circulation by bridging and plugging off voids, fractures, and all types of permeable formations.

MAGMA FIBER is compatible with all oil and water based muds and emulsion. The interlocking nature of these strong fibers provides a framework for forming a low permeable mud cake with a resultant reduction in drilling fluid loss and hole caving. Low alkaline, flexible, inorganic MAGMA FIBER is inert to drilling fluids. This fiber is non-corrosive to equipment while maintaining high-solubility diluted hydrochloric acid. It is particularly adaptable to rework operations.

MAGMA FIBER is coated with a mono-molecular film of a specially formulated surfactant (that speeds separation of the fibers), then formed into nodules. These nodules are formed into loosely connected groups so that when they are immersed in drilling fluids and subjected to agitation the nodules separated into the individual fibers. Acid soluble, easily wetted, non-combustible, non-fermenting, inorganic, non-polluting, non-corrosive, non-toxic, temperature stable, and contains no asbestos.

TYPICAL CHEMICAL ANALYSIS

COMPOSITION	% WEIGHT
SiO_2	38-42
Al_2O_3	9-12
CaO	31-40
MgO	8-15
Fe_2O_3	0-10
Total alkalines as Na_2O	1-2
SO_3	0.5 or less
pH in water	7.0-8.0
Loss on ignition	Less than 0.5
% water soluble	Less than 0.2
Water soluble sulfate	Less than 0.05
Melting point	2400 ˚F

APPLICATIONS

MAGMA FIBER can be used in concentrations of up to 30 + lb/bbl in slug treatments or as additive to entire system. MAGMA FIBER has been used in concentrations of 0.5 bag every 30 minutes for ongoing seepage, to concentrations of 5-15 lb/bbl for seepage/partial or total losses. MAGMA FIBER is particularly suitable for oil base mud. When more than 6-10 bags are mixed at once, a man should be at the shaker screen when the slug comes around (to clean or bypass the shaker screen). MAGMA FIBER can be used in all oil and water base mud systems. MAGMA FIBER should be added directly into pits and gunned Into the mud, it can be mixed through the mud hopper but it is much slower.

LIMITATION

When acid solubility is not important, a combination of materials can be added to ensure a good particle size distribution.

PACKAGING

25 lb bag, 40 per pallet. All pallets are plastic-wrapped.

2870 Forbs Avenue ■ Hoffman Estates, IL 60192 ■ P 800.527.9948 ■ F 847.851.1332 ■ www.cetco.com/dpg

All weights are approximate. The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information. REV 1/09

Country(s) or region	Inventory name	On inventory (yes/no)*
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

A "Yes" indicates that all components of this product comply with the inventory requirements administered by the governing country(s)

State regulations WARNING: This product contains a chemical known to the State of California to cause cancer.

16. Other Information

Further information This safety datasheet only contains information relating to safety and does not replace any product information or product specification.

HMIS ratings

NFPA ratings
Health: 0
Flammability: 0
Instability: 0

Disclaimer The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The manufacturer expressly does not make any representations, warranties, or guarantees as to its accuracy, reliability or completeness nor assumes any liability, for its use. It is the user's responsibility to verify the suitability and completeness of such information for each particular use.

Third party materials: Insofar as materials not manufactured or supplied by this manufacturer are used in conjunction with, or instead of this product, it is the responsibility of the customer to obtain, from the manufacturer or supplier, all technical data and other properties relating to these and other materials and to obtain all necessary information relating to them. No liability can be accepted in respect of the use of this product in conjunction with materials from another supplier.

Issue date 19-December-2008

MULTI-SEAL™

BLENDED LOST CIRCULATION MATERIAL

DESCRIPTION

MULTI-SEAL is a select blend of four types of materials normally used for lost circulation. A flake material (cellophane), a granular material (nut shells), fine fibrous material (DRAGNET), and coarse fibers (cedar fibers). MULTI-SEAL is blended in the proper ratio to produce the most effective seal. MULTI-SEAL contains no fermenting materials or materials that chemically change the rheological properties of the fluid, even polymer mud's.

RECOMMENDED USE

MULTI-SEAL is used to stop the most costly loss returns which are the unexpected. MULTI-SEAL plugs formations that contain fractured sandstones, unconsolidated or highly permeable formations, natural fractures or voids, and cavernous type loss zones. MULTI-SEAL was specially formulated for all loss circulation conditions.

ADVANTAGES

- Assists in forming a fast effective bridge
- Blended to have the proper particle size for maximum plugging
- Most effective loss circulation material available
- Regains circulation quickly

CHARACTERISTICS

Appearance:

- coarse fibers (cedar fibers)
- fine fibrous material (DRAGNET)
- flake material (cellophane)
- granular material (nut shells)

MIXING AND APPLICATION

MULTI-SEAL concentrations will vary in different type fluids depending on weight and viscosity. As a preventive measure in concentrations of 2-10 lbs per 200 gallons. As a "pill" mixed with the mud being used at concentrations of 15-20 lbs per 200 gallons. These are recommendations only. The concentrations will vary depending on the mud weight, viscosity, and type of loss circulation involved.

PACKAGING

40 lb bag, 60 per pallet. All pallets are plastic-wrapped.

All weights are approximate. The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information. REV 1/09

N-SEAL™

Lost Circulation Material

Description

A acid soluble lost circulation material N-SEAL is specially formulated extrusion spun mineral fiber.

N-SEAL is compatible with all oil and water based mud systems. Nodules are formed into loosely connected groups so that when they are immersed in drilling fluids and subjected to agitation the nodules separate into individual fibers. Due to its solubility in weak acids, N-SEAL is easily removed in production reservoirs.

Applications/Functions

N-SEAL can be used in concentrations of up to 30 lb/bbl (85.6 kg/m^3) in slug treatments or as additive to entire system.

- Seepage control
- Bridging
- Plugging voids
- Fractures
- Work over operations
- Oil muds
- Water muds
- Completion fluids
- Cement additives

Advantages

- Acid soluble
- Easily-wetted
- Non-combustible
- Non-fermenting
- Inorganic
- Non-polluting
- Non-corrosive
- Non-toxic
- Temperature stable
- Contains no asbestos

Continued on the back

N-SEAL is a trademark of Halliburton Energy Services, Inc. • © Copyright 1998, 1999, Baroid, a Halliburton Company • 5/99 • DN 018

Because the conditions of use of this product are beyond the seller's control, the product is sold without warranty either express or implied and upon condition that purchaser make its own test to determine the suitability for purchaser's application. Purchaser assumes all risk of use and handling of this product. This product will be replaced if defective in manufacture or packaging or if damaged. Except for such replacement, seller is not liable for any damages caused by this product or its use. The statements and recommendations made herein are believed to be accurate. No guarantee of their accuracy is made, however.

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Typical Properties

- Appearance — Gray white fiber
- Specific gravity — 2.6

Recommended Treatment

1. N-SEAL can be added directly through the hopper.
2. For normal treatment, add 5-8 lb/bbl (14.3-22.8 kg/m^3) of N-SEAL.
3. As a pill, add 15-30 lb/bbl (42.8-85.6 kg/m^3) of N-SEAL.
4. N-SEAL is 98% acid soluble in 7.5% HCl or a blend of HCl and acetic acid.

Packaging

N-SEAL is packaged in 30-lb (13.6-kg) sacks.

PLUGZ-IT™/MAX

Certified to NSF/ANSI 60

PLUGZ-IT™/MAX is a lost circulation material designed to mix and pump with a drilling fluid into cobble, gravel, or fractured zones to restore mud circulation. Based on the original PLUGZ-IT™ material, PLUGZ-IT™/MAX is a coarser product engineered specifically for use in vertical drilling operations. It readily seals off coarse gravels, fractured formations, and other profiles where mud-loss is a problem. PLUGZ-IT™/MAX can be placed directly through the jets in the bit provided they are a minimum of 3 mm or 1/8" in size. PLUGZ-IT™/MAX ax is environmentally safe and non-toxic.

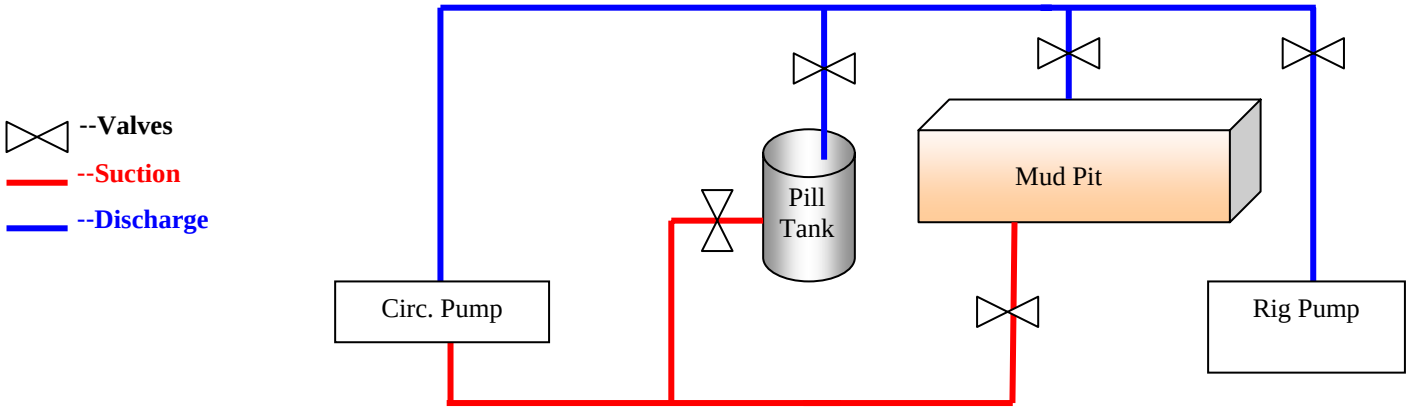
APPLICATION:

A. As a **Pill:** In a separate ("pill") tank, mix EXTRA HIGH YIELD™ to a Marsh Funnel Viscosity of 45 to 65 seconds. Add PLUGZ-IT™/MAX at a rate of 20 to 40 pounds per 100 gallons. Mix in small batches, 50 to 100 gallons at a time.

1. Add PLUGZ-IT™/MAX slowly into "Pill" tank and circulate for 1 to 2 minutes.
2. Once the appropriate quantity is added, quickly pump from the "Pill" tank into place, pulling the drill steel back slowly as the mixture is pumped into the loss zone.
3. Pump pressure should remain elevated while pumping to insure PLUGZ-IT™/MAX is being squeezed into fractured or unconsolidated zones.
4. Once all the material is in place, pullback 5 to 10 feet and continue to pump in order to purge the drill string. Once in place the PLUGZ-IT™/MAX pill should set for 20 to 30 minutes, allowing for complete hydration and swelling to take place. Circulation should be restored at this point.
5. Advance back into the hole slowly, using low pump pressure, circulating as you progress and continue the drilling operation. If mud loss is still a problem, repeat the process.

B. At this first sign of mud loss, PLUGZ-IT™/MAX can be added slowly at the suction to be carried by the fluid into the loss zone.

MIXING SCHEMATIC



PLUGZ-IT™/MAX is conveniently packaged in 30-pound multi-walled paper bags.

WYO-BEN, INC. P.O. Box 1979 Billings, Montana 59103

Internet: www.wyoben.com email@wyoben.com 800-548-7055 or (406) 652-6351

SABAL TRAIL PROJECT

Karst Mitigation Plan

FERC Docket No. CP15-17-000

February 16, 2015

Revision 1.0

KARST MITIGATION PLAN

TABLE OF CONTENTS

1. INTRODUCTION 1
2. KARST RISKS ASSOCIATED WITH PIPELINE CONSTRUCTION 1
3. IDENTIFICATION OF KARST FEATURES 6
4. EVALUATION OF THE POTENTIAL FOR SINKHOLE DEVELOPMENT 7
5. EVALUATION OF KARST FEATURES 7
6. EVALUATION OF RESULTS 10
7. MITIGATION OF CONSTRUCTION RELATED KARST ISSUES 26
8. GLOSSARY 31

KARST MITIGATION PLAN

1. INTRODUCTION

Sabal Trail Transmission, LLC (Sabal Trail), is proposing to design, construct and operate a natural gas pipeline (the Project) that will extend approximately 509 miles through portions of Alabama, Georgia, and Florida. Mitigation is being conducted to assess and minimize karst related issues that may arise during construction and operation of the Project. Karst conditions and sinkhole development are potential issues at various locations along the proposed pipeline alignment and at pipeline facilities.

Avoidance was used as the primary mitigation measure during the planning and selection of the proposed alignment. Where avoidance is not feasible, the karst features identified were further evaluated and remediation measures developed. In addition, field survey, testing and evaluations were conducted at each of the proposed above-ground facilities (compressor and meter stations) and horizontal directional drilling (HDD) locations to evaluate design and support of the proposed facilities and the potential for sinkhole development. Response plans for sinkholes, depressions or other karst related issues that may arise during construction or operation of the Project have also been prepared and have been included as part of the overall mitigation plan.

2. KARST RISKS ASSOCIATED WITH PIPELINE CONSTRUCTION

Sinkholes are naturally occurring phenomena in areas underlain by carbonate bedrock, such as the limestone formations associated with the Floridan aquifer, in the southeastern United States. Most sinkholes are triggered by external factors such as significant or prolonged rainfall, periods of drought, heavy groundwater pumping, or stormwater management practices. Experience with pipeline installation in the area has shown that the frequency of localized subsidence occurrences will be low and the scale of the features will be small enough to ensure that remediation efforts will not be complicated. The following addresses the risks associated with different aspects of Project construction.

2.1. Pipeline

The majority of the proposed pipeline will be constructed with conventional cut and cover techniques, where a length of trench is excavated, the pipe is placed and connected to the previous section, and the trench is backfilled with material excavated from the trench. While, there is some potential for unknown karst features to be encountered during pipeline installation, the probability that these features will be large in scale or that sinkholes or surface depressions in areas outside the immediate excavation area will be low. Exposed karst features discovered during pipeline installation can be readily identified, evaluated and remediated.

Hydrostatic testing performed during pipeline construction can introduce significant amounts of water to the area. Mitigation measures for managing hydrostatic test water in the vicinity of karst features are discussed in the Remediation Section (Section 7) of this report.

2.2. Facilities (Compressor and Meter Stations)

Above ground facilities associated with the Project include compressor and meter stations. The structures associated with these facilities will be constructed with typical and proven methods utilized throughout the project area. The majority of the structures can be supported by shallow foundations bearing within compacted in-place residual soils. Compaction of the native soil used to support the building foundations will be performed from the ground surface with conventional construction equipment.

Heavier equipment or structures with larger structural loads may require support from a deep foundation system. Driven displacement piles are the proposed deep foundation system for support of the heavier project structures. Steel sections such as pipe and H-piles are preferred over concrete sections in areas where the depth to bearing may be variable. Other methods of deep foundation support include auger cast piling and drilled shaft foundations.

As an alternative to deep foundation systems for support of Project structures, ground improvement methods such as compaction grouting and vibro-replacement (stone columns) are being considered. These methods improve the subsurface materials and allow for the use of conventional shallow foundation systems such as mats, footings and slabs-on-grade. Compaction grouting can also be used as a means to reduce the potential for sinkhole development at a given site or within a proposed building footprint.

Standard stormwater management practices will be employed during design and construction of ponds required for stormwater retention/detention. However, in karst sensitive areas, shallow ponds with larger surface areas may be considered, where feasible, to mitigate the risk of affecting aquifer confining units. Ponds will be located away from structures to the extent possible or at least the distance of typical sinkhole dimensions for the area. In addition, direct rainfall on impervious areas will be diverted away from building and equipment foundations.

2.3. HDD Crossings

Sabal Trail has consulted with nationally recognized horizontal directional drilling (HDD) contractors with experience completing HDD installation in the Project's region, as well as other karst areas, to help evaluate the potential risks to the Project and to develop mitigation measures that may be employed during construction.

Areas of karst activity pose increased risks to the successful installation of pipelines by HDD. While the risk of impacts to the environment or a failed installation may be increased in karst areas, mitigation measures, proven on other projects, have been identified and will be employed during all phases of the project from routing through construction to lower these risks to help ensure successful pipeline installations. Although there are increased risks associated with HDD installations in karst areas, numerous HDD pipeline installations have been successfully completed at sites subject to karst activity, including in central Florida. Just a few examples are Florida

Gas Transmission multiple pipeline crossings of Santa Fe River and Suwannee River in Florida, Southern Natural and Dixie pipeline crossings of Flint River in Georgia.

The general risks associated with HDD construction methods in karst areas include difficulties arising from very loose unstable soils and open voids along the drill path. More specifically, these risks include:

- Loss of drilling fluid into open conduits and inadvertent drilling fluid returns leading to turbidity in nearby wells, springs, and rivers.
- Ground subsidence and possible sinkhole formation due to excavating zones of loose unstable soils.
- Stuck drill tooling and the possibility of the carrier pipe becoming stuck in loose unstable zones during pullback.

2.3.1. Lost Drilling Fluid Returns

Drilling fluid is circulated through the drilled hole during horizontal directional drilling operations. Water based bentonite drilling fluids are an integral part of a successful HDD operation and are used to lubricate and cool the downhole tooling, suspend and transport cuttings to the surface, and stabilize the borehole by forming a thin layer of clay on the inside of the hole (wall cake). Additionally water based bentonite drilling fluids help maintain the open hole condition by offsetting the formation's geostatic pressure with increased hydrostatic pressure. The clay in drilling fluid utilized for HDD operations is composed of bentonite, which is a naturally occurring clay mineral that absorbs several times its weight in water. When mixed with water in measured quantity, bentonite augments and optimizes the engineering properties of the mixture to support HDD operations in specified geological conditions.

While drilling fluid loss to conduit and cave systems is possible in karst affected areas, site characterization of the HDD sites does not suggest that cave systems will be directly encountered along the HDD profiles. In addition, there is only one spring located within 2,000 feet of the HDD crossing of the Suwannee River (Suw923972, 4th Magnitude). It is recognized that small conduits feeding cave systems could be encountered along the HDD profiles; however, these conduits are not always "open" but could be a series of interconnected small-diameter fractures or channels filled with permeable sediments that create a preferential pathway for groundwater flow. In some instances, loss of drilling fluid from the borehole to these conduits will subside over time as the drilling fluid builds a layer of bentonite in the borehole and seals it to further flow. Drilling fluid properties will be managed, on a site specific basis, to ensure that they are optimal for the conditions being encountered.

The partial or full loss of drilling fluid may also occur as a result of encountering loose unstable zones of soil that have in-filled existing

sinkholes or by intersecting conduits or voids. In zones of loose unstable soil, the properties' of drilling fluid may be augmented to aid in stabilizing the soils and in maintaining drilling fluid returns to the entry and/or exit pits. If open voids are encountered along the HDD path, a temporary loss of drilling fluid returns can be expected until the fluid being pumped into the borehole fills the cavity and drilling fluid returns are restored. In the event that conduits intersect the HDD path, lost circulation materials (LCMs) may be used in an attempt to seal around the borehole and prevent drilling fluid from escaping into the formation and allow for the reestablishment of drilling fluid returns to the entry and/or exit pits. Many types of LCMs are available for use during HDD operations that are inert and environmentally benign. These can include wood fibers, cotton seed husks, ground walnut shells and other natural materials.

Special polymers that swell to several times their original size when introduced to water can also be used. These polymers are industrial grade equivalents of food grade polymers that are used to swell and absorb fluids in the food industry. The type of products used is typically left to the discretion of the HDD Superintendent and the Environmental Inspector. These products are readily available should the need arise.

Grout and concrete plugs have been successfully utilized to fill subsurface voids and conduits to restore drilling fluid returns and stabilize the borehole during HDD operations. The details of how grout plugs are installed are highly dependent on conditions encountered during HDD operations. There are many types of equipment, methods and materials to successfully install a grout plug and their use will be determined on a case by case basis by a specialty grouting contractor. Potential short-term impacts to groundwater quality resulting from grout plug installation would be negligible because the grout will set up after a short time.

2.3.2. Fracture and Conduit Size Limitations for HDD

Successful installation of pipelines using HDD methods requires sufficient stability of the borehole to allow the passage of the pipe during pullback operations. In mature karst areas, fractures and conduits are present within the limestone bedrock units that could pose risks to the successful completion of the pipeline installation. When designing HDD installations in rock formations, the key characteristic of the bedrock which determines how stable the formation will be during drilling and pullback operations is the rock quality designation (RQD). Rock core samples are typically recovered from exploratory hole in 5 to 10-foot intervals referred to as core runs. RQD is a measure of the fracture spacing of the formation and is expressed as a percentage value. RQD is calculated by dividing the total length of rock core pieces over 4 inches in length recovered from a core run by the total length of the core run.

In competent rock formations, RQD values less than 50 percent provide evidence that borehole stability during HDD operations may be compromised, which introduces risk of difficulties during construction. In the karst limestone formations expected along sections of the pipeline alignment, RQD values less than 50 percent do not necessarily present a large risk of borehole instabilities. The lower RQD values in these formations, which may be due to reduced core recovery in weathered and poorly cemented/in-filled zones of the formation that wash away or are broken during the coring process are not necessarily detrimental to borehole stability during HDD operations. The identified fracture traces that intersect the HDD crossings of the pipeline alignment may be zones where more weathering of the limestone has occurred. The weathered state of the formation does not negate the feasibility of successfully completing the installations.

Open conduits can present a risk of stuck and/or lost tooling in the borehole during HDD operations. In karst-sensitive areas, conduits in the limestone formations feed groundwater to springs in the region. Near the mouth of these springs, the conduits can be large enough to be explored by divers. Essentially, the springs are fed by irregular networks of smaller conduits that become increasingly smaller with distance from the spring. Because of the distance the HDD sites are from the nearest documented springs, as discussed in Resource Report 2, it is anticipated that any conduits encountered will be less than a few feet in size. Additionally, evidence of large open voids or conduits was not observed during site characterization activities.

When estimating the type and width of subsurface voids that can be successfully spanned, consideration must be given to the type, strength and rigidity of drilling tooling and mainline pipe. During consultations with HDD contractors experienced in karst-sensitive areas, it has been determined that open conduits or voids of approximately 15 feet or less in diameter have been successfully spanned utilizing similar tooling and in similar conditions as those expected on the proposed Sabal Trail Project. Voids of this nature can be successfully spanned because the stiffness/strength of the downhole tooling and mainline pipe is sufficient to allow drilling operations to continue without compromising the geometry of the hole, the integrity of the tooling or mainline pipe.

2.3.3. Sinkhole Development from HDD Operations

HDD operations could trigger or reactivate sinkhole activity where the borehole passes through loose, unstable soils that have in-filled existing sinkholes, where the borehole passes through the throat of an in-filled sinkhole, or where soil in-filling in conduits is removed by circulation of drilling fluid. This occurs through a process of over-mining where the loose soil continues to ravel into the drilled hole, similar to how sand passes through the constriction in an hourglass. As drilling fluid is circulated through the borehole, loose soils are entrained into the drilling fluid and carried out of the

hole. This process can eventually lead to the activation or reactivation of ground settlement. Proven techniques, used throughout the HDD industry, will be implemented on a site specific basis.

3. IDENTIFICATION OF KARST FEATURES

Sabal Trail assembled a team of Georgia and Florida karst experts to identify and investigate karst features in proximity to the proposed pipeline alignment, above-ground facilities, and HDD crossings. The team is led by Ian Kinnear of PSI and Gregg Jones of Cardno ENTRIX. Ian Kinnear, P.E., has 36 years of geotechnical experience in and around the pipeline alignment specializing in ground improvement techniques and procedures to repair and restore areas where sinkholes have occurred. Gregg Jones, P.G., is a karst hydro geologist with 28 years of experience investigating springs, sinkholes, fractures, and the flow system of the Floridan aquifer in north and central Florida.

The karst team contacted numerous agencies to obtain information and data including the Florida Geological Survey, the Georgia Environmental Protection Division, the Suwannee River Water Management District, and the Southwest Florida Water Management District. Potential karst features including sinkholes, fracture traces, springs and springsheds were identified by reviewing regional published geologic and geotechnical data; aerial photography; and sinkhole, closed depression, and springs databases. In addition, training of field and survey crews was conducted to assist them in identifying topographic or other indicators of possible sinkhole activity. Several features were identified during survey of the proposed alignment and facilities.

3.1. Sinkholes

Within a 0.5 mile-wide corridor centered on the proposed pipeline centerline, more than 1,500 closed depression features were identified in Florida and more than 150 were identified in Georgia. The proposed alignment in Alabama does not cross limestone formations so no karst features were identified there. Some of the closed depression features may be quarries and excavations, but most are true karst sinkholes. The majority of these features are relatively small and located at significant distances from the centerline of the proposed pipeline.

3.2. Fracture Traces

Fracture traces were located by identifying large-scale parallel lines of sinkholes and river segments on aerial photographs. Fracture traces of significant scale that intersected the proposed pipeline alignment were identified in Florida (Hamilton, Madison, Suwannee, Gilchrist, Alachua and Levy Counties) and in the counties in Georgia where the Floridan aquifer was mostly unconfined (Terrell, Dougherty, Brooks, and Lowndes Counties).

3.3. Springs

A search of the Florida Department of Environmental Protection springs database for springs located within 2000 feet of HDD crossings was conducted. Only one

spring, Suw923972, a 4th magnitude spring located approximately 1,040 feet from the HDD crossing of the Suwannee River, fit these criteria.

4. EVALUATION OF THE POTENTIAL FOR SINKHOLE DEVELOPMENT

The general geologic conditions in each county traversed by the alignment were evaluated and assigned a risk ranking (low, medium, or high) regarding the potential for sinkhole development. Due to the varied geologic conditions in some counties, they were assigned more than one category. In general the risk criteria for the three rankings are as follows:

LOW The probability of an occurrence is unlikely. Although historical occurrences may have been reported or documented in the area, they are infrequent and recent activity is low or insignificant.

MEDIUM Historical occurrences are well documented and conditions favorable to development are believed to be present.

HIGH Historical occurrences are common and frequent and conditions favorable to development are present and well documented.

Natural factors that influence sinkhole risk in any given area include the depth to rock, the composition of the overburden soils above the rock (confined with clayey soils present over the rock or unconfined with essentially sands from the ground surface to top of rock), recharge potential, presence and concentration of fractures, and the potentiometric surface elevation of the aquifer. These factors were taken into consideration while assessing the sinkhole risk in each county. The most significant human-caused influence that can significantly increase sinkhole collapse/risk in any given area is water management; either through heavy pumping of groundwater or directing significant stormwater run-off to isolated ponds.

In addition, the most common types and dimensions of surface depressions formed by sinkholes within the general area were identified. The assigned risk rankings, general geologic conditions and most common sinkholes on a county by county basis along the entire alignment are summarized in Resource Report 6.

5. EVALUATION OF KARST FEATURES

From the list of closed depression and fracture-related sinkholes in Georgia and Florida discussed previously, a subset of features thought to be representative of the types of sinkhole features that would be encountered along the alignment, were selected for further investigation and analysis. The karst features selected as being representative span sections of the pipeline alignment in Georgia and Florida and encompass cover-collapse, subsidence, and solution sinkhole-type features and various depths of aquifer confinement and cover expected along the alignment. These representative sinkholes, possible sinkhole activity identified by field crews, proposed above-ground facilities, and HDD river crossings were investigated using geophysical and geotechnical techniques to provide data that will assist with pipeline design and evaluation of karst features or activity that may affect pipeline

construction or operation. These features, facilities, and river crossings are listed and discussed in greater detail in Tables 1, 2, and 3.

From the results of these investigations, mitigation measures were developed that will be utilized to insure the stability of these features if they cannot be avoided during pipeline construction. Mitigation measures are included in Section 7.

5.1. Description of Geophysical and Geotechnical Evaluations

Geophysical testing involves the subsurface site characterization of the geology and geological structure beneath the surface based on the lateral and vertical mapping of physical property variations that are remotely sensed using non-invasive technologies. Geophysical techniques are typically not utilized in more traditional geotechnical studies for pipeline construction outside of karst areas, but are considered a necessary inclusion to support mitigation measures in karst-sensitive areas.

Ground penetrating radar (GPR) and electro-resistivity imaging (ERI) surveys were used at the representative karst features selected along the proposed alignment, proposed facility sites, HDD crossings, and possible sinkhole features identified by field personnel.

When using geophysical tools, variations in properties of subsurface materials cause man-made energy wave speed changes and partial energy reflections. Variations in soil resistivity are measured and these reflections or changes are mapped to create a two-dimensional profile. Down-warping of the profile, variations in reflection depth or changes in resistivity are indications of possible raveling or sinkhole activity. These indicators are identified as anomalies in the general or typical soil profile. The term anomaly describes a layer or pocket of subsurface material that has properties different than the surrounding soil.

Advantages of geophysical testing include the ability to evaluate large areas in a short timeframe while limiting destructive or intrusive conventional sampling methods. Once anomalies, which may be indicative of deeper geologic problems, are identified by the geophysical testing, the subsurface conditions can be confirmed and further evaluated by geotechnical assessment by drilling and sampling conventional soil borings.

The geotechnical evaluation used for Sabal Trail involved the performance of soil test borings to further investigate anomalous conditions identified by the geophysical testing. The borings were carried out using rotary wash procedures and sampled using standard penetration test (SPT) procedures. The borings were extended at least 10 feet into competent limestone or a minimum of 10 feet below the deepest pipeline element or construction depth, whichever was greater, to evaluate foundation support requirements and sinkhole risk. The field data was then reviewed and an assessment was made as to whether ground improvement/modification is needed to remediate potential sinkhole formation or reduce sinkhole risk.

Used together, geophysical and geotechnical assessments provide Sabal Trail with a strong understanding of subsurface conditions and the ability to develop a confident design and construction strategy.

5.2. Pipeline Construction - Evaluation of Representative Karst Features

Each of the representative karst features was given an initial risk ranking (low, medium, or high) in general accordance with the definitions and procedure for the county rankings discussed previously. A two phase testing program was developed for each feature to further define the potential risk. The initial phase, which included geophysical testing using GPR and/or ERI, provided further insight into the depth, extent and morphology of the features and anomalous conditions that require further evaluation. The second phase included the performance of soil test borings to better define subsurface conditions and evaluate site specific conditions or indicators of current karst activity and sinkhole risk. Following completion of the geophysical and geotechnical testing, the features were given an updated risk ranking and recommendations for remediation of the feature were developed.

5.3. Evaluation of Above-Ground Facilities (Compressor and Meter Stations**)**

Geophysical testing was completed at each of the proposed above-ground facility sites. Subsurface conditions within the facility sites were also evaluated by drilling/sampling site specific borings. This included the performance of borings in identified anomalous areas determined from the geophysical survey as well as in proposed building footprints and areas of equipment support. The borings were carried out using rotary wash procedures and sampled using standard penetration test (SPT) procedures. The borings were extended to depths sufficient to evaluate foundation support requirements and sinkhole risk with several of the facility explorations extending into the underlying rock formation. The field data was then reviewed to determine the sinkhole risk/potential at the site with an assessment being made as to whether ground improvement/modification is needed to reduce sinkhole risk.

5.4. Evaluation of HDD Sites

At each HDD site located in karst terrain, geophysical and geotechnical investigations were conducted to characterize subsurface conditions that could be experienced during HDD operations. The geotechnical investigations consisted of completing borings offset from the pipeline alignment utilizing rotary wash and rock coring techniques to advance the borings and sample the subsurface strata. The interval between samples was reduced where deemed necessary. Geophysical investigations consisted of ERI surveys along the alignment of each HDD. Areas identified as potential karst features by the ERI surveys were targeted for further investigation by completing additional geotechnical borings. Data collected during the site investigation phase of the project was utilized during the design phase to design the HDD geometry to maximize the likelihood of successful installation and reduce the risk of impacting areas along the alignment of the HDDs.

More specifically, the following methodologies, where possible, were employed during the design phase:

- The depth of HDD was designed to avoid zones that were interpreted to represent the largest potential risk to the successful installation of the pipeline while minimizing the risk of inadvertent drilling fluid returns to the surface.
- The length of each HDD was developed to ensure that its associated surface work space would avoid impacts to environmentally sensitive areas while minimizing the length of the HDD drill path.
- Workspace has been identified for fabrication of the pipe pull section in one continuous section so that intermediate tie-in welds will not be required during pullback operations.

6. EVALUATION OF RESULTS

The results of geophysical and geotechnical investigations are included in Table 1 for the representative karst features, Table 2 for the above ground facilities, and Table 3 for the HDD crossings. The results of these investigations were used to assist with the development of the mitigation measures outlined in section 7.

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features					
Location	**Initial Risk Ranking**		**Geophysical Results**	**Geotechnical Results**	**Current Risk Ranking**
Milepost 148.7 Spread 2 Dougherty County Georgia Parcel Ga-DO-007	MEDIUM A closed circular depression was identified just west of proposed pipeline alignment	Cover-collapse sinkholes most common type in Dougherty County. Typically range from 10-30 feet in diameter.	None	Pending	Pending
Milepost 159.8 - 161.3 Spread 2 Dougherty County, Georgia Parcel GA-DO-044.004	MEDIUM Alignment parallels well field with documented sinkholes	Cover-collapse sinkholes most common type in Dougherty County. Typically range from 10-30 feet in diameter.	ERI and GPR One anomaly identified by ERI	The soil boring performed at the anomaly encountered 6 feet of slightly silty sands underlain by alternating strata of clayey sands, sandy clays and clays to a depth of approximately 38 feet below current grade. Measured SPT resistance N - values generally increased with depth throughout the boring. Refusal limestone was encountered at a depth of 38 feet and extended to the boring termination depth of 65 feet. Drilling fluid circulation was lost within the limestone formation at approximately 48 feet below current grade which coincided with a slightly softer zone of limestone.	LOW to MEDIUM Sinkhole risk deemed to be low at the boring location based on the geophysical and geotechnical test results, however; the overall area is believed to have a medium or moderate risk based on the adjacent land use. In unlikely event sinkhole occurs on pipeline route, the area should be stabilized by backfilling. Evaluation & testing of sinkhole should then be conducted. The City of Albany should be solicited regarding proposed remediation methods due to the potential for negatively impacting the production of the well-field from such methods as grouting.

KARST MITIGATION PLAN

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Milepost 260.5 Spread 3 Hamilton County, Florida Parcel FL-HA-043.000	MEDIUM Closed circular depression was identified west of proposed alignment in existing power-line easement.	Solution sinkholes most common type in Hamilton County. Typically range from 10-30 feet in diameter.	GPR Two anomalies identified	Pending	Pending
Milepost 335.3 Spread 5 Gilchrist County, Florida Parcel FL-GI-078.000	MEDIUM Several small circular depressions were identified in the vicinity of the proposed alignment. The depressions appeared to be approximately 10-15 ft. in diameter.	Cover-subsidence and solution sinkholes are the most common types in Gilchrist County and are typically less than 10 feet in diameter.	GPR Three anomalies identified	Three soil borings performed, 15- 25 ft. loose- medium dense clean to silty sands underlain by fat clay (CH). Limestone formation is 33- 38 ft. below grade. The upper limestone encountered was weathered to 45-50 ft. where SPT resistance values indicated hard materials. No voids or cavities in limestone formation.	LOW While some zones of soft limestone material and loss of drilling fluid were noted, they occurred at or near the limestone interface which is a common occurrence in North Florida. The relative density of the upper sands generally increased with depth and at least 10-15 feet of clay materials were encountered above the limestone formation which reduces the potential for sinkhole development. Sinkhole mitigation not necessary.
Milepost 340 Spread 5 Alachua County, Florida Parcel FL-AL-016.000	MEDIUM Two circular depressions identified just east of proposed alignment.	Cover-subsidence sinkholes most common type in Alachua Co. & typically less than 10 ft. in diam.	GPR No anomalies were identified	One soil boring performed. Encountered clean to silty sands to 100 feet. SPT resistance values increased with depth to approximately 50-55 feet. No loss of drilling fluid.	LOW Based on geophysical and geotechnical testing, feature was reclassified with LOW risk ranking and no mitigation is necessary.

KARST MITIGATION PLAN

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Milepost 363.8 Spread 5 Levy County, Florida Parcel FL-LE-104.000	HIGH Line of several small circular depressions identified in vicinity of pipeline. Depressions generally 3 to 4 feet in diameter and 2 to 3 feet in depth.	Cover-subsidence sinkholes most common type in Levy County and typically less than 10 feet in diameter.	GPR Three anomalies identified	Three soil borings. Alternating strata of clean fine sand, clayey sand & silty fine sands encountered to depths of 23-43 feet, underlain by clay. Limestone formation was 43- 48 feet below current ground surface. Losses of drilling fluid at limestone interface in borings at central & northern anomalous areas.	HIGH While loss of drilling fluid at limestone interface is not uncommon, a relatively thin (5 ft. or less) clay confining strata was observed above the limestone formation. Observed surface depressions in area indicate elevated risk of sinkhole potential. While risk of sinkhole formation is high, the depth, type and relatively small diameter of sinkholes do not pose a threat to pipeline, if remediated. Depressions that have occurred or that may occur should be backfilled with compacted sand. Compaction grouting could be conducted in area of pipeline to further reduce sinkhole potential.
Milepost 422 Spread 6 Sumter County, Florida Parcel GSA-FL-SUM-109.000	MEDIUM Two small circular ponds and a depression along possible reroute alignment. Ponds approximately 60 and 150 feet in diameter.	Cover-subsidence and solution sinkholes most common types in Sumter County. Typically range from 10 to 30 feet in diameter.	GPR 25 anomalies identified primarily surrounding northern pond	No borings are planned since the main route will avoid these two ponds	HIGH Northern pond believed to be relic sinkhole. Based on elevated risk ranking, reroute of pipeline in area abandoned. Because feature will be avoided, no mitigation necessary.

KARST MITIGATION PLAN

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Milepost 427.4 Spread 6 Sumter County, Florida Parcel GSA-FL-SUM-119.050	MEDIUM Closed circular depression identified	Cover-subsidence and solution sinkholes most common types in Sumter County and typically range from 10 to 30 feet in diameter.	GPR No anomalies identified	One soil boring performed Encountered organic sand with roots and peat to 8 feet. Underlain by clean-silty fine sands to 120 feet. Groundwater not apparent in upper 10 feet of soil boring. SPT resistance values increased with depth to about 60-65 feet. No loss of drilling fluid observed.	LOW No indicators of potential sinkhole activity identified in geophysical or geotechnical testing
Milepost 433.3 Spread 6 Sumter County, Florida Parcel A4-FL-SUM-132.000	MEDIUM Series of circular depressions identified, two of which appeared to be 50 to 60 feet in diameter.	Cover-subsidence & solution sinkholes most common types in Sumter County. Typically range from 10 to 30 feet in diameter.	GPR Three anomalies identified	Soil borings performed within the anomalous areas identified. Borings encountered overburden of loose to medium dense sands underlain by clay soils. The granular soils extended to depths of 23 feet in borings B-1 and B-3, however, clayey material was not encountered until 43 feet within anomaly A-2 (boring B-2). The limestone formation was 43 feet within anomaly A-1 (Boring B-1) and at 63 feet in the other two borings. The initial limestone encountered appeared to be weathered with varying SPT N-values ranging from 12 to 65 bpf. The initial sample of limestone in boring B-2 was highly weathered with a blow count of 11 bpf. Below 63 feet in B-1 and 68 feet	MEDIUM Drilling fluid was lost in boring B-3 at or near the limestone interface which is a common occurrence in northern Florida. Although some weathering of the limestone was noted, no significant voids or cavities were observed within the limestone formation in any of the borings. Significant clay confining layers were encountered in all the borings above the limestone. The downwarping of the GPR reflector set at anomaly A-2 corresponded to a deeper clay and limestone in this area. Definitive indicators of sinkhole activity were not observed in the borings. However, due to the observed surface depression at anomaly A-1 and the proximity of the anomalies, the overall area has some potential for sinkholes. Based on the results of the soil borings

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
				in the other borings the limestone was very hard.	and geophysical testing, we do not recommend any sinkhole remediation at this time.
Milepost 438.8 - 439.3 Spread 6 Lake County, Florida Parcel FL-LA-030.000	MEDIUM Series of circular depressions (60 to 150 feet in diameter) none located directly on alignment.	Solution sinkholes most common type in Lake County and generally range from 10 to 80 feet in diameter.	GPR Eight anomalies identified	No borings are planned since the pipeline was rerouted in this area and the noted depressions are even farther from the proposed alignment.	MEDIUM to HIGH Based on the geophysical test results the area is believed to have an elevated risk of sinkhole development.

KARST MITIGATION PLAN

Table 1. Results of Geophysical and Geotechnical Testing of Representative Karst Features					
Location	**Initial Risk Ranking**		**Geophysical Results**	**Geotechnical Results**	**Current Risk Ranking**
Milepost 452.2 Spread 6 Lake County, Florida Parcel FL-LA-097.000	MEDIUM Circular depression identified on alignment. Ponds located north and south of alignment and the identified depression.	Solution sinkholes most common type in Lake County. Generally range from 10 to 80 feet in diameter.	GPR One anomaly identified	One soil boring performed which encountered an overburden consisting of approximately 78 feet of medium dense to very loose sands underlain by very soft sandy clay (CL). A layer of cemented silty sand "hardpan" was encountered between 7 and 15 feet. Measured SPT resistances (N-Values) in this strata ranged from 37 to 58 bpf indicating a dense to very dense condition. Below the cemented sands the stratigraphy was generally medium dense to 30 feet where very loose soil conditions and N-values less than 5 bpf were observed. The deeper sandy clay strata between 78 and 108 feet were very soft. Limestone was approximately 108 feet below current grade. The limestone was very hard with refusal blow counts (50+ blows for less than 6 inches of penetration).	MEDIUM Although indications of weathering or voids within the limestone formation were not noted, measured SPT resistances decreased with depth and approximately 75 feet of very soft or very loose soil conditions including weight of rod were encountered. Significant losses of drilling fluid were noted throughout completion of the boring including a complete loss of drilling fluids at a depth of approximately 102 feet. Based on the relatively dense to very dense materials encountered within the upper 15 feet to 30 feet, conventional pipeline construction such as open trenching is not likely to trigger sinkhole activity. We recommend stormwater and dewatering discharge be diverted from the area during construction activities and hydraulic testing not be performed within this portion of the pipeline. If potential changes in hydraulic stresses are anticipated, the area may be stabilized by compaction grouting.

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
COMPRESSOR STATIONS					
Alexander City, Alabama (MP 0.0)	LOW Alabama Sinkhole Map (Nov. 2011), shows nearest sinkhole more than 8 miles from site. "Hackneyville, Alabama" & "Alexander City, Alabama" topographic maps show no closed depressions within 1 mile of site. Sinkholes are uncommon		None performed	Borings encountered clay soils underlain by silty soils to 23-42 ft. where very hard limestone was encountered.	LOW No indicators of sinkhole activity identified. Conventional shallow foundations feasible without mitigation or remediation measures
Albany, Georgia (MP 159.2)	MEDIUM Facility located adjacent to well field with documented sinkholes	Cover-collapse sinkholes are the most common type in Dougherty County and generally range from 10 to 30 feet in diameter.	ERI One anomaly identified which may be associated with an increase in sand thickness or a naturally occurring lateral variation in resistivity not related to sinkhole activity	Borings encountered sands/clays atop continuous limestone formation. Sands graded from very loose to medium dense and generally became more silty and clayey with depth. Very loose to very soft conditions just above limestone interface. Some small voids in limestone observed. In boring B-1, drill rods fell under own weight from 93 to 98 ½ feet. Losses in drilling fluid noted from 70 to 95 feet.	MEDIUM Possible indicators of solution activity within limestone formation. & potential for sinkhole development observed in soil borings. Combined with historic occurrence of sinkholes in nearby Albany well field, mitigation of sinkhole potential recommended.

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Hildreth, Florida (MP 269.2)	MEDIUM to HIGH Sinkhole potential higher in southern part of county	Solution sinkholes are most common in Suwanee County and typically less than 10 feet in diameter	GPR 15 anomalies identified	Borings indicate overburden consisting of layers of clean fine sands & silty fine sands underlain by clayey sands, clays/silts. Sand, silt & clay soils extended to depths of 50 to 85 feet. Below overburden soils limestone present. Depth to limestone varies greatly but generally occurred around 50 feet or greater. Limestone is sandy, silty, very hard & well cemented. Blow counts in limestone typically 50 blows or more for less than 6 inches of sample spoon penetration. No significant losses of drilling fluid noted. Borings drilled without need for temporary casing.	LOW to MEDIUM Based on the results of the project specific borings, we do not consider it necessary to carry out any grouting below buildings or equipment foundations.
Dunnellon, Florida (MP 389.8)	LOW to MEDIUM	Cover-subsidence and solution sinkholes most common. Typically 10 to 30 feet in diameter.	GPR Three small anomalies identified	The borings indicated an overburden of interbedded layers of sands underlain by clayey sands and clays. Based on SPT blow counts, the sands typically grade in a loose to medium-dense condition. The clays varied from a soft to medium-stiff consistency. Below the overburden soils limestone is present about 25 feet below the existing grade. The limestone grades sandy to silty and locally very hard to well-cemented. Blow counts in the limestone ranged from 8 bpf to greater than 50 blows for essentially no sample spoon penetration. No significant losses of drilling fluid was observed in the borings and temporary casing was not required to advance the borings.	LOW to MEDIUM The anomalies identified by geophysical testing were small and located around the outside perimeter of the site and not within proposed structure locations. There were decreasing SPT blow counts with depth and some weathering of the limestone formation noted in the borings, indicating there is some potential for sinkhole development at the site. We do not consider it necessary to

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
					carry out any grouting below buildings or equipment foundations at this time.
Reunion, Florida (MP 474.4)	LOW	Cover-subsidence sinkholes are most common and typically range from 10 to 80 feet in diameter	GPR and ERI Three anomalies identified by GPR and four by ERI	Borings indicate overburden of interbedded clean fine sands & silty fine sands. Clay layers encountered in some borings at 33 ½ feet & just above limestone. Sand & clay soils extend to depths of 65 to 70 feet. Zones of weight of hammer material in overburden soils in borings BH-2 and BH-8/BH-8A. In several deeper borings, shells encountered. Circulation lost in these materials and localized ground collapse during initial drilling. Below overburden soils limestone present which was sandy or silty and very hard to well-cemented. SPT blow counts in limestone ranged from 9 to 50 bpf for no sample spoon penetration.	LOW to MEDIUM Given difficulties experienced in completing deep borings & presence of very loose/soft zone at 20 to 35 feet. Some ground improvement may be necessary to support the proposed structures on conventional shallow foundations.
M&R STATIONS					
Transco Hillabee Tallapoosa County, Alabama (MP 0.0)	LOW Alabama Sinkhole Map (Nov 2011) shows nearest sinkhole more than 8 miles from site. “Hackneyville, Alabama” and “Alexander City, Alabama” topographic maps, do not indicate presence of closed depressions within 1 mile of the site.		None performed	Borings encountered stiff to very stiff, clay soils to depths of approximately 13 ½ feet underlain by silty sands. The silty sands transitioned to very hard materials with depth where apparent bedrock was encountered at depths of 20 to 40 feet.	LOW No indicators of sinkhole activity identified. Conventional shallow foundations feasible without sinkhole mitigation or remediation measures

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities					
Location	**Initial Risk Ranking**		**Geophysical Results**	**Geotechnical Results**	**Current Risk Ranking**
	Sinkholes are uncommon				
FGT Suwanee Suwannee County, Florida (MP 299.7)	MEDIUM to HIGH	Solution sinkholes most common and typically less than 10 feet in diameter	GPR 11 anomalies identified	Borings indicate overburden of inter-bedded layers of clean fine sands, slightly silty fine sands, silty fine sands, clayey sands, and clays. Overburden soils extended to depths of 60 to 105 feet. Based on SPT blow counts, sands graded in very loose to medium-dense condition. Clays varied from soft to medium-stiff consistency. Weight of rod materials encountered in boring B-1 between 80 and 95 feet. Below overburden soils, limestone present at 60 to 105 feet. Variation in depth to limestone fairly typical for Suwannee County. Limestone is sandy to silty and locally very hard and well-cemented. Material is porous and likely part of Floridan Aquifer. Blow counts in limestone typically 50 blows for no sample spoon penetration. Loss of drilling fluid in boring B-1 at 98 feet and in boring B-2 at 60 feet near depths at which overburden soils contact limestone. Borings drilled without need for temporary casing.	LOW to MEDIUM At this time, based on the results of the project specific borings, we do not consider it necessary to carry out any grouting below buildings or equipment foundations.
FSC Osceola County, Florida (MP 474.4)	LOW	Sinkholes that do develop are typically shallow, small to large in diameter (10'-80') and develop gradually. Cover-	GPR One anomaly identified in western portion of site	Borings indicate overburden of clean fine sands, slightly silty fine sands, silty fine sands, silts and clays. Overburden extended to depths of 60 to 65 feet. Sands varied from very loose to medium-dense with occasional dense to very dense layers. Dense & very dense layers consisted of slightly silty sand or silty	LOW to MEDIUM Given the indicated presence of an anomaly and our experience with conditions at the adjacent Reunion Compressor Station Site, some ground

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
		subsidence type sinkholes are most common.		sand "hardpan". Silts and clays beginning at 35 to 40 feet & stiff to very stiff. Shell observed at 60 to 62 feet just above limestone. Circulation lost in this strata. Upper limestone generally sandy to silty, locally very hard and well-cemented. FSC-1, SPT blow counts in limestone > 50 blows for no sample spoon penetration. In boring FSC-2, weight of rod material at 65 feet. The other N-values in limestone ranged between 13 and 50 bpf.	improvement may be necessary to support the proposed structures on conventional shallow foundations.
Gulfstream Osceola County, Florida (MP 474.4)	LOW	Sinkholes that do develop are typically shallow, small to large in diameter (10'-80') and develop gradually. Cover-subsidence type sinkholes are most common.	GPR Two anomalies were identified	Borings indicate overburden of layers of clean fine sands, slightly silty fine sands & silty fine sands. Sands extend to 65 feet and varied from very loose to medium-dense with occasional dense to very dense layers. Dense and very dense layers consisted of a slightly silty sand or silty sand "hardpan". Shell layer was encountered at 60 feet just above limestone. Circulation lost within shell strata. Limestone is sandy to silty, locally very hard, well-cemented, porous & likely part of Floridan Aquifer. SPT blow counts in limestone > 50 blows for no sample spoon penetration to about five inches of penetration. Borings did not encounter open voids or weight of rod material.	LOW to MEDIUM Given the indicated presence of an anomaly and our experience with conditions at the adjacent Reunion Compressor Station Site, some ground improvement may be necessary to support the proposed structures on conventional shallow foundations.
FGT Hunters Creek Orange County, Florida (MP 13.1)	LOW	Sinkholes that do develop are typically shallow, small to large in diameter (10'-80')	ERI Two anomalies identified	Soil borings indicated an overburden primarily consisting of sands which varied from a very loose to medium-dense condition. A clay layer was encountered between 80 and 95 feet. The clay persisted in a medium-stiff to stiff	LOW No indicators of sinkhole activity identified in the soil borings. Conventional shallow foundations

Table 2. Results of Geophysical and Geotechnical Testing of Above-Ground Facilities

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
		and develop gradually. Cover-subsidence type sinkholes are most common.		consistency. No loss of drilling fluid circulation was observed during drilling and the boring was completed without the need for temporary casing.	feasible without mitigation or remediation measures
DEF Citrus County Citrus County, Florida (MP 21.4)	MEDIUM	Solution sinkholes most common and typically are less than 10 feet in diameter	GPR Two small anomalies identified	The borings indicate an overburden primarily consisting of sands, clayey sands, and clays. The overburden soils were relatively thin with limestone materials being encountered at depths ranging from 2 ½ to 20 feet below current grades. The relatively shallow depth to limestone is fairly typical for this area of Citrus County. The limestone is a sandy silty rock that is locally very hard and well-cemented. Some weathering of the limestone formation was observed with blow counts as low as 7 blows per foot in some areas. Weight of rod materials and highly weathered limestone was encountered in boring B-1 between depths of 15 and 18 ½ feet and 18 ½ and 23 ½ feet respectively. Loss of drilling fluid was not observed and the borings were drilled without the need for temporary casing.	MEDIUM Some indications of elevated sinkhole potential were observed within the borings including zones of soft soil and highly weathered limestone. At this time, based on the results of the project specific borings, we do not consider it necessary to carry out any grouting below buildings or equipment foundations.

Table 3. Results of Geophysical and Geotechnical Testing for HDD Crossings					
Location	**Initial Risk Ranking**		**Geophysical Results**	**Geotechnical Results**	**Current Risk Ranking**
Withlacoochee CCL MP 1.27	LOW	Solution sinkholes most common and typically are less than 10 feet in diameter	ERI and SBP Six anomalies were identified	Borings indicate very loose to medium dense silty and clayey sands and very soft to medium stiff clays overlying poorly to moderately indurated (weathered) limestone. Top of limestone at depths of 20 to 28 feet. Borings did not encounter voids or weight of rod materials.	LOW – Installation of pipeline at site feasible but some construction difficulties expected with loss of drilling fluid returns possible during HDD operations & localized ground settlement near entry and exit. . Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material expected. Mitigation measures outlined in this document will increase likelihood of successful installation.
Withlacoochee MP 229	LOW	Solution sinkholes most common and typically are less than 10 feet in diameter	ERI and GPR Three anomalies were identified	Borings indicate loose to medium dense sands and stiff to hard clays overlying poorly to moderately indurated (weathered) limestone. Top of limestone 25 to 45 feet. Drilling fluid returns lost at 61, 55, 22, & 51 feet in WRH-B-1, WRH-B-2, WRH-B-3 & WRH-B-5, respectively. Voids ranged from 1 to 3 feet thick vertically.	MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with possible loss of drilling fluid returns during HDD operations & localized ground settlement near entry and exit. Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document will increase likelihood of a successful installation.

Table 3. Results of Geophysical and Geotechnical Testing for HDD Crossings

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Flint River	MEDIUM	Solution sinkholes most common and typically are less than 10 feet in diameter	ERI and SBP 14 anomalies were identified	Borings on west side of crossing indicate soft to very stiff clay, loose to medium dense clayey sand, medium dense sand, & hard sandy clay overlying very loose to very dense sand. Boring B-1 encountered weight of rod material at 68 and 88 feet along with a possible void at 108 feet. Approximately 70 feet of hollow stem auger stuck and abandoned in boring B-3 following completion of boring. Borings on the east side of the river indicated medium stiff clay and very loose to medium dense sands underlain by weathered limestone in borings FR-B-4 and FR-B-6 and loose to medium dense sands for the full depth of boring FR-B-5	MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with possible loss of drilling fluid returns during HDD operations & localized ground settlement near exit. Large voids not anticipated along HDD path but possible. Drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document will increase likelihood of successful installation.
Suwanee River	LOW	Solution sinkholes most common and typically are less than 10 feet in diameter	ERI and SBP 11 anomalies were identified	Borings indicate very loose to medium dense silty and clayey sands and soft to medium stiff sandy clay overlying poorly to moderately indurated (weathered) limestone. Top of limestone 20 to 45 feet. Drilling fluid returns lost at 15, 18, 12, & 13 feet in SR-B-1 through SR-B-4, respectively. Voids not noted in the borings but small voids (<12 inches) likely.	MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with loss of drilling fluid returns during HDD operations & localized ground settlement near entry and exit. Large voids not anticipated along HDD path, but drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document will increase likelihood of successful installation.

Table 3. Results of Geophysical and Geotechnical Testing for HDD Crossings

Location	Initial Risk Ranking		Geophysical Results	Geotechnical Results	Current Risk Ranking
Santa Fe River MP 306	MEDIUM	Solution sinkholes most common and typically are less than 10 feet in diameter	ERI and SBP Three anomalies were identified	Borings indicate very loose to medium dense sand with variable silt/clay content & minor very soft to medium stiff clays overlying poorly to moderately indurated (weathered) limestone. Top of limestone at 22 to 28 feet. Drilling fluid returns lost from 8 to 25 feet. Borings encountered weight of hammer materials in overburden soils. Large voids not observed, however; small voids (<12 inches) likely.	MEDIUM – Installation of pipeline at site feasible but construction difficulties expected with loss of drilling fluid returns during HDD operations and localized ground settlement near entry and exit. Large voids not anticipated along HDD path, however drilling fluid loss to smaller voids or zones of loose material such as those encountered in borings expected. Mitigation measures outlined in this document will increase likelihood of successful installation

7. MITIGATION OF CONSTRUCTION RELATED KARST ISSUES

The following is a discussion of mitigation measures that will be employed to reduce the frequency, magnitude, and severity of karst related issues that may arise during construction of the pipeline and above ground facilities and during HDD operations.

7.1. Pipeline Construction

7.1.1. Hydro –Testing

To reduce the potential for sinkhole development during hydrostatic testing, the test water from a new pipe will not be discharged directly into the vicinity of a known karst feature open to the surface. The water will be discharged down-gradient of identified karst features. If site conditions prevent a down-gradient discharge, the water will be discharged as far from the karst feature as practicable with a discharge and sediment and erosion control features detailed in the Project Erosion and Sediment Control Plan (ESCP). Post-construction monitoring will ensure proper re-vegetation and restoration of these areas.

7.1.2. Ground Subsidence or Sinkhole Formation

As required by Code 49 of Federal Regulations, Part 192.613, route surveillance will be conducted during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline alignment for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Signs of sinkhole formation, ground subsidence or surface depressions will be immediately and clearly marked. Work will be temporarily halted and the immediate area around the depression evacuated until it is deemed safe and stable. The project geotechnical engineer will also be notified of the occurrence.

Based on the direction of the geotechnical engineer, the area may be backfilled with clean sand fill to temporarily stabilize the area until further evaluation can be conducted. This may include geophysical and/or geotechnical testing.

In some cases, pipeline construction will necessitate the backfilling of closed depressions without visible openings/voids at the ground surface and depressions with karst voids or openings exposed to ground surface. A common approach is to infill these features with clean sand. Backfill activity would consist initially of vegetation removal and placement of a clean sand fill. If it is an “open hole” with no readily visible bottom, an effort should be made to use water to aid in the filling process.

If sand infill does not provide for a stable subgrade for pipe support, compaction grouting may be required. Compaction grouting is a common method of remediating ongoing active or potential sinkhole formation. The process involves installing pipe by driving or drilling into the area of concern and injecting grout under pressure to fills voids, cavities and soft zones within the limestone formation. As the pipe is withdrawn, grout is continually pumped to stabilize any loose or raveled soils in the overburden by compression and compaction. To effectively stabilize the feature without pumping excessive amounts of grout, a volume limit is typically established for each hole. If the limit is reached, secondary or tertiary points are added to ensure the feature is stabilized.

Based upon the final remediation method the alignment of the pipe maybe modified.

7.2. Above-Ground Facilities (Compressor and Meter Stations)

Site specific measures to assure structural integrity in the facility areas will be used. Similar to other industrial facilities in the immediate area founded over karst conditions, reinforced grade beams and slabs capable of spanning small drop outs, or utilizing deep foundations (piles or drilled shafts) that extend into competent rock may be used. In the event of a drop out, heavily reinforced grade beams and slabs can be placed after the completion of hole in-filling and compaction grouting.

7.3. HDD Crossings

During construction, the Chief Inspector, HDD Superintendent and other members of Sabal Trail's inspection staff will maintain close communication regarding daily progress and any potential karst features (zones of concern) that may have been encountered. Close communication between all members of the construction staff will be important to ensure that all possible risks are addressed and accounted for in the drill plan. The following sections outline methods that will be employed during construction to minimize negative impacts associated with HDD activities in karst-sensitive areas.

7.3.1. Pilot Hole

During pilot hole operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

- Rates of penetration and resistance to forward progress will be monitored for zones of loose soils or open voids indicating that zones of concern may be present. A decrease in the resistance

required to advance the bottom hole assembly could indicate a zone of loose, unstable soils or open voids.

- The pilot hole driller/surveyor will monitor the steering inputs required to advance the pilot hole along the alignment and profile of the HDD path. Zones where larger steering inputs are required to advance the pilot hole within acceptable tolerance could indicate a zone of loose, unstable soils or open voids.
- Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids and/or conduits are located along the drill path and that the bottom hole assembly is entering a karst feature.

The following actions will be taken if, based on the above observations, it is believed that zone of concern has been encountered along an HDD drill path.

- The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.
- The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.
- Observations made during pilot hole operations will be used to modify the original drill plan for subsequent HDD operations.
- The HDD contractor will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the borehole or the HDD profile geometry becomes compromised through attempts to restore drilling fluid returns, the HDD contractor will notify Sabal Trail. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor will proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.
- In the event of inadvertent drilling fluid returns, the Best Drilling Practices Plan for the Sabal Trail Project will be followed.
- In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic surveys will be conducted if nearby structures may be impacted.
- If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, all or a portion of pilot hole would be abandoned and a new pilot hole started at an alternate depth. Drilling will continue and the

affected waterbody will be monitored in accordance with the Best Drilling Practices Plan for the Sabal Trail Project

- If practical, an increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns.
- Twenty four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.

7.3.2. Reaming and Swabbing

During reaming operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

- Rates of penetration and rotary torque on the downhole drill pipe string can be monitored for zones of loose material indicating where zones of concern may be present.
- Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids and/or conduits are located along the drill path and that the reaming assembly is entering a karst feature.

The following actions will be taken if, based on the above observations it is believed that zone of concern is encountered along an HDD drill path.

- The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.
- The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.
- The observations made during reaming operations will be used to modify the original drill plan for subsequent HDD operations.
- The HDD contractor(s) will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the drilled hole becomes compromised through attempts to restore drilling fluid returns, the HDD contractor shall notify Sabal Trail or their authorized representative. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor should proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.
- In the event of inadvertent drilling fluid returns, the Best Drilling Practices Plan for the Sabal Trail Project will be followed.

- In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic survey will be conducted if nearby structures may be impacted.
- If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, reaming operations will continue and the affected waterbody will be monitored in accordance with the Best Drilling Practices Plan for the Sabal Trail Project.
- Increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns and over-mining of loose soils.
- Twenty four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.
- The HDD contractor will employ modified reaming practices to limit impacts and maximize the chances for a successful installation.

7.3.3. Pullback

To maximize the chances of a successful installation, pullback operations will commence immediately following one or more acceptable swab passes which indicate that the hole is in a condition to accept the carrier pipe. The HDD Superintendent, in consultation with the STT Inspection Team, will make the determination as to when the reamed borehole has been adequately prepared for installation of the pipeline. Pullback operations will be carried out on a 24-hour basis until the completion of pipe installation.

8. GLOSSARY

- BLS or BGS – an abbreviation for below surface or below ground surface.
- Carrier Pipe – pipe designated to contain and carry the product, in this context - natural gas
- Compaction Grouting – a grouting technique that displaces and densifies loose granular soils, reinforces fine grained soils and stabilizes subsurface voids or sinkholes, by the staged injection of low-slump, low mobility aggregate grout.
- Cut and Cover – a pipeline construction technique where a trench is excavated, the pipeline is laid in the trench then the trench is backfilled.
- Drill Tooling – HDD tooling used to drill a pilot hole or ream (increase the diameter of) the hole for the carrier pipe installation. This tooling includes the drill pipe, drill bit and or reaming tools and stabilizers.
- Drilling Fluid - a water-based drilling fluid consisting of water and bentonite (a naturally occurring clay mineral). The drilling fluid is pumped downhole during drilling operations to remove soil and rock cuttings from the hole, stabilize the hole and cool and lubricate the downhole tooling.
- Drilling Fluid Returns – Drilling fluid that is pumped downhole through the drill pipe to the drill bit or reaming tool and travels to the entry and/or exit sides of the crossing via the annulus of the drilled hole.
- Electric Resistivity Imaging (ERI) – also known as electric resistivity tomography (ERT), a geophysical technique for imaging sub-surface structures from electrical resistivity measurements made at the surface, or by electrodes in one or more boreholes.
- Ground Penetrating Radar (GPR) - a geophysical method that uses radar pulses to image the subsurface.
- HDD pullback – A process of pulling the carrier pipe through a previously reamed hole.
- Magnitude – in case with natural springs, a classification method based on the volume of water the spring discharges; the 1st magnitude springs discharge more than 100 cubic feet of water per second, 2nd magnitude springs discharge between 10 and 100 cubic feet of water per second
- Mitigation – the action of reducing severity or seriousness of something. In the context of this plan, karst mitigation is a set of actions intended to reduce a probability and/or impacts associated with karst terrain.
- Standard Penetration Test (SPT) - an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil.

Characterization of Karst Sensitive Areas Relative to the Proposed Route of the Sabal Trail Natural Gas Transmission Pipeline in Florida

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Table of Contents

1 Characterization of Karst Sensitive Areas Relative to the Proposed Route of the Sabal Trail Natural Gas Transmission Pipeline 2

1.1 Hydrogeologic Characterization 2

1.2 Karst Features 4

1.3 Construction Activities 9

References 13

Tables

Table 1. Distance from each Major Spring in a Springshed to the Route of the Proposed Pipeline at its Closest Approach to the Spring 8

Table 2. Location of the Fracture Traces Relative to the Proposed Pipeline Route. 12

Figures

Figure 1. Approximate Location of the Proposed Pipeline Route (red line) in Relation to the Area where the Upper Floridan Aquifer is Unconfined (the Karst Sensitive Area). 2

Figure 2. The Proposed Pipeline Route Relative to the Extent of the Cody Scarp. 3

Figure 3. Approximate Springshed Boundaries of First Magnitude and Major Second Magnitude Springs in the Northern Portion of the Karst Sensitive Area. 6

Figure 4. Approximate Springshed Boundaries of First Magnitude and Major Second Magnitude Springs in the Southern Portion of the Karst Sensitive Area. 7

Figure 5. Fracture Traces of Significant Size that Intersect the Proposed Pipeline Route in the Northern Portion of the Karst Sensitive Area. 10

Figure 6. Fracture Traces of Significant Size that Intersect the Proposed Pipeline Route in the Southern Portion of the Karst Sensitive Area. 11

Appendices

Appendix A Closed Depression Features Within A 0.5 Mile Wide Pipeline Corridor Encompassing the Proposed Pipeline Route in th Karst Sensitive Area

Appendix B Aerial Photographs Showing Location of Major Fracture Traces That Intersect the Proposed Pipeline Route in the Karst Sensitive Area

Appendix C Data References Used for Defining Groundwater Flow Paths to Springs and Wells Downgradient of HDD Crossings

1 Characterization of Karst Sensitive Areas Relative to the Proposed Route of the Sabal Trail Natural Gas Transmission Pipeline

This report characterizes the hydrogeology of the region underlying the proposed Sabal Trail Natural Gas Transmission Pipeline in the karst region of north central and west central Florida. The report also identifies important karst features that could convey contaminants into the Upper Floridan aquifer and affect the construction and stability of the pipeline.

1.1 Hydrogeologic Characterization

Figure 1 shows the route of the proposed pipeline where it enters the area where the Upper Floridan aquifer is unconfined (area highlighted in blue) just north of the Florida border and exits it in southern Sumter County. For the purposes of this report, this area, which is characterized by numerous sinkholes, internal drainage, sinking streams, and springs, is referred to as the "Karst Sensitive Area." The term "sensitive" is in reference to the ease of development of karst features in this area due to the unconfined nature of the Upper Floridan aquifer.

Shortly after entering Florida, the proposed pipeline route crosses the Cody Scarp, a karst escarpment that extends from near Gainesville, in Alachua County, to west of Tallahassee in Leon County (Figure 2). The Cody Scarp coincides with the northern extent of the area where the Upper Floridan aquifer becomes unconfined.

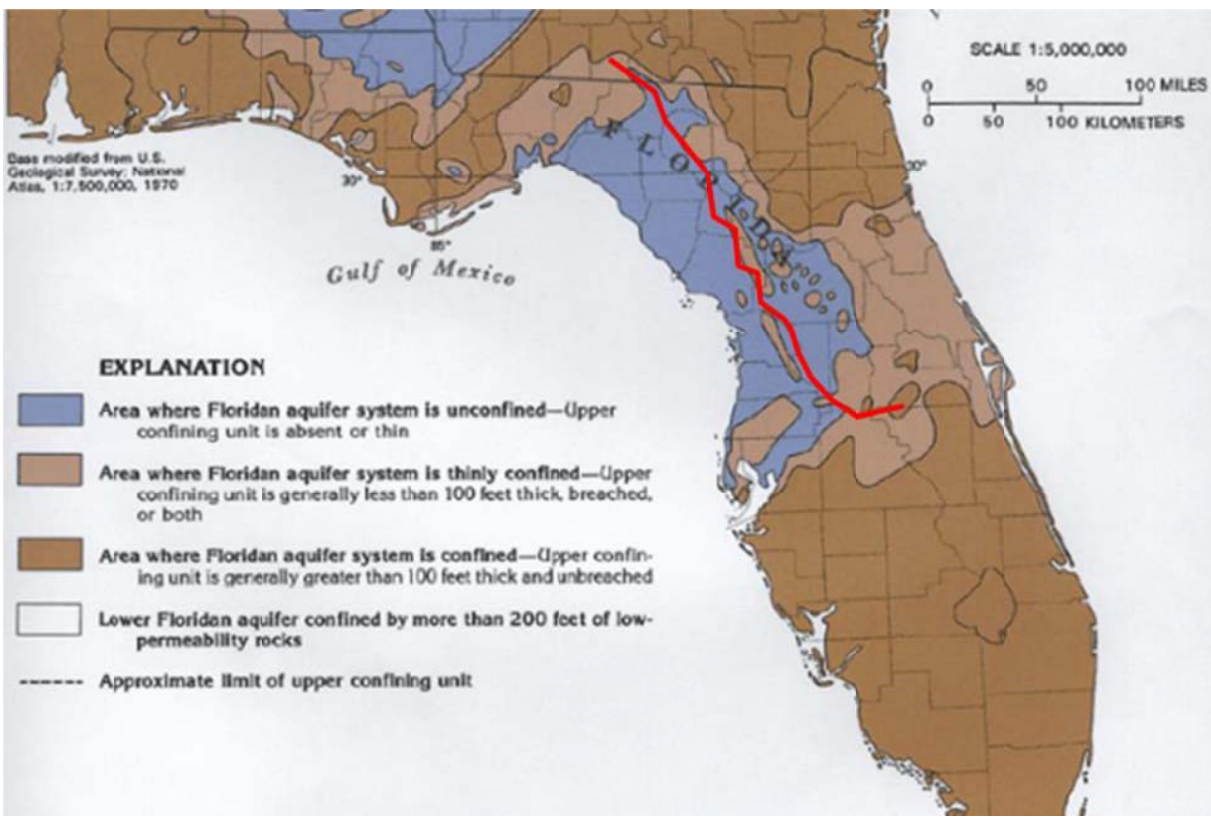

Figure 1. Approximate Location of the Proposed Pipeline Route (red line) in Relation to the Area where the Upper Floridan Aquifer is Unconfined (the Karst Sensitive Area).

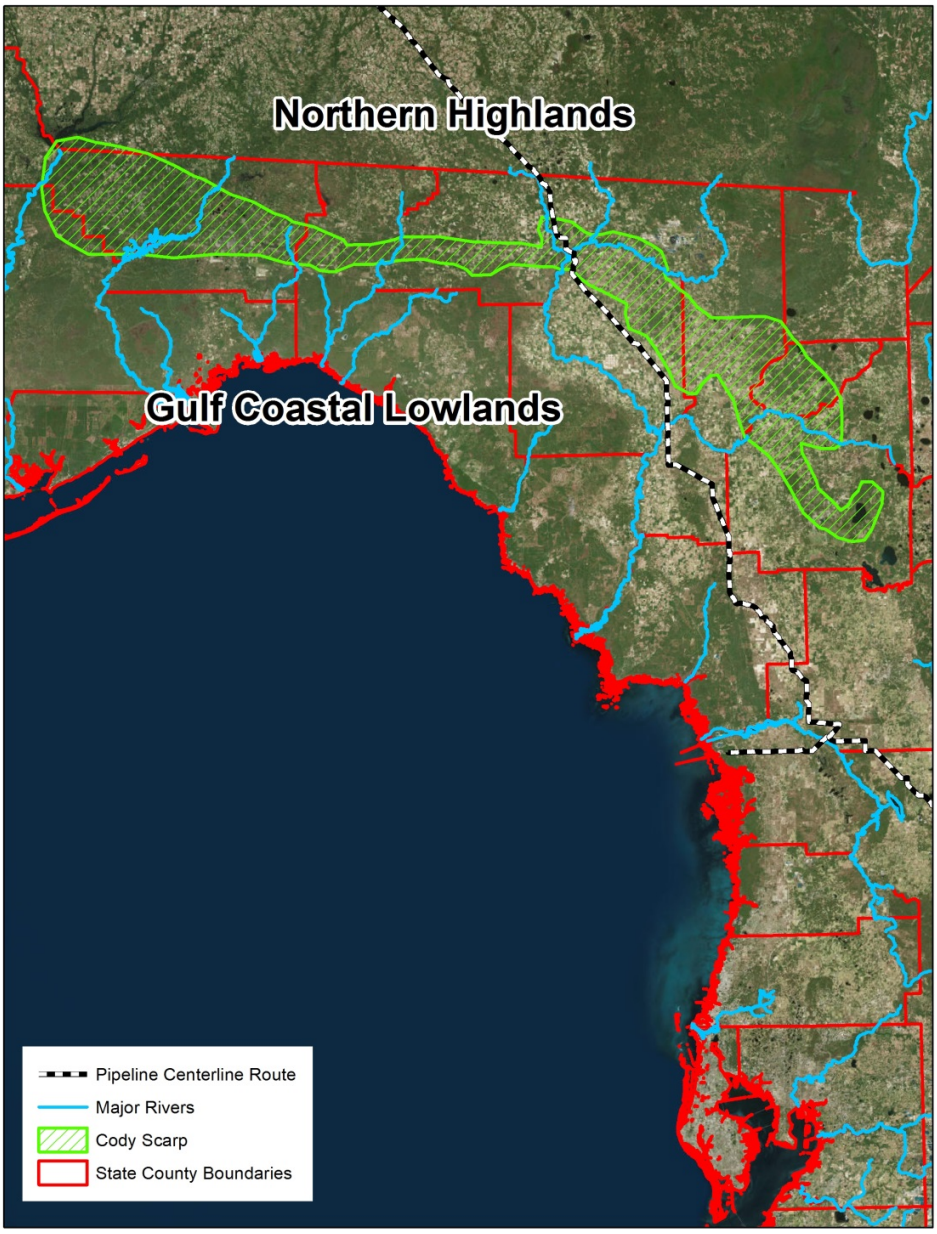

Figure 2. The Proposed Pipeline Route Relative to the Extent of the Cody Scarp.

Because numerous sinkholes, sinking streams, siphons, springs, and other karst features extend along the length of the scarp, it is the most sensitive area in Florida that the pipeline will traverse.

The following information on the Cody Scarp was obtained from a report prepared by Upchurch (2007) entitled: An Introduction to the Cody Escarpment, North Central Florida. The Cody Scarp was first named by Puri and Vernon (1964), who attributed its formation to a combination of Plio-Pleistocene shoreline development and fluvial/karst erosion. The segment of the scarp within the Suwannee River Water Management District (District) is predominantly a karst escarpment (White, 1970) that has been modified in many areas by marine shoreline processes. The Cody Scarp is important to understanding the hydrology of the Suwannee River Basin and other areas of north-central Florida because the processes that have formed it greatly affect rivers, groundwater, land forms, and water quality throughout the region.

The Cody Scarp is a topographic break with up to about 100 feet of relief between the Northern Highlands Physiographic Province to the north and east and Gulf Coastal Lowlands Province to the west and south of the scarp. Within the District, the scarp is characterized by sinking streams, springs, and large sinkholes. The sinkholes are large because of the thickness of sand and clay cover that remains over the limestone between these large sinkhole features.

The Northern Highlands are underlain by a thick sequence of erosion-resistant sand, clay, and carbonate sediments of the Miocene Hawthorn Group. More easily eroded limestone and dolostone of the Eocene Ocala Limestone and Oligocene Suwannee Limestone characterize the shallow sediments of the adjacent Gulf Coastal Lowlands. The scarp is a result of marine, fluvial, and karst-related erosion of the Hawthorn Group sediments of the highlands.

Streams that drain to the south and southeast across the Northern Highlands Province have well-developed drainage systems with dendritic drainage patterns. As the streams cross the scarp, they flow into poljes (large flat-floored depressions within karst limestone) and uvalas (multiple smaller individual sinkholes that coalesce into compound sinkholes that are often shallow and irregular in their overall shape due to the merging of smaller sinkholes).

The large sizes of sinkholes in the Cody Scarp are a result of thick cover over the limestone. This cover consists of erosional remnants of the intact Hawthorn Group sediments of the Northern Highlands Province plus residua and sediment derived from erosion and transport of Hawthorn sediments created by scarp retreat. The thicker the cover, the larger the sinkholes will be. Cover is thin in the Gulf Coastal Lowlands Province so sinkholes are small and separated into individual depressions.

Karst development is limited in the Northern Highlands Province. Limestone and dolostone beds within the Hawthorn Group may develop localized caverns and sinkholes that are limited to the thin Hawthorn strata. This form of karst (interstratal karst) results in minor aquifer development and has little effect on the hydrology of the Cody Scarp area.

Because of the localized recharge by streams entering swallets along the scarp, karst is very well developed. Recharge tends to result in vertical karst conduits, both under the large sinkholes and in association with swallets and siphons that capture runoff from the Northern Highlands Province. As the groundwater flow turns to the south and east, away from the scarp, horizontal passages develop. These processes result in the siphon/resurgence systems that characterize many of the streams and rivers.

The route of the proposed pipeline trends slightly to the southeast as it crosses the Cody Scarp in Hamilton County. It then stair-steps east then south until it crosses the Suwannee River and enters Suwannee County, paralleling the scarp until it nears the western boundary of the Ichetucknee Springshed. It then turns south where it crosses the Santa Fe River and enters Gilchrist County.

For the remaining length of the proposed pipeline route in the Karst Sensitive Area, the pipeline is located in the Gulf Coastal Lowlands Province. As explained above, sinkholes tend to be smaller and separated into individual depressions in this province because sediments overlying the limestone are thinner.

1.2 Karst Features

Important karst features in the vicinity of the proposed pipeline route (0.5 mile survey corridor) that were identified for this report include the springsheds of major springs, closed depressions, and fracture traces. The following section provides a description of the features, the methodology used to identify them, and how they could impact or be impacted by the pipeline.

Springsheds - Springsheds in north Florida are groundwater basins where all precipitation that falls on the surface infiltrates into the limestone of the Upper Floridan aquifer where it becomes entrained in the flow system to eventually discharge at a discrete spring or group of springs. Investigations conducted by the Southwest Florida Water Management District (Jones and Upchurch, 1996), and the U.S. Geological Survey (Katz and others, 1999) have shown that the residence time of water in the groundwater basin (the interval of time between precipitation on the surface and discharge at the spring) can range from days to years to decades. Water with a residence time of days likely originates as rainfall in the vicinity of

the spring, enters the aquifer through a nearby sinkhole, and becomes entrained in the conduit system that flows directly to the spring. Water with a residence time of decades may fall as rainfall at the outer boundary of a springshed, where it enters the aquifer and moves as diffuse flow through the intergranular porosity of the matrix of the limestone formation. Eventually, as the water nears the spring, it seeps from the matrix into a conduit that transmits it to the spring.

The flow system in the Upper Floridan aquifer within a springshed is likely to be well developed in the vicinity of a spring and dominated by conduits in the limestone that may be large enough to be explored by divers. As distance from the spring increases, the conduits become progressively reduced in size to the point where eventually most of the flow is diffuse through the intergranular porosity of the limestone matrix. This conceptualization is supported by Upchurch (1992) who stated that even though karst features suggest the existence of large, secondary cavernous porosity, most of the pores tend to be small. This infers that flow within a springshed is slow and predominantly intergranular.

The approximate boundaries of the springsheds of first and second magnitude springs intersected by the proposed pipeline route are shown in Figures 3 and 4. These springsheds were obtained from a number of different sources that include Upchurch (2007), SRWMD GIS data, and SWFWMD GIS data.

The figures show that almost the entire route within the Karst Sensitive Area is contained within the springsheds of numerous springs. In some areas, the proposed route does not appear to be within a springshed. However, because the majority of the Karst Sensitive Area is internally drained, it is likely these areas are contained within springsheds that have not yet been delineated.

Table 1 shows the distance from the proposed pipeline route to each first magnitude spring and major second magnitude springs in a springshed at its closest approach. The table and Figures 3 and 4 indicate that for most of the springs, the proposed route is just outside of the springshed boundaries or crosses the most upgradient portion of the springshed many miles from the spring. As discussed above, diffuse flow through the matrix becomes increasingly more dominant over conduit flow as distance from the spring increases. This will afford the springs a degree of protection because sediment, turbid water, and drilling mud that could enter the aquifer during construction and testing is likely to be filtered out and diluted in the aquifer long before it reaches the spring.

Springsheds that could potentially experience the highest level of effects from the proposed pipeline are those of Rainbow Springs in Marion County and Gum Slough in Marion and Sumter Counties. The proposed route crosses a large portion of the western third of the springshed for Rainbow Springs and passes within 1.8 miles of Rainbow Springs at its closes approach. The proposed route also crosses a significant portion of the Gum Slough Springshed in close proximity to the spring, passing within 1.1 miles of the spring at its closest approach.

Cave Systems and Swallets – The Florida Geological Survey (FGS) has compiled the location of known and mapped cave systems and swallets in a GIS database. The database created by the FGS was used to determine whether cave systems and swallets were located within a 0.5 mile-wide corridor of the proposed pipeline route. According to the FGS database, there are no mapped cave systems or swallets within the 0.5 mile-wide corridor.

Closed Depressions – Although some closed depression features are quarries, excavations, and other features not related to karst, the mapping of closed depressions is a rapid method to obtain a general sense of the location, size and density of sinkholes in an area.

The FGS “closed topographic depressions” GIS dataset was used to identify closed depressions in a 0.5 mile-wide corridor representing the proposed pipeline route. The closed depressions were identified, counted and entered along with the nearest mile post and noted in Appendix A. Approximately 2,895 closed depressions were identified within the corridor but the proposed pipeline will not actually intersect

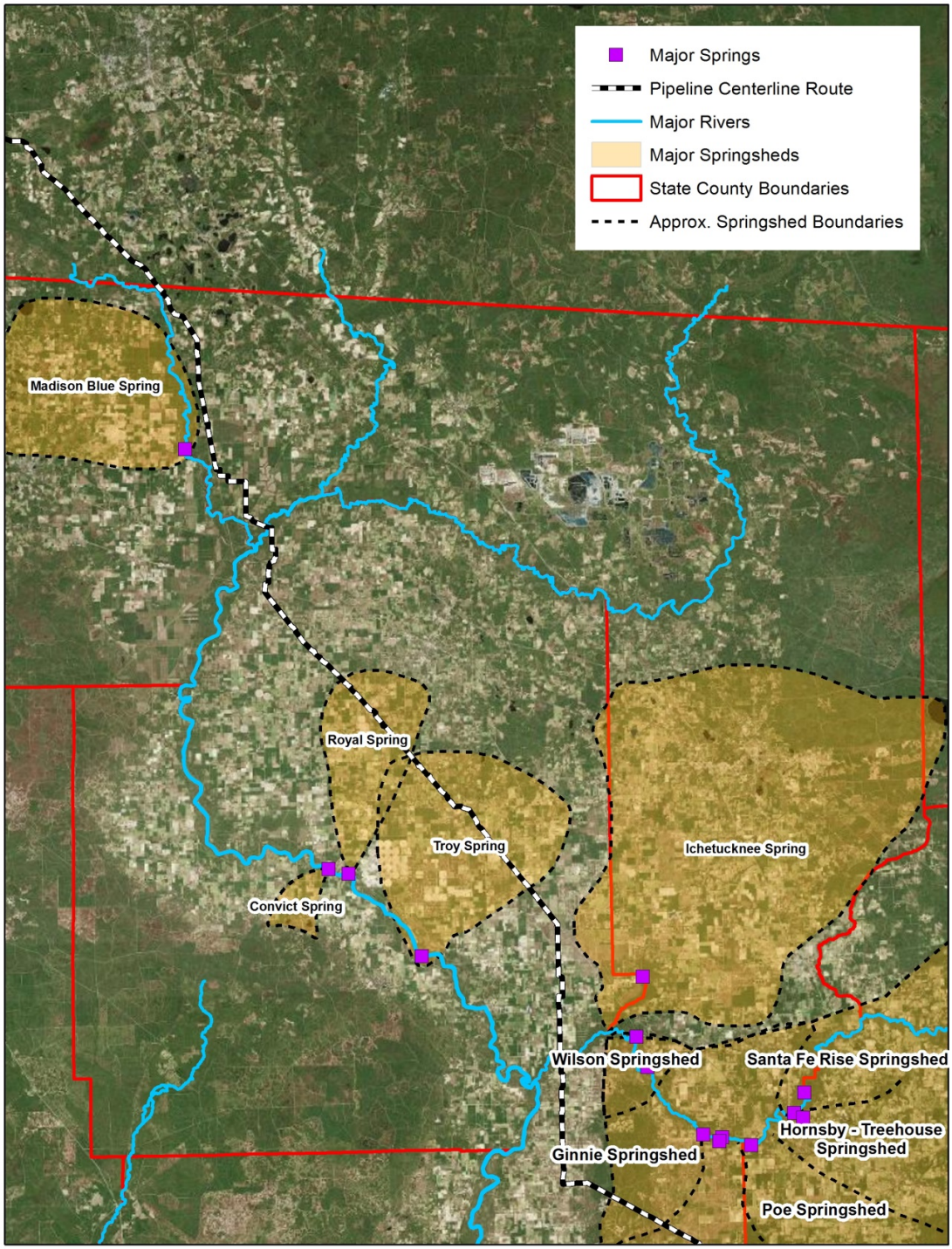

Figure 3. **Approximate Springshed Boundaries of First Magnitude and Major Second Magnitude Springs in the Northern Portion of the Karst Sensitive Area.**

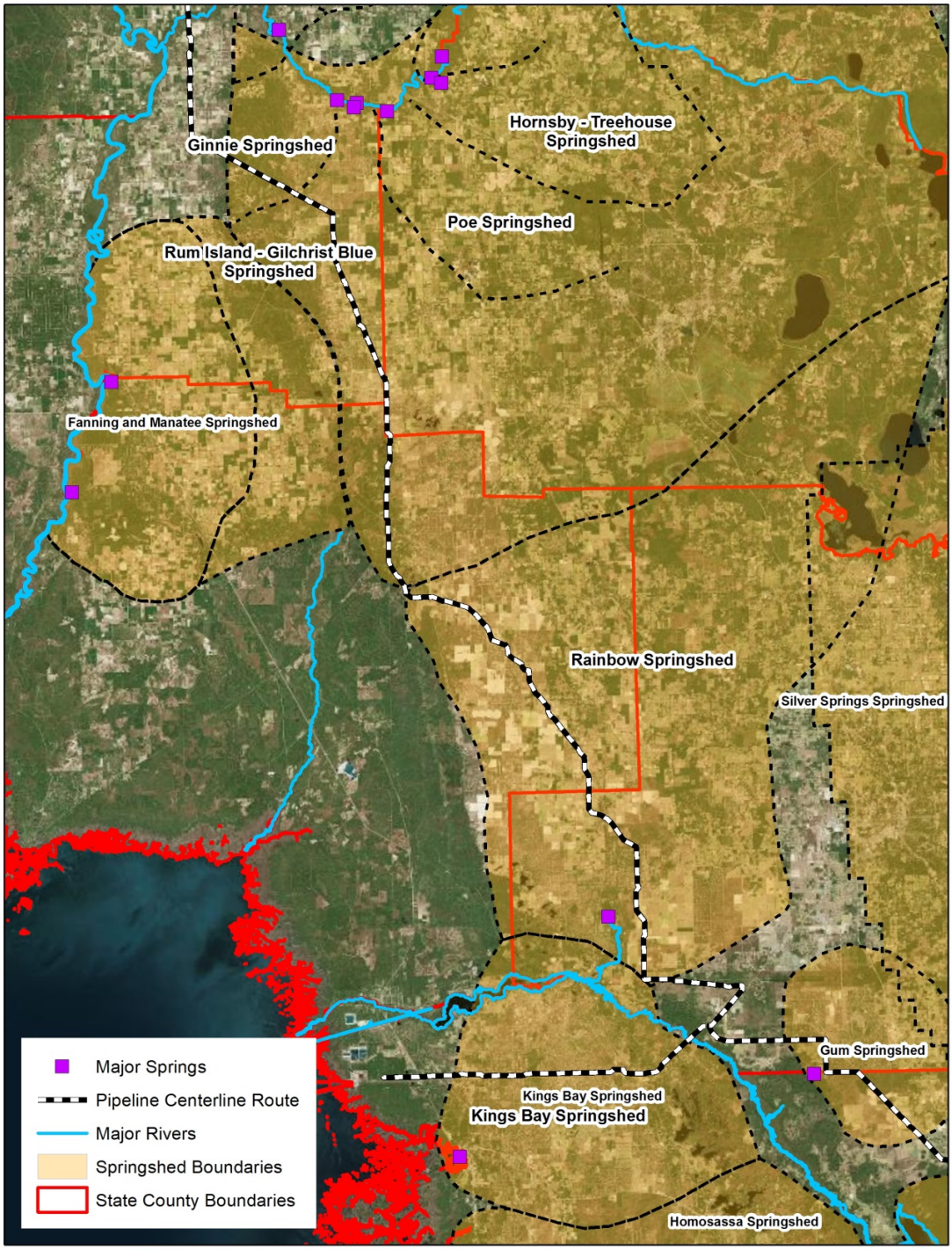

Figure 4. Approximate Springshed Boundaries of First Magnitude and Major Second Magnitude Springs in the Southern Portion of the Karst Sensitive Area.

Table 1. Distance from each Major Spring in a Springshed to the Route of the Proposed Pipeline at its Closest Approach to the Spring.

Spring Name	County	Closest Distance to the Pipeline within the Springshed (miles)
Madison Blue Spring	Madison	1.7
Royal Spring	Suwannee	8.0
Convict Spring	Lafayette	8.7
Troy Spring	Lafayette	8.1
Ichetucknee Spring	Suwannee	5.2
Sunbeam Spring	Columbia	4.9
Wilson Spring	Columbia	5.4
Ginnie Spring	Gilchrist	6.2
Santa Fe Rise Spring	Columbia	11.8
Hornsby Spring	Alachua	10.5
Treehouse Spring	Alachua	10.3
Poe Spring	Alachua	7.1
Rum Island Spring	Spring	6.7
Gilchrist Blue Spring	Spring	6.4
Fanning Spring	Levy	16.9
Manatee Spring	Levy	19.3
Rainbow Spring	Marion	1.8
Kings Bay Springs	Citrus	5.0 (Citrus County Line)
Gums Slough	Sumter	1.1

a great many of these. It is suggested that the closed depressions that the pipeline will actually intersect and large closed depression near the pipeline, should be assessed in the field by sinkhole experts to determine the degree that each feature could affect pipeline construction.

Fracture Traces - Photolinear analysis is a type of remote sensing analysis where linear features observable on aerial photographs or other remotely-sensed images are mapped. For linear features of geologic origin, lineaments are defined as those photolinear features greater than one mile in length, whereas fracture traces are the same type of feature having a total length of less than one mile. The fracture trace is the surface expression of the vertical zone of fracture concentration of the underlying limestone and the width of these zones can vary from a few to tens of meters. In general, longer lineaments tend to have wider surface expressions of the zone of fracture and wider zones of fracture concentration at greater depths. Zones of fracture concentration in soluble rocks such as limestone can lead to enhanced dissolution of these rocks due to accelerated chemical and physical weathering. In the case of rocks prone to karstification, the development of karst conduits begins when fracture apertures reach about one centimeter.

In Florida, fracture traces are detected and identified based primarily upon indicators such as aligned solution depressions, surface ponds, vegetation, variations in soil tone, and straight stream segments. Sinkhole development can be expected to follow orientation of fracture traces, as these represent areas of higher permeability and porosity.

A fracture trace analysis was conducted in the vicinity of the proposed pipeline route using aerial photographs from Hamilton (2010), Madison (2010) Suwannee (2010), Gilchrist (2010), Alachua (2011)

and Levy (2011) Counties. Fractures were identified by visually interpreting linear features that could indicate a fracture zone in the underlying limestone. Twenty-Nine fractures traces that appeared to be of significant scale and that crossed the proposed pipeline route were identified. These are shown in Figures 5 and 6 and listed in Table 2. Appendix B contains the aerial photographs upon which the fracture traces have been highlighted. Nearly all of the fractures are concentrated in the vicinity of the Cody Scarp in the Northern Portion of the Karst Sensitive Area as shown in Figures 5 and 6.

Where fracture traces cross the proposed pipeline route, an enhanced degree of caution should be exercised because these areas could be prone to subsidence during construction or sinkhole formation at some point in the future or could serve as pathways for sediment and contaminants to enter the Upper Floridan aquifer. However, it should be noted that fractures exist throughout the state of Florida and that construction activity in the vicinity of fracture traces is common. A higher degree of inspection during construction practices is required in these areas to ensure that those activities do not cause the impacts described above. Prior to construction, the intersections of the pipeline route and fracture traces should be inspected in the field and geophysical surveys should possibly be employed to assess the potential for subsidence or sinkhole formation.

1.3 Construction Activities

Trenching - Trenching for the installation of the pipeline is not anticipated to cause adverse impacts in the above mentioned springsheds and the Karst Sensitive Area. Trenching during pipeline construction will occur at a depth of approximately 6 to 7 feet below land surface throughout the Karst Sensitive Area. At that depth, construction activities will primarily occur in the sediments that overlie the limestone throughout most of the Karst Sensitive Area. This overburden consists mostly of unconsolidated clay, sand, and gravel that is a result of weathering of the limestone. It is therefore unlikely that trenching will interrupt or collapse major groundwater flow conduits, which tend to occur at significantly greater depths within the limestone.

Areas that may require additional monitoring during trenching include areas where the overburden has been completely eroded away and limestone exists at land surface, such as the vicinity of rivers. This also occurs nears springs but as shown in Table 1, the proposed pipeline route is no closer than approximately 1.1 miles to any major spring. Other sensitive areas include areas where the pipeline route is near large sinkholes or where fracture traces are crossed. The use of geotechnical borings and geophysical surveys in these areas to identify subsurface karst features that can be avoided or properly mitigated will reduce the risk of impacts to conduit flow channels that provide water for spring discharge.

The potential exists for small domestic supply wells in the vicinity of the pipeline route to be affected during construction. These affects would likely be related to increases in turbidity or sedimentation that would dissipate when construction was completed. Permanent damage to wells such as collapse of the well bore or decreases in yield would not be likely

Horizontal Directional Drilling – Appendix C contains data sources used to define groundwater flow paths to springs and wells downgradient of horizontal directional drill crossings for Alabama, Georgia, and Florida.

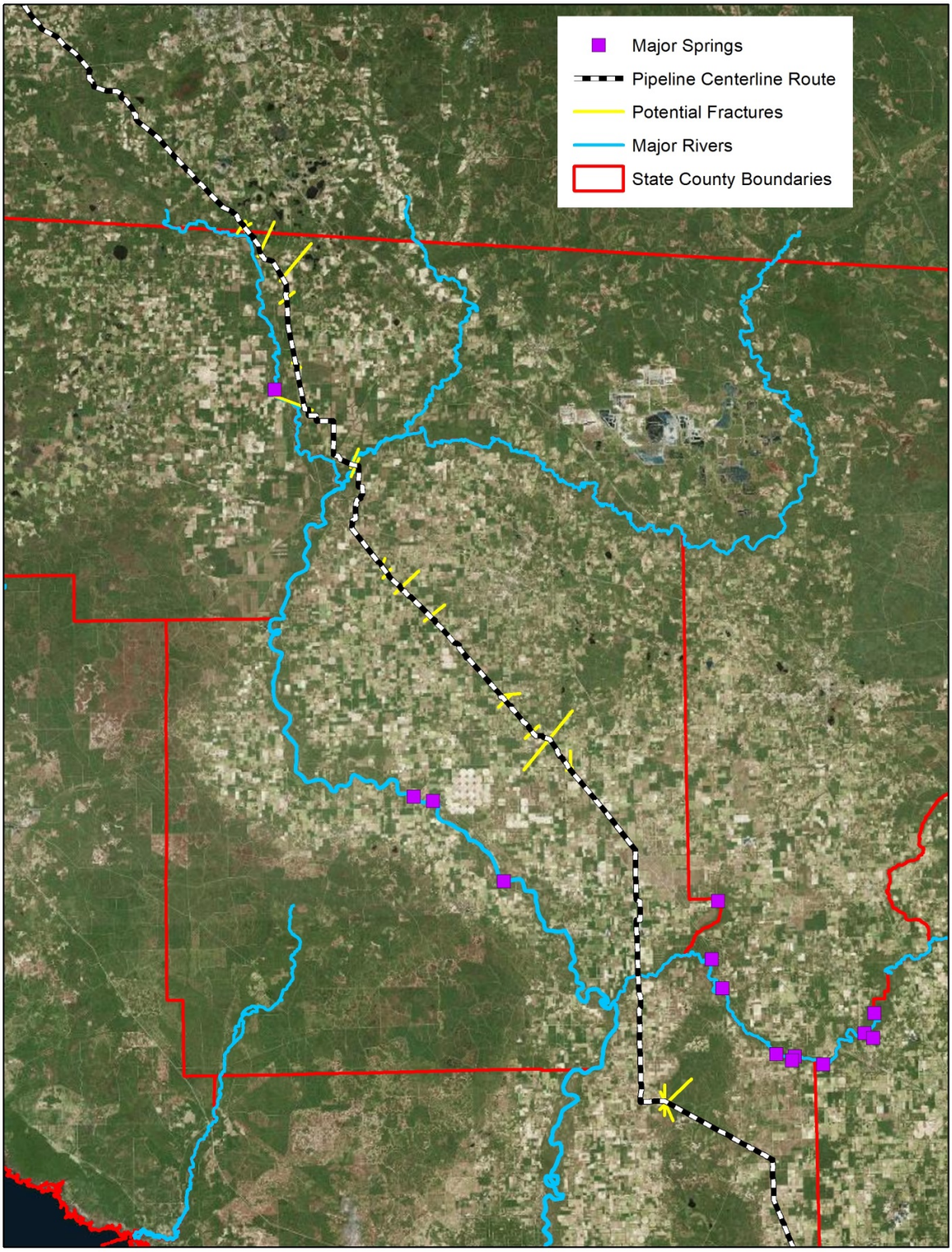

Figure 5. Fracture Traces of Significant Size that Intersect the Proposed Pipeline Route in the Northern Portion of the Karst Sensitive Area.

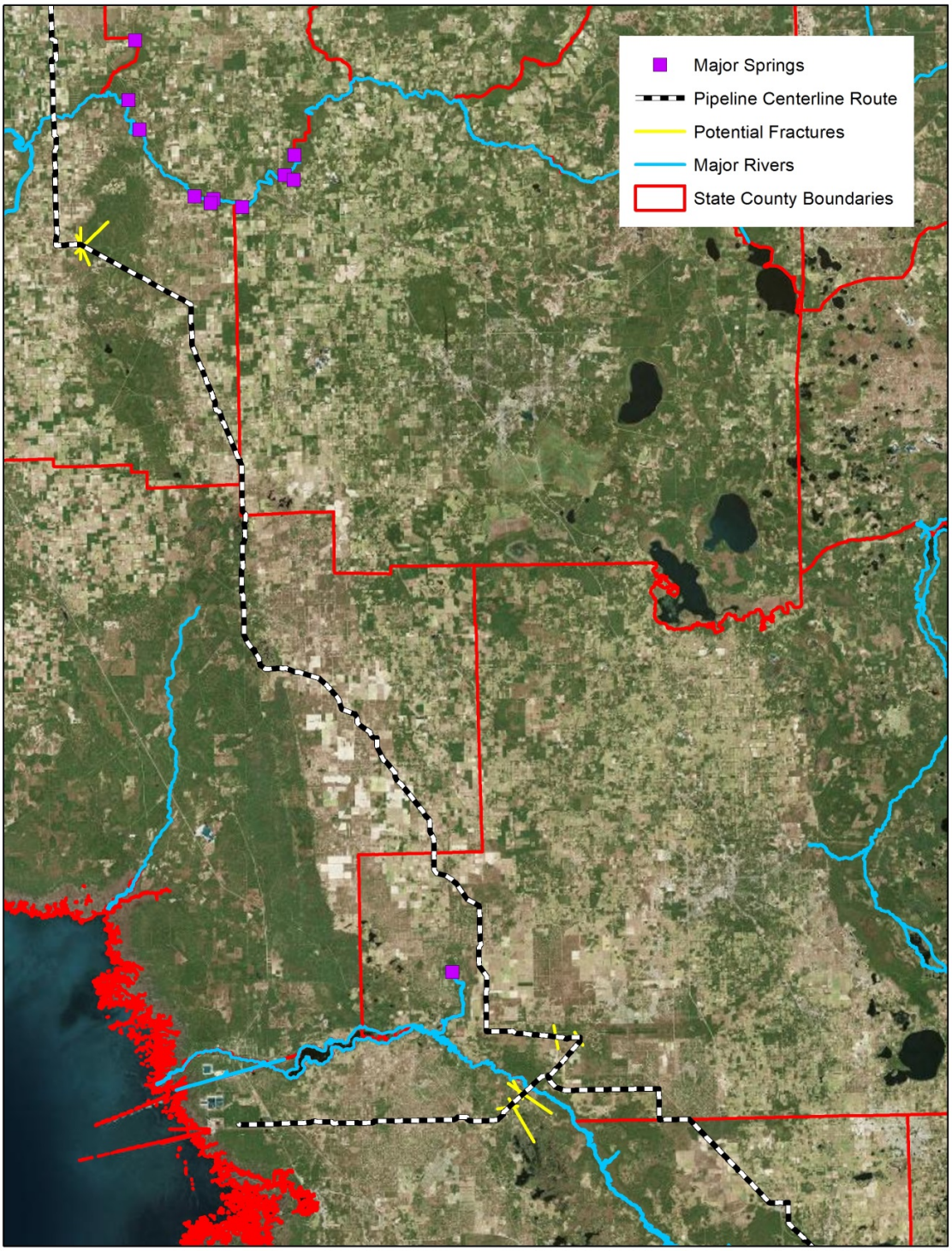

Figure 6. Fracture Traces of Significant Size that Intersect the Proposed Pipeline Route in the Southern Portion of the Karst Sensitive Area.

Table 2. Location of the Fracture Traces Relative to the Proposed Pipeline Route.

Potential Fracture ID	Mile Post
1	247.5
2	247.4
3	247.2
4	249.5
5	251.8
6	253.3
7	257.8
8	260.7
9	267.1
10	267.4
11	273.6
12	274.2
13	275.6
14	278.4
15	285.8
16	286.1
17	288.9
18	290.2
19	292.7
20	292.7
21	318.4
22	318.4
23	318.6
24	387.7
25	389.2
26	1.8 (Citrus County Line)
27	2.0 (Citrus County Line)
28	2.8 (Citrus County Line)
29	3.1 (Citrus County Line)

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Characterization of Karst Sensitive Areas Relative To the Proposed Route of the Sabal Trail Natural Gas Transmission Line

APPENDIX A

CLOSED DEPRESSION FEATURES WITHIN A 0.5 MILE WIDE PIPELINE CORRIDOR ENCOMPASSING THE PROPOSED PIPELINE ROUTE IN THE KARST SENSITIVE AREA

Appendix A Closed Depression Features Within A 0.5 Mile- Wide Pipeline Corridor Encompassing the Proposed Pipeline Route in the Karst Sensitive Area

Closed Depressional Features	Nearest Mile Post
1	244.7
1	245.2
3	245.8
3	245.9
3	246
2	246.2
5	246.3
6	246.7
3	246.8
1	246.9
2	247
3	247.3
2	247.4
1	247.5
2	247.6
1	247.7
2	247.8
1	248
5	248.4
1	248.6
1	248.7
1	249.2
1	249.6
1	249.7
2	249.8
1	250.1
1	250.2
1	250.4
1	250.6
2	250.7
1	250.9
2	251

Closed Depressional Features	Nearest Mile Post
3	251.2
1	251.3
2	251.4
1	251.5
1	251.6
1	251.8
1	251.9
1	252
1	252.1
1	252.3
1	252.5
3	252.6
1	252.7
2	252.9
4	253.2
1	253.4
2	254
2	254.3
2	254.5
1	254.6
1	254.8
1	255.1
1	255.5
1	255.7
1	255.9
1	256.2
1	256.3
1	256.5
1	256.7
1	257
1	257.1
1	257.7
1	257.9
1	258.1
2	258.2
2	258.3
1	258.4
3	258.6
3	258.8
2	259

Closed Depressional Features	Nearest Mile Post
1	259.1
1	259.2
1	259.6
1	259.7
2	259.8
4	259.9
1	260
1	260.7
1	260.8
1	261
2	261.1
1	261.5
3	261.7
1	261.9
1	262.1
4	262.4
1	262.9
1	263.4
1	263.5
2	263.7
1	264.1
1	264.3
1	264.4
1	264.5
1	264.6
1	264.8
2	264.9
1	265.1
1	265.4
1	265.6
1	265.7
1	265.9
1	266.7
2	266.9
5	267
4	267.1
5	267.2
1	267.4
1	267.8
1	267.9

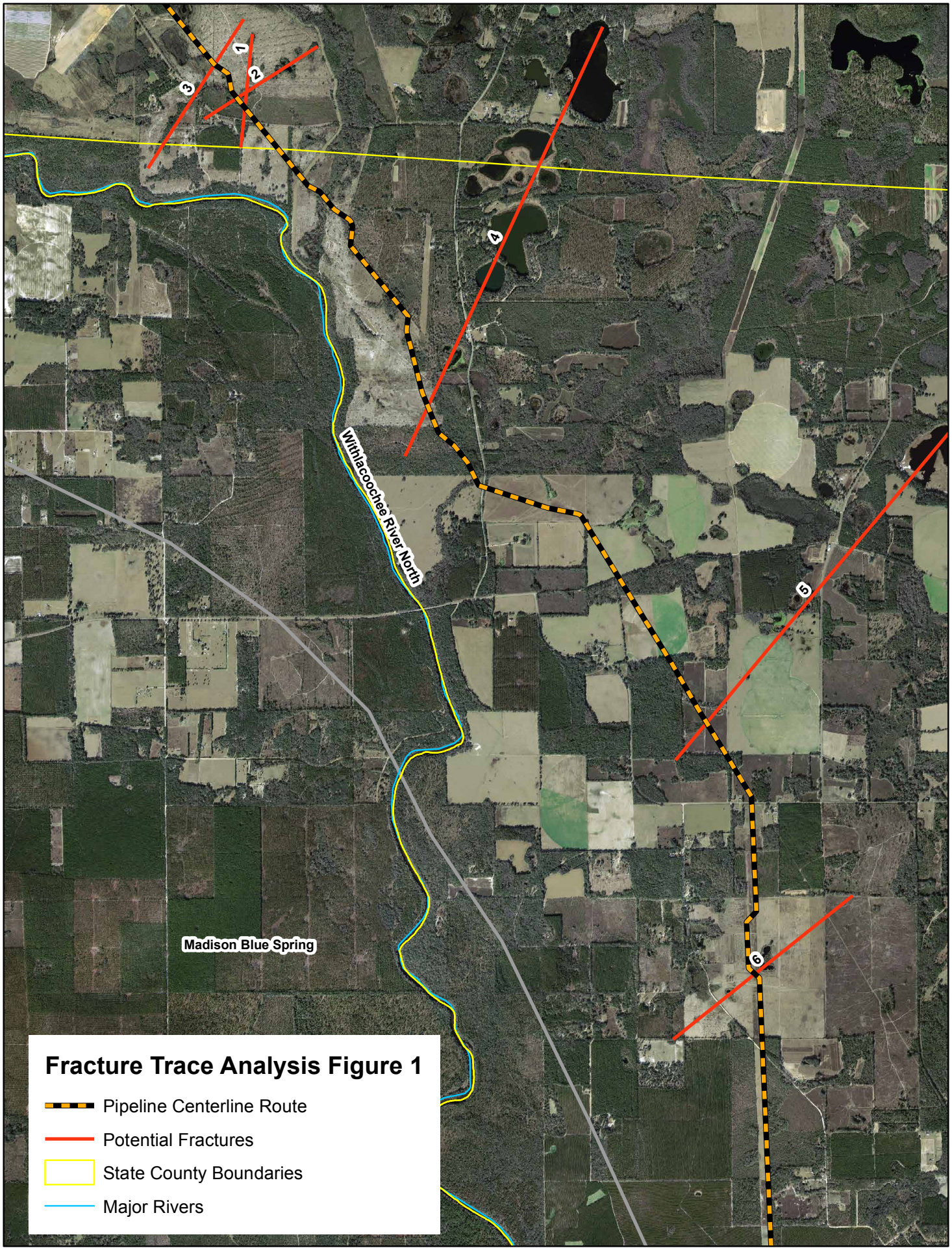
Closed Depressional Features	Nearest Mile Post
2	268.1
1	268.4
1	268.7
4	269
1	269.1
1	269.4
2	269.5
3	269.6
1	269.8
2	269.9
3	270
3	270.1
5	270.2
2	270.3
3	270.4
3	270.5
2	270.7
2	270.8
1	271
2	271.1
1	271.2
1	271.4
3	271.5
2	271.6
2	271.7
3	271.8
1	272.3
1	272.4
2	272.5
1	272.6
3	272.7
1	272.9
2	273
1	273.1
1	273.2
4	273.3
4	273.5
2	273.6
3	273.7
1	273.9

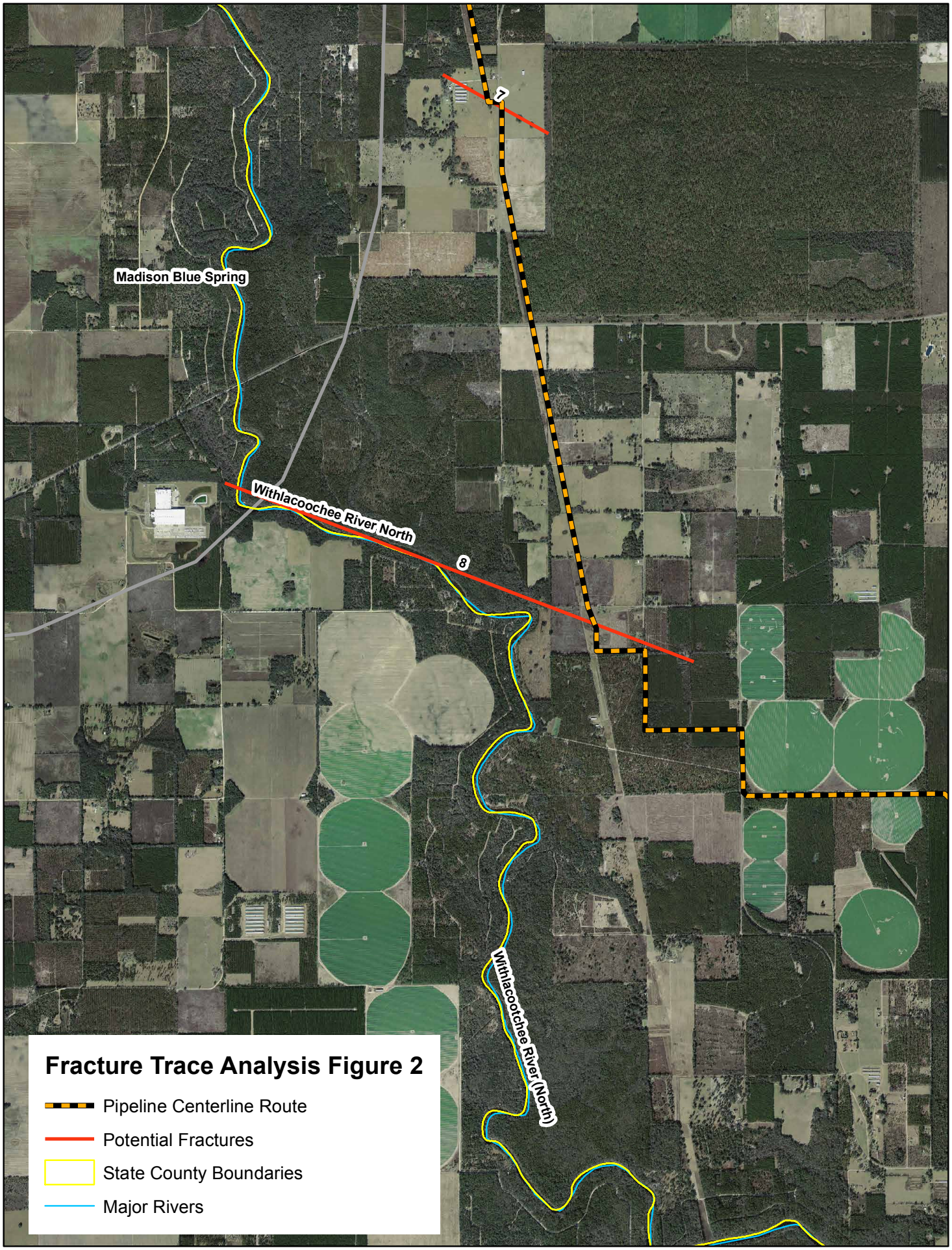
Closed Depressional Features	Nearest Mile Post
2	274
2	274.3
2	274.4
3	274.6
2	274.7
1	274.8
2	275
6	275.1
6	275.2
4	275.4
1	275.5
2	275.6
2	275.7
3	275.9
1	276
6	276.1
6	276.2
3	276.4
1	276.5
2	276.6
2	276.7
2	276.8
1	276.9

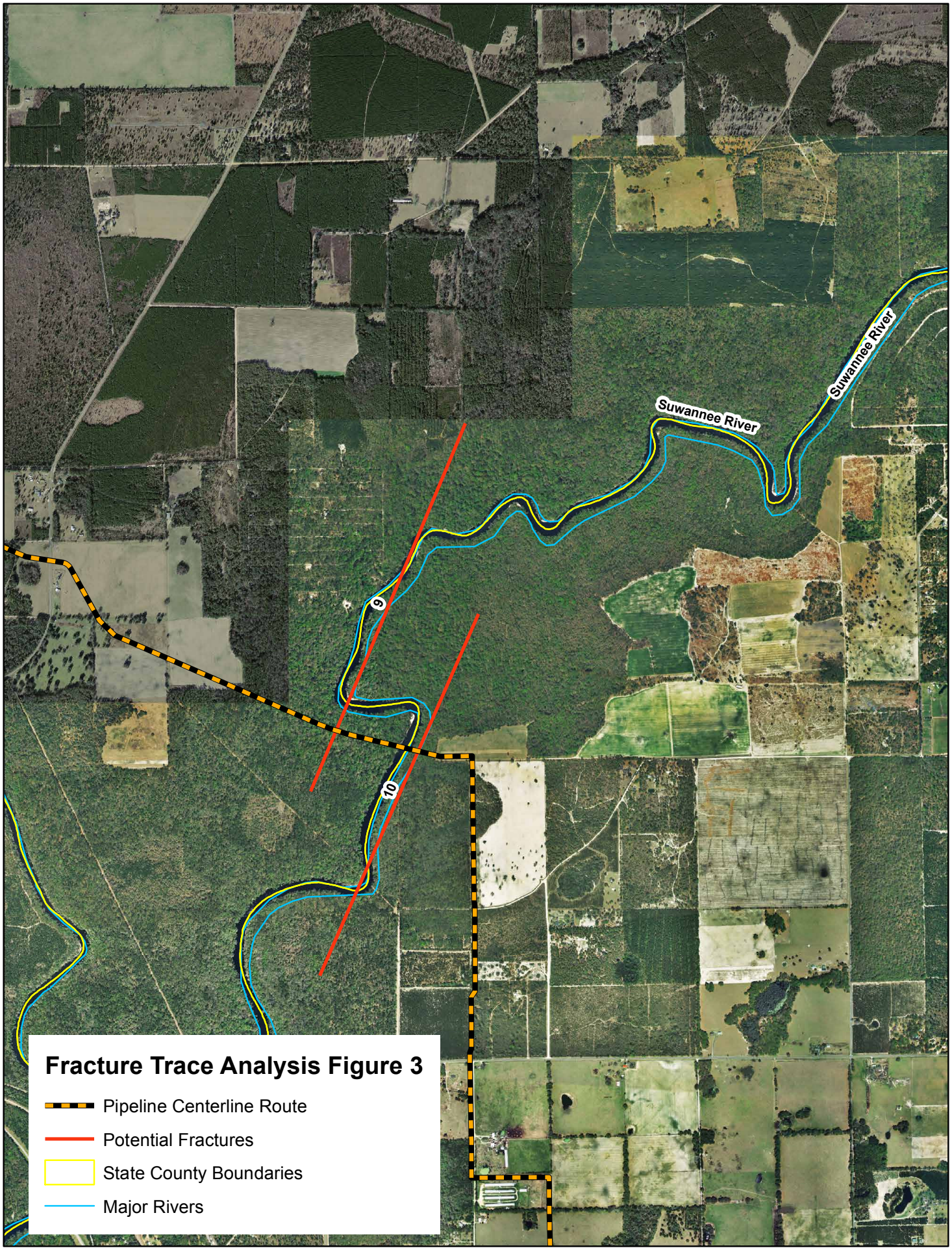
Characterization of Karst Sensitive Areas Relative To the Proposed Route of the Sabal Trail Natural Gas Transmission Line

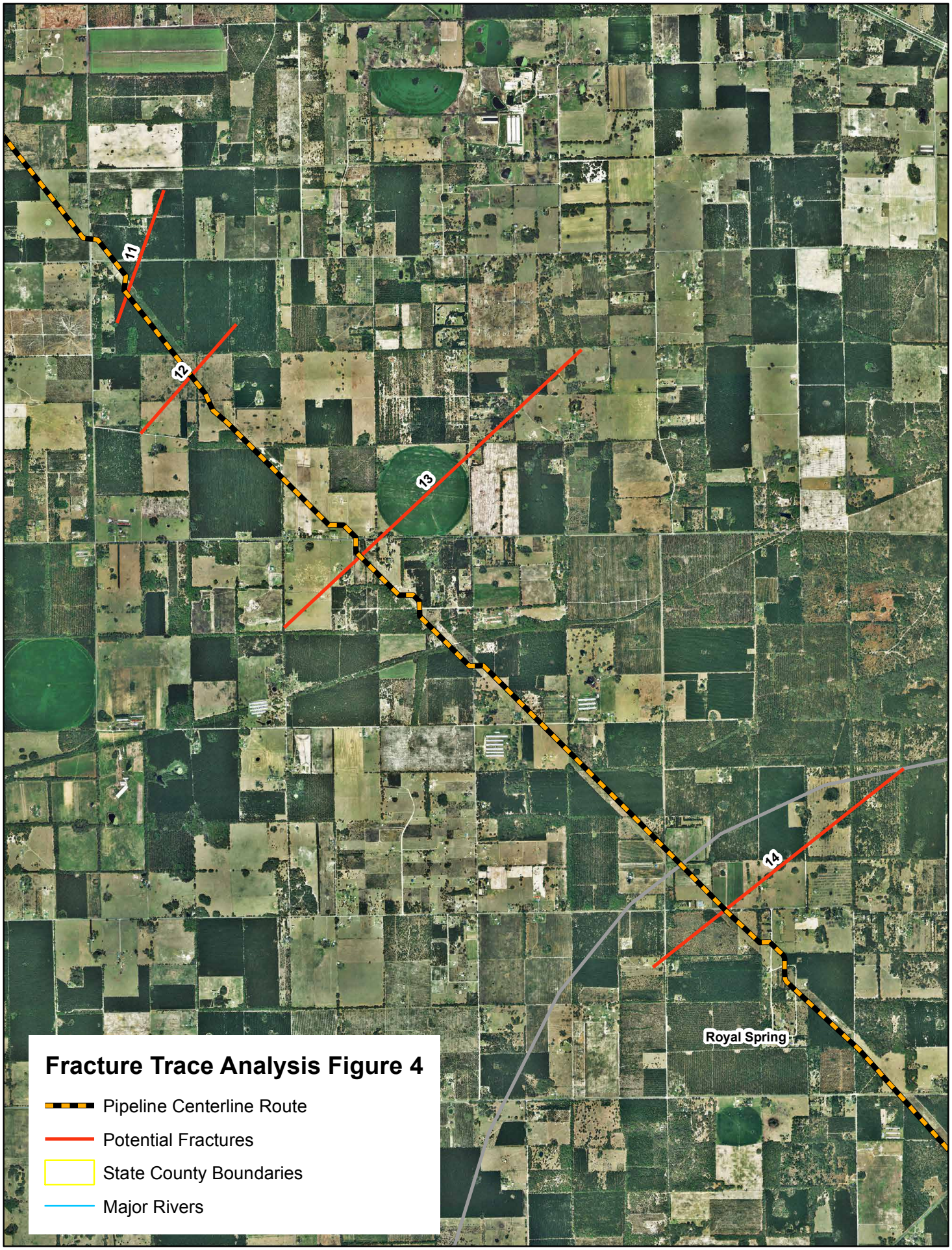
APPENDIX B

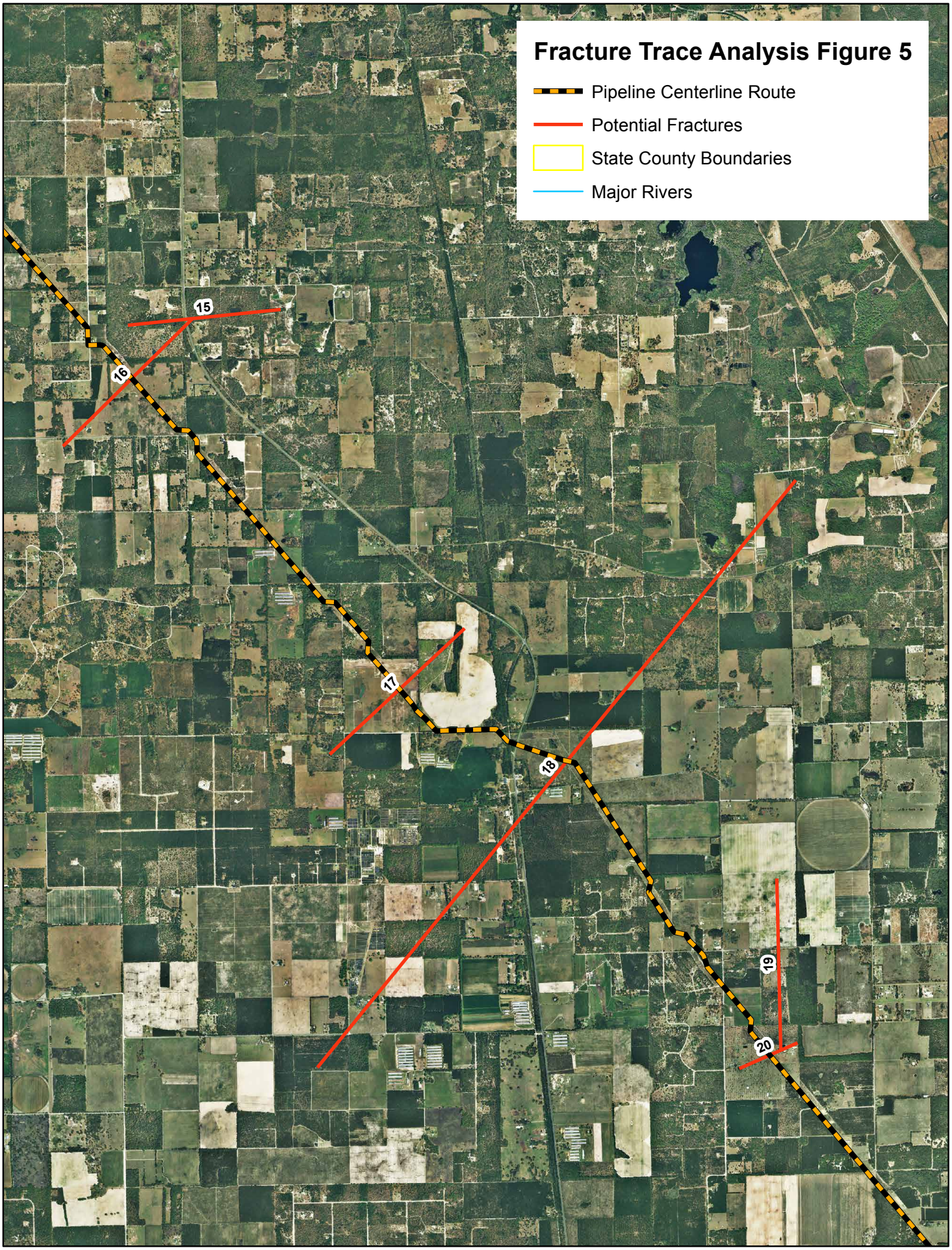
AERIAL PHOTOGRAPHS SHOWING LOCATION OF MAJOR FRACTURE TRACES THAT INTERSECT THE PROPOSED PIPELINE ROUTE IN THE KARST SENSITIVE AREA

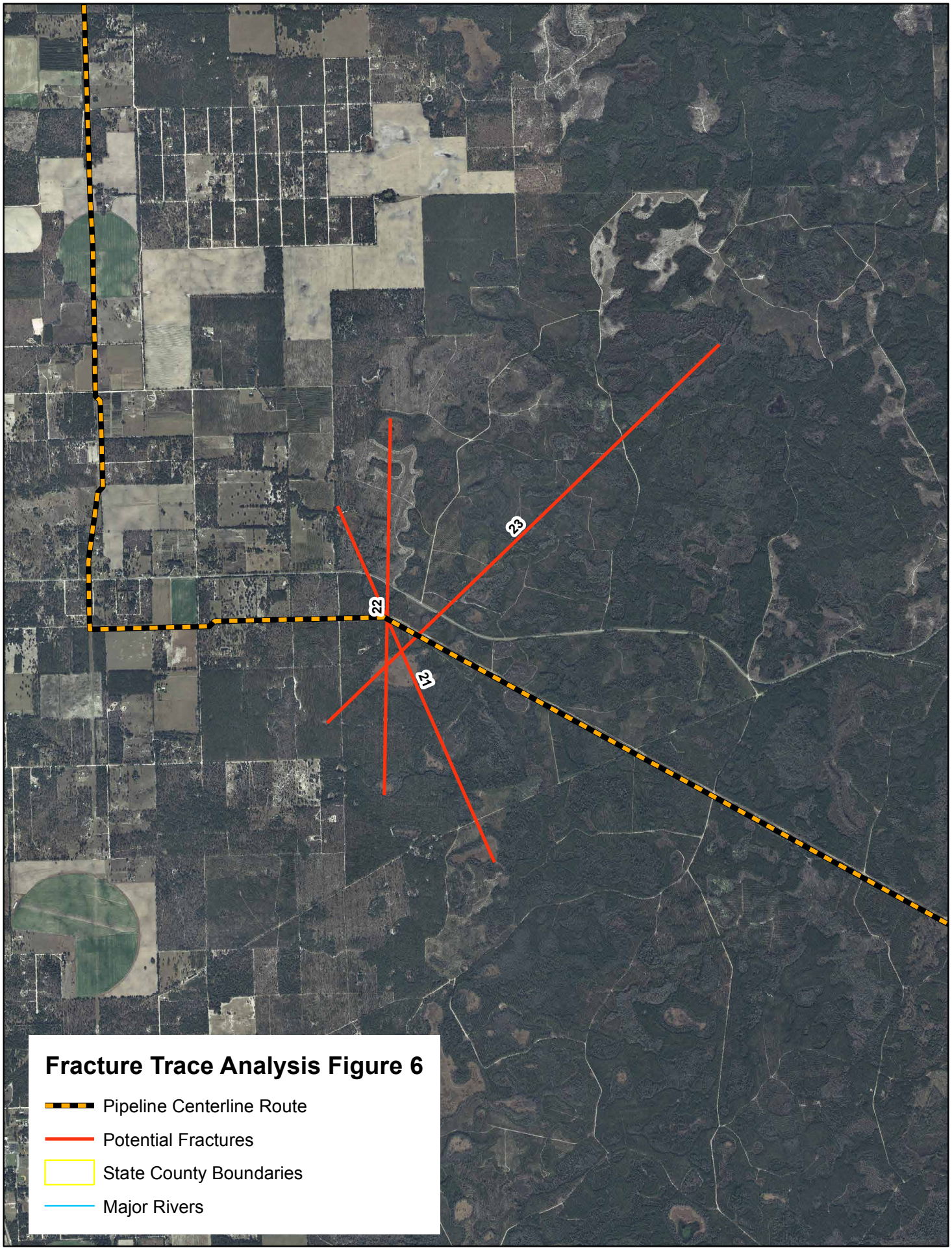

1
2
3
4
5
6
Withlacoochee River North
Madison Blue Spring
Fracture Trace Analysis Figure 1
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers

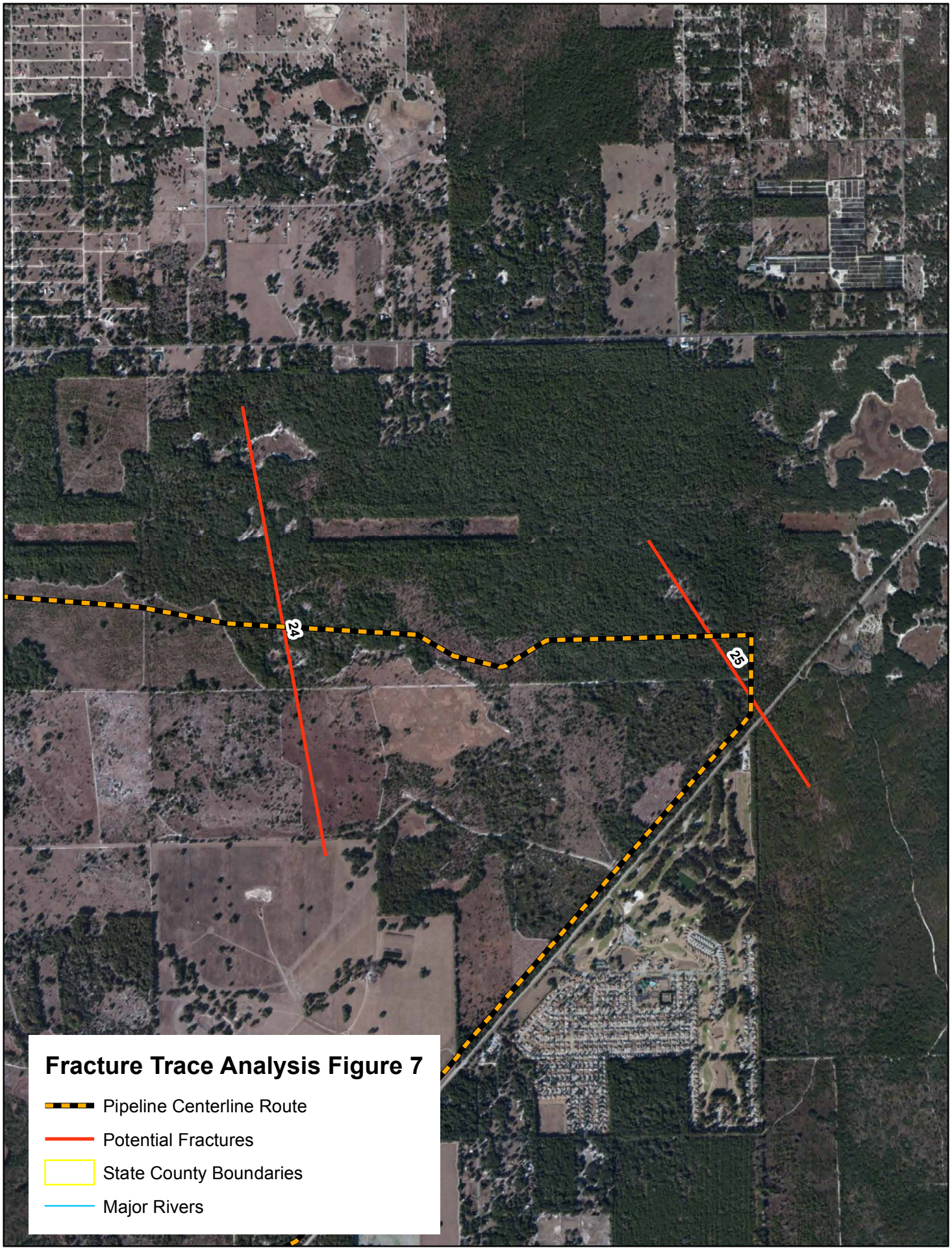

Madison Blue Spring
Withlacoochee River North
7
8
Withlacootchee River (North)
Fracture Trace Analysis Figure 2
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers

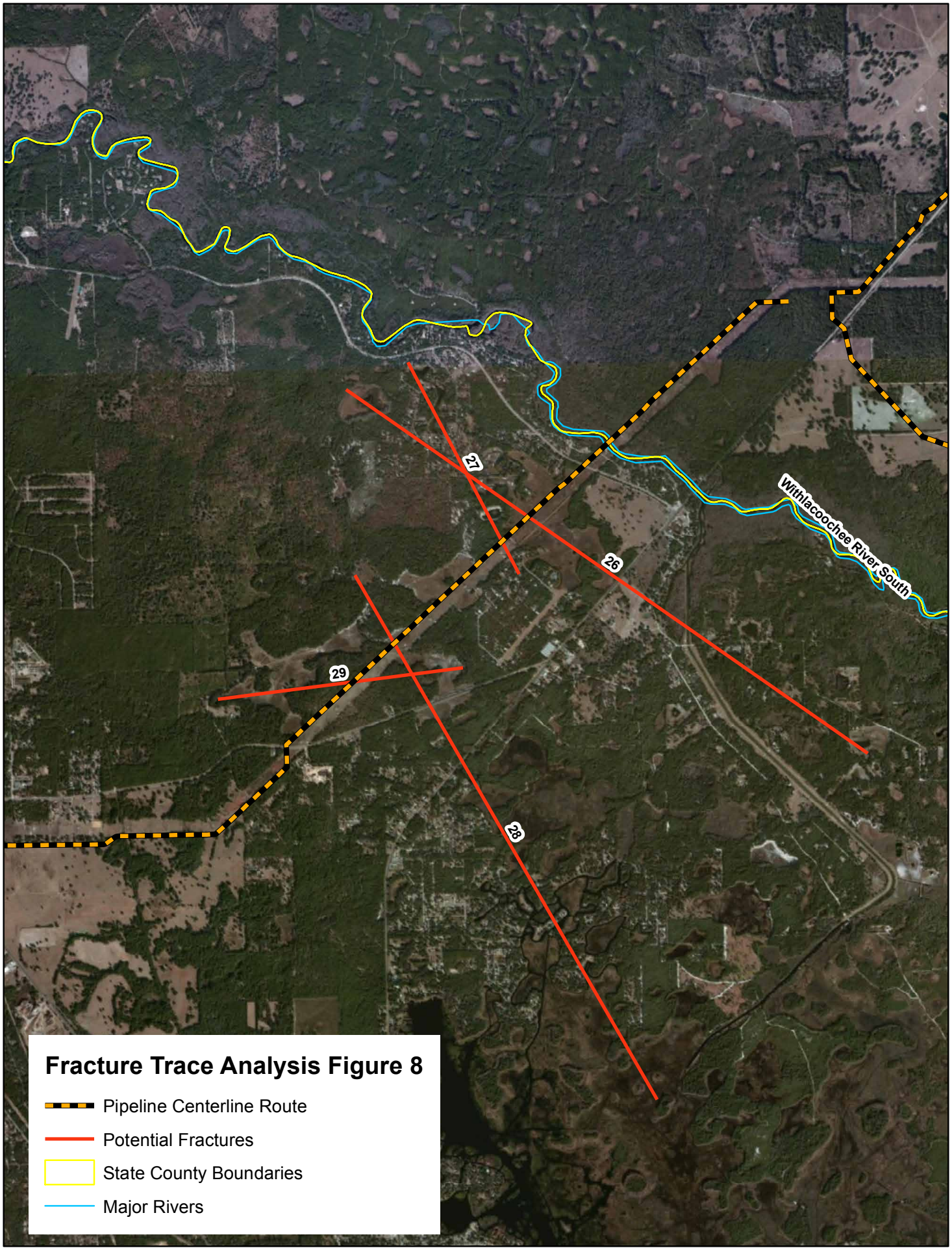

Suwannee River
Suwannee River
9
10
Fracture Trace Analysis Figure 3
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers


11
12
13
14
Royal Spring
Fracture Trace Analysis Figure 4
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers


Fracture Trace Analysis Figure 5
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers
15
16
17
18
19
20


Fracture Trace Analysis Figure 6
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers
22
23
21


24
25
Fracture Trace Analysis Figure 7
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers


Fracture Trace Analysis Figure 8
Pipeline Centerline Route
Potential Fractures
State County Boundaries
Major Rivers
27
26
29
28
Withlacoochee River South

Characterization of Karst Sensitive Areas Relative To the Proposed Route of the Sabal Trail Natural Gas Transmission Line

APPENDIX C

DATA REFERENCES USED FOR DEFINING GROUNDWATER FLOW PATHS TO SPRINGS AND WELLS DOWNGRADIENT OF HDD CROSSINGS

Appendix C Available Data for Definition of Groundwater Flow Paths to Springs and Wells Downgradient of HDD Crossings by State

Alabama
According to the "Hydrogeology and Vulnerability to Contamination of Major Aquifers in Alabama: Area 5" created by the State of Alabama Geological Survey (2000) the aquifers in the vicinity of the proposed Sabal Trail pipeline are not conducive for public supply or groundwater withdrawals due to yields that average 15 - 50 gallons per minute. This area also does not have karst features due to the metamorphic geology of the area.

Georgia
Georgia Environmental Protection Division cannot publicly release the location of groundwater public supply wells; as such they do not have a shapefile for public use that details the location of groundwater wells.

United States Geological Survey, Potentiometric Surface of the Upper Floridan Aquifer in Florida Parts of Georgia, South Carolina and Alabama, May – June 2010 (http://pubs.usgs.gov/sim/3182/)

Florida
Southwest Florida Water Management District 2010 Upper Floridan aquifer potentiometric surface lines form the USGS September 2010 (http://www.swfwmd.state.fl.us/data/gis/layer_library/category/potmaps)

Southwest Florida Water Management District 2012 Water Use Permit Well Withdrawal Database (http://www.swfwmd.state.fl.us/data/gis/layer_library/category/regulatory)

Suwannee River Water Management District 2005 Upper Floridan aquifer potentiometric surface lines from May 2010 (http://www.srwmd.state.fl.us/index.aspx?NID=319)

Suwannee River Water Management District 2013 Water Use Permit Well Withdrawal Database (http://www.srwmd.state.fl.us/index.aspx?NID=319)

United States Geological Survey, Potentiometric Surface of the Upper Floridan Aquifer in Florida Parts of Georgia, South Carolina and Alabama, May – June 2010 (http://pubs.usgs.gov/sim/3182/)

South Florida Water Management District, Water Use Regulation Facility Site 2010 (http://my.sfwmd.gov/gisapps/sfwmdxwebdc/dataview.asp?query=unq_id=1576)