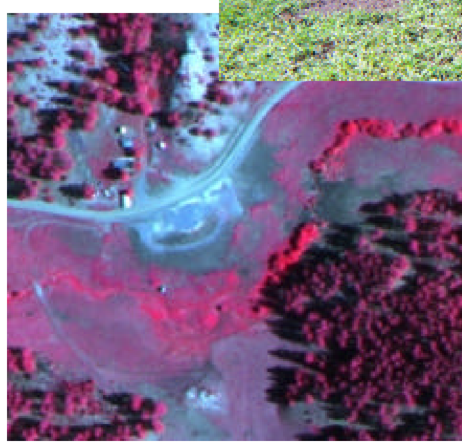
FRUITLAND OUTCROP MONITORING
DATA ACQUISITION MODIFICATION REPORT

LA PLATA COUNTY, COLORADO



JANUARY 2003

Prepared for:

THE GROUP
Durango, Colorado

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Prepared for:

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EXECUTIVE SUMMARY

Since 1998, LT Environmental, Inc. (LTE) has conducted methane seep monitoring on the Fruitland Formation (Kf) outcrop in La Plata County, Colorado (Figure 1). The study area is located along the north rim of the San Juan Basin, north of the Southern Ute Indian Reservation. The objectives of the monitoring program are to observe and document the relative change in methane seepage from the Kf outcrop over time and space. The overriding goal of the program is to ensure the safety of the public and the environment.

The purposes of this report are to describe the changes to and initial results of the flux chamber modifications and present the results of the detailed seep mapping and infrared (IR) imagery pilot study. The three objectives of the modifications were as follows:

- Relocate and/or increase the capture zone radius of the flux chambers to more effectively and consistently measure surface methane flow;
- Perform detailed seep mapping in known methane seep areas to assist in monitoring changes over time and space; and
- Conduct a pilot study using IR technology to map dead and/or stressed vegetation and evaluate effectiveness of the relationship between vegetation characteristics and methane seepage.

Gas Flux Chamber Modifications

In May 2002, LTE implemented the proposed modifications to the existing gas flux chamber network. The modifications included: moving three of the six existing flux chambers to more active seep areas; burying and extending the capture zone radius at the Carbon Junction and Pine River locations; installing an additional flux chamber on land at Texas Creek; and equipping each of the flux chambers with an updated datalogger.

In general, each of the modifications has provided an increase in monitored flow rate to more effectively view changes over time. Based on the data collected from the flow meters and field observations of groundwater table elevation, it appears that dilution and dispersion processes in the vadose zone are factors in evaluating seepage flow. Reduced flow, as compared to previous data, is likely a result of the increase dispersion and dilution of the gas in the vadose zone caused by a low groundwater table. The reduced flow rates were observed throughout the study area. It is anticipated that measurable flows will increase once groundwater levels return to normal.

LTE recommends that monitoring of the flux chamber system continue as originally planned. The new locations and increased capture zone should allow for more consistent monitoring of changes over time.

LTE recommends a review of the soil gas monitoring probe data collected by the Bureau of Land Management. At the time of this report, data collected after January 2001 were not available to LTE. LTE recommends review and comparison of the soil gas probe data to determine if trend decreases have been observed in the soil gas monitoring probes from June 2002 to December 2002 due to drought conditions similar to trends observed in the flux chambers at Texas Creek and Pine River.

Detailed seep mapping

Detailed seep mapping was completed in the areas of Basin Creek, Carbon Junction, Florida River, South Fork Texas Creek, and a limited portion of Pine River from October 2, 2002 through October 9, 2002. The procedure involved walking the known seep areas and vicinity and noting dead, stressed, and non-vegetated areas. Areas where visible seeps were occurring within surface water bodies were also identified and mapped. LTE mapped the dead or stressed trees, areas of dead or impacted grass using the Global Positioning System (GPS) technology. Subsurface measurements of methane, hydrogen sulfide (H_2S), oxygen (O_2), and carbon monoxide (CO) were collected where appropriate.

The seep trends observed are similar to those trends previously identified with the most active seeps occurring in the basal portions of the Kf in areas where a surface drainage feature transects the geologic contact between the Pictured Cliffs Formation (Kpc) and Kf, based on surface geology.

A methane seep area was identified along the Florida River near the Florida Farmers Canal Headgate. This area was not included in previous surveys along the outcrop. The seep area is stratigraphically positioned over the Lewis Formation (Kl). The potential sources for this gas are biogenic gas from a local source; thermogenic gas from the Kl; or thermogenic gas from the Kf via subsurface fractures and preferential pathways.

The detailed mapping activities that have identified the presence of dead or stressed vegetation does not necessarily imply that methane has caused the condition. In many areas mapped, particularly west of the Texas Creek area, dead or stressed vegetation was observed with no detectable concentrations of methane noted during the sampling event. However, the condition of the vegetation does appear to be a good indicator to assist in identifying areas where methane seepage is occurring or may have occurred in the past.

Inferences to the extent of the seep areas can be made from the results of the mapping activities, although specific boundaries are difficult to define. Trends of decreasing methane concentrations are observable with increased elevation away from the major drainage features.

LTE recommends continuing the detailed seep mapping program as described in this report and performing an additional seep mapping event in the spring of 2003. This method appears to be effective at identifying and broadly delineating the known seep area. Over time, continued mapping should provide an indication if changes in the seep dimensions are occurring.

IR Pilot Study

LTE performed an IR imagery pilot study to evaluate the ability of the technology to identify areas of dead and/or stressed vegetation. The suspect areas would then be used as a guide to focus reconnaissance surveys to confirm the presence of methane seepage in the suspect areas. The photo-documentation record will also provide a baseline to monitor changes in vegetative conditions which in turn may suggest methane seepage conditions over time.

After collecting and interpreting the imagery from the pilot study area, this technology can be effective at providing a detailed look at the condition of vegetation across a large area. The imagery is capable of identifying dead and stressed trees and bushes on upland areas and condition of the vegetative cover on lowland areas.

The use of heads-up digitizing techniques appears to be the most efficient means by which to recognize most of the suspect areas. Spectral analysis is useful for identifying more subtle differences that define a suspect area. Heads-up digitizing along with field verification is reproducible. Because of the wide range of color variability, spectral analysis has limited use for our application due to the lack of reproducibility.

When the IR imagery is compared to the detailed field mapping data, the results indicate that the IR imagery is capable of defining many of the areas impacted vegetation are associated with methane seepage. Additional field confirmation of suspect areas is still required in areas not visited during the detailed mapping activities. Depending on the results of the field confirmation, the suspect areas identified during the IR evaluation may be removed from the reconnaissance monitoring or continued to be inspected over time. As additional IR missions are performed, additional suspect areas may be identified which will require field inspection.

LTE recommends evaluating the IR imagery for the remainder of the outcrop area. LTE has already acquired this imagery during the pilot study activities. As part of the evaluation, LTE would identify suspect areas along the entire outcrop. A field crew can then inspect the suspect areas for the presence of methane producing a baseline for the entire outcrop. Changes in vegetation conditions can then be compared with subsequent IR missions and field verification activities allowing for a better understanding of the methane seepage across the entire outcrop.

LTE recommends that the regional reconnaissance survey (pedestrian surveys) program be modified to incorporate the results of the detailed seep mapping and the IR aerial reconnaissance. Increasing difficulty with access to private lands must also be resolved to continue an effective field program.

Finally, both the detailed mapping and IR imagery provide better techniques to record the observable conditions along the outcrop. There are limitations primarily associated with the number of natural factors which influence the vegetation conditions and methane seepage. These conditions include, but are not limited to: disease, groundwater table elevation, drought, preferential pathways, and temperature.

SECTION 1.0

INTRODUCTION

Since 1998, LT Environmental, Inc. (LTE) has conducted methane seep monitoring on the Fruitland Formation (Kf) outcrop in La Plata County, Colorado (Figure 1). The study area is located along the north rim of the San Juan Basin, north of the Southern Ute Indian Reservation. The objectives of the monitoring program are to observe and document the relative change in methane seepage from the Kf outcrop over time and space. The overriding goal of the program is to ensure the safety of the public and the environment.

This program has been completed on behalf of BP, Inc. (BP); XTO Energy, Inc. (XTO); Pure Resources, Inc (Pure); ChevronTexaco Production Company (ChevronTexaco); the Bureau of Land Management (BLM); the Colorado Oil and Gas Conservation Commission (COGCC); and La Plata County. These companies and governmental agencies are collectively referred to as “The Group”.

1.1 OBJECTIVES

LTE’s field monitoring program has augmented investigations conducted by BP, Inc., the COGCC, and the BLM. Based on a detailed analysis of the data collected to date, The Group requested modifications to the monitoring program, primarily expansion of the data collection capability. LTE was requested to modify the existing flux chamber system and reconnaissance survey techniques, and to evaluate infrared (IR) aerial imagery technology for use in the overall outcrop monitoring program. A primary goal of the modifications was to have the ability to repeat the reconnaissance monitoring on a routine basis to be able to document changes over time and space. The three objectives of the modifications were as follows:

- Relocate and/or increase the capture zone radius of the flux chambers to more effectively and consistently measure surface methane flow;

- Perform detailed seep mapping in known methane seep areas to assist in monitoring changes over time and space; and

- Conduct a pilot study using IR technology to map dead and/or stressed vegetation and evaluate effectiveness of the relationship between vegetation characteristics and methane seepage.

The purposes of this report are to describe the changes to and initial results of the flux chamber modifications and present the results of the detailed seep mapping and IR pilot study.

1.2 ORGANIZATION OF REPORT

This report is organized into six sections including this introduction, which presents the objective of the study and discusses background information related to the project. The field methods used to complete the scope of work are described in Section 2.0. Section 3.0 presents the results of the flux chamber modifications. The results of the detailed mapping activities are summarized in Section 4.0. The results of the IR pilot study are presented in Section 5.0. Section 6.0 presents recommendations for continued monitoring. Figures and appendices follow the text in separate sections. Pertinent photographs have been included in the text.

1.3 BACKGROUND INFORMATION

The study area consists of approximately 23 miles of the Kf outcrop extending from the Southern Ute Indian Reservation northern boundary north and eastward to an area three miles east of Pine River. There have been a number of previous and ongoing studies, which support the overall methane seepage evaluation. Some of the previous studies include:

- Ongoing detailed mapping, methane seepage data collection, and mitigation in the Pine River area by BP since 1994;

- Reconnaissance survey by Stonebrooke in 1995, which consisted of collection of over 1,100 surface and/or subsurface methane sample points. This survey identified four additional primary methane gas seepage areas besides Pine River including Basin Creek, Carbon Junction, Florida River, and South Fork Texas Creek (Texas Creek);

- Installation of 162 permanent soil gas monitoring probes by LTE in 1998 and ongoing monitoring of the points by the BLM. The probes are sampled approximately six to eight times per year;

- Installation and ongoing monitoring of six flux chambers in the primary seepage areas. The gas flux chambers measure gas flow on 10-minute intervals. Data are downloaded from the flux chambers every 45 days; and

- Routine reconnaissance surveys of the outcrop by LTE since 1998.

These studies have noted the variability of the methane seepage both in time and space as a result of changes in rain fall, barometric pressure, temperature, and data collection techniques.

1.3.1 Flux Chambers

After evaluating data collected from the gas flux chambers, several limitations were noted with their current geographic locations and available measurement technology. For example, the flux chambers located on land at the ground surface positioned away from the drainage areas had not recorded consistent methane flow rates when compared to those flux chambers located in the drainage areas (Texas Creek flux chamber and BP pyramids). In addition, the rate of methane seepage appears to be higher within the creeks.

A working hypothesis or explanation for this observed phenomena is that the variation in the thickness of the unsaturated zone (vadose zone), due to fluctuations in the groundwater table, influences the rate of dispersion and diffusion of methane as it migrates out of the underlying coal seams through the saturated zone. This process would impact the ability of a fixed collection point at the ground surface to consistently measure the rate of methane seepage. When the water table is relatively low (large vadose thickness), the gas migrating vertically through the groundwater reaches the vadose zone and begins to diffuse and dilute before it reaches the surface. When the groundwater table is relatively high (small vadose thickness), surface measurements are relatively less skewed by dilution, dispersion, and air exchange processes.

Moreover, available technologies are limited for measuring low flow rates (less than one liter per minute) under field conditions. The existing flux chambers located at the ground surface are subjected to a wide range of climatic conditions including temperature and wind variability that can influence the accuracy of the low flow measurement devices.

Two possible solutions have been developed to improve the consistency of the data collection at the fixed flux chambers. Transfer of the chambers into the creek beds or within standing water to reduce the impacts of the vadose zone thickness variation. Where land-based flux chambers are necessary, expansion of the collection area should allow for more consistent flow rates. Sections 2.0 and 3.0 discuss the modifications and initial results of the flux chamber monitoring system.

1.3.2 Reconnaissance Survey

The Kf outcrop study area has been surveyed since 1995. Re-occurring reconnaissance surveys encompassing the entire study area began in 2000. LTE has conducted surface reconnaissance surveys along portions of the outcrop annually since 1998. The surveys conducted in 1995 incorporated both surface and subsurface measurements. The surveys initiated in 1998, and those surveys that followed, incorporated the collection of only surface measurements of methane concentration. In addition, the surveys conducted by LTE noted areas of dead or stressed vegetation, but exact configurations and dimensions were not measured precisely enough to accurately compare changes in vegetative conditions over time and space.

Results from these reconnaissance surveys indicated that methane seepage generally occurs in lower elevation areas where a creek or river transects the outcrop. The reconnaissance surveys also noted a consistent decrease in detectable methane concentration at the surface over time.

It appears that changes in vegetative conditions have occurred since the inception of the monitoring program. However, the observation methods employed in the monitoring program did not allow the quantification of these changes. Only qualitative estimates on areas of dead vegetation were made, and quantifying the numbers of dead or stressed trees across the outcrop was not performed during reconnaissance surveys. The reconnaissance surveys are labor intensive, requiring traverses on foot across steep and heavily vegetated terrain, especially in those areas of higher elevation.

In order to increase the reliability of the data collected and provide increased efficiency in data gathering, LTE proposed several modifications to the methane seep reconnaissance monitoring program. The modifications included the performance of a detailed seep-mapping program in known seep areas similar to those performed by BP in the Pine River and Texas Creek areas. Implementation of the detailed mapping activities will be presented in Sections 2.0 and 3.0 of this report.

1.3.3 Evaluation of IR Technology

As part of the modification to the reconnaissance survey monitoring program, LTE recommended the use of IR technology to identify suspect areas of dead or stressed vegetation along the outcrop, which through field verification, can be correlated to the presence or absence of methane. Once completed for the study area, the IR photo-record would be used for future comparisons to vegetative conditions and accurately quantify changes in vegetative conditions over time. Results of the evaluation to apply this technology as a mechanism to increase the efficiency and accuracy of the reconnaissance survey are presented in the following sections.

SECTION 2.0

FIELD METHODS

This section describes the approach and procedures used to complete the flux chamber modifications, the detailed seep mapping, and conduct the IR pilot study. Photographic documentation of the modifications is included throughout the report and in the appendices.

2.1 GAS FLUX CHAMBER MODIFICATIONS

In August 2002, LTE implemented the proposed flux chamber modifications. The flux chambers located at Basin Creek, Carbon Junction, and Florida River were moved from their existing location to a location adjacent to or within the water where active seeps were visible. The existing flux chambers at Texas Creek and East Pine were not altered. LTE installed an additional gas flux chamber at the Texas Creek study area on land approximately 150 feet from the flux chamber positioned within the creek. LTE believes that the new positioning will facilitate the measurement of increased flow rates so that changes over time can be more accurately monitored.

To further increase measured flow rates collected by the flux chambers, the construction design of the flux chambers was altered to increase the radius of influence (capture zone) at the Carbon Junction, Texas Creek Land, and Pine River locations. The flux chamber's capture zone was extended using poly-sheeting around the base of the chamber. In addition, those flux chambers equipped with poly-sheeting were partially buried beneath the ground surface to reduce the surface effects.

The existing flux chambers at Basin Creek and Florida River were placed directly in surface water where known visible seeps were occurring. The capture zone at the East Pine flux chamber was also not altered since this location is remote and set on more competent surface materials.

The dataloggers at each flux chamber were also upgraded with new technology to eliminate the recent difficulty in communication caused by technological changes in standard computer communication techniques. Appendix A contains equipment specifications for the new dataloggers.

The modified flux chamber locations are presented in Figures 2 through 11.

2.2 DETAILED METHANE GAS SEEP MAPPING

Detailed seep mapping was completed in the areas of Basin Creek, Carbon Junction, Florida River, South Fork Texas Creek, and a limited portion of Pine River from October 2, 2002 through October 9, 2002. Reconnaissance was performed at each location on October 2, 2002 to get an overview of the mapping areas. Detailed mapping began on October 3, 2002. The LTE field crew was equipped with the aerial photographs (orthoquads and uncorrected IR imagery), topographic maps, digital camera, sampling equipment (slide-hammer and probe), global positioning system (GPS), and an MSA GasPort® capable of detecting methane, hydrogen sulfide (H_2S), oxygen (O_2), and carbon monoxide (CO).

The scope of the detailed seep monitoring program was based on the previous surveys performed by BP in the Pine River area (Paul Oldaker) and in the Texas Creek area (Rusty Riese). The procedure involved walking the known seep areas and vicinity and noting dead, stressed, and non-vegetated areas. Areas where visible seeps were occurring within surface water bodies were also identified and mapped. LTE mapped the dead or stressed trees, areas of dead or impacted grass using the GPS. Subsurface measurements of methane, H_2S, O_2, and CO were collected where appropriate.

Previous studies identified the most active seep areas to be in lowland areas where a creek or river transects the Kf outcrop. The seep mapping was conducted within 0.5 miles of the creek/river banks along the strike of the outcrop. LTE mapped beyond the upper and lower extent of the Kf outcrop to cover more of the seep areas and account for faulting, inter-fingering, or other potential geologic anomalies.

When the surface water flow was relatively low enough, LTE waded through the creeks and walked along the banks looking for methane seep bubbles and dead or stressed vegetation. If wading was not possible, the banks of each waterway were traversed. Pertinent features on each side of the waterway were mapped in areas where property access was granted.

Digital Orthophoto Quarter Quadrangles (DOQQs) and uncorrected IR Imagery were used as preliminary field guides to locate suspect areas, such as clusters of dead or stressed trees, patches of dead or stressed grass, or bare ground in the seep areas. This preliminary review of the aerial photographs was conducted as a mechanism to help with the initial mapping.

2.2.1 Types of Features Observed

The types of features noted during the mapping survey included the following:

- non-vegetated areas;
- dead vegetated areas;
- stressed vegetated areas;
- pertinent live vegetated areas;
- dead trees;
- pertinent live trees;
- stressed trees;
- bifurcated trees;
- creek seeps;
- creek seep areas; and
- seep trend lines.

In the lowland areas, LTE focussed on non-vegetated areas that were adjacent to live vegetation areas. These areas were commonly located in the valley lowlands and appear to have been vegetated in the past but have since died off. The dead vegetated areas were observed as patches of dead bushes and/or grass. Stressed vegetation areas were defined as co-mingled sparsely vegetated areas and non-vegetated areas. The small dead or non-vegetation areas were mapped independently at each mapping area. Pertinent live vegetation features were mapped when they appeared as mappable surface areas coexisting with dead or non-vegetated areas.

Dead, stressed, and bifurcated trees were mapped, as practicable, in each of the mapping areas. LTE initially attempted to map tree stumps but dropped these features from the mapping program due to time constraints. The trees were divided into scrub oak, pine, aspen, juniper, and cottonwood.

Bifurcated trees were also mapped. These trees were characterized by trunks that have split or forked as a result of a historic stress event. Both sides of the bifurcation attempt to continue growing however, one of the two stems often dies off.

LTE mapped individual seeps observed within surface water bodies. In some cases, visible methane seeps were often closely spaced and therefore mapped as seep areas or seep trends, especially if the flow in the rivers was high. When linear stressed or dead features where noted they were also mapped as seep trend lines.

The mapping results are presented in figures, which are contained in a separate section following the text. The subsurface methane measurement location symbols were graduated based on concentration. While the lowest concentration range depicted is from 0.0 parts per million (ppm) to 25 ppm, the majority of these locations were actually measured to be 0.0 ppm. In many cases, subsurface methane concentrations were collected at dead and stressed areas and at dead and stressed trees. The results of the subsurface measurements for these features were presented using text labels rather than graduated symbols.

2.2.2 Use of GPS

LTE used a Trimble ProXR® GPS with a real-time correction processor to map observed dead, bifurcated, and pertinent live trees; dead, stressed, and non-vegetated patches; and obvious methane seeps in the creeks/rivers. Specifications of the unit are included in Appendix A. The methane measurements and other relevant field notes were stored as attributes in the GPS unit with the associated GPS mapped positions. The GPS data were later downloaded to a computer and manipulated using Trimble GPS Pathfinder Office® version 2.90. The data was converted to shape files and grouped according to the type of feature, as either points, lines, or polygons.

The data were collected with GPS in the WGS 84 coordinate system and converted to decimal degrees NAD 83 for use in the Durango Methane ArcView® project file developed by LTE in 2001. Trees were mapped as point locations and vegetation patches were mapped as polygons. On average, 20 GPS readings were collected for each tree in order to obtain more accurate positioning. The perimeter of each mapped area was slowly traversed collecting positioning data at a rate of approximately one logged point per foot.

2.2.3 Gas Measurement Collection

A slide hammer was used to advance a half-inch diameter steel rod (probe) to a depth of approximately 36 inches in irregular areas observed during the seep mapping. Some probe holes were shallower than 36 inches due to the density of the ground surface. One-quarter inch diameter polyethylene tubing perforated at the bottom six inches was inserted into each probe hole to collect subsurface gas measurements. The MSA GasPort® field meter was utilized to measure the concentration of methane, H_2S, O_2, and CO in each probe hole. After recording the gas reading, the tubing was removed from each probe hole and backfilled with native soil.

The MSA GasPort® is capable of detecting methane in concentrations from 0.0 ppm to 100 percent (%) methane. Specifications for the unit are included in Appendix A. The field meter was calibrated to methane, H_2S, and CO each morning and again at midday to ensure the equipment was working properly.

Surface measurements were taken at the water surface of the creeks, rivers, and ponds. A funnel was connected to the MSA GasPort® field meter and placed at the water's surface to take approximate methane readings. The funnel was not placed below the water's surface due to the risk of water being pulled into the meter and causing the meter to fail. These surface readings were used for verification of methane seepage and not recorded in the GPS unit.

Subsurface methane measurements were recorded at selected dead, stressed, or bifurcated trees. Probe holes were advanced adjacent to the trees to collect the measurements. If the stressed or dead trees were grouped together a representative number of measurements were recorded inside the cluster to depict the entire area.

2.3 AERIAL PHOTOGRAPHS AND INFRARED IMAGERY PILOT STUDY

The purpose of the pilot study is to evaluate the ability of the technology to identify areas of dead and/or stressed vegetation areas. The suspect areas would then be used as a guide to focus reconnaissance surveys to confirm the presence of methane seepage in the suspect areas. The photo-documentation record will provide a baseline to monitor changes in vegetative conditions related to methane which in turn suggest methane seepage conditions over time. LTE contracted Mr. Kevin Lee Hayes, a digital IR imaging expert, to implement the IR pilot study. A resume summarizing Mr. Hayes' qualifications is included in Appendix B.

2.3.1 Pilot Study Area Description and Other Important Factors

The pilot study area is approximately 2.5 miles long and is located between the Texas Creek area and the Pine River area. The Kf coal seams are within several hundred feet of each other and the entire formation usually covers an area less than one mile wide.

Although the entire 23-mile long monitoring area is arc-shaped, it is considered linear and unusually narrow for photographic purposes.

Several other unusual imaging factors were considered for this task. Vegetation and geologic parent materials vary considerably across the project area providing a high level of background influence and variety. Dark soils with high carbon content provide a background for some sites, while highly reflective alluvial fills are found along the river systems crossing the formation. Riparian vegetation and grass is common in lowland areas, while most of the region is composed of ponderosa, piñon, juniper, and scrub oak on hillsides. In some areas there is a dense shrub layer. The topographic variation across the pilot study area is high. Fires burning in the area produced smoke plumes that affected air quality and aircraft access, so a flexible acquisition method was required.

2.3.2 Available Technologies

The technology options for imaging vegetation kill that were investigated for this project include:

- Quickbird Satellite Imagery;
- Traditional Color Infrared (CIR) Transparency Film;
- Airborne Multispectral Imagery with Complex Orthorectification; and
- Digital CIR (DCIR) - Airborne Multispectral Imagery with Georectification.

Given the wide range of background soils and vegetation, Color Infrared (CIR) imaging will most likely provide the needed contrast. The particular method recommended to capture imagery for this project is based on cost and performance projections from imagery vendors and published literature.

2.3.2.1 Quickbird Satellite Imagery

This technology uses imagery acquired from a satellite orbiting the earth. It provides high altitude images with relatively good quality. Some of the pertinent parameters of this technology include:

- 25 square mile (mi^2) minimum order;
- Images are collected at 10:30 AM local time;
- Within 25 degrees off nadir (straight up);
- 30 to 90-day turnaround; and
- 2.4 meters (m) multispectral and 0.61 m panchromatic products may be used to "pan-sharpen" the image, but is not as effective as 1.0 m multispectral imagery.

The advantage of this technology is that it is much less expensive to georectify. The acquisition of color imagery is also possible. This technology is readily available and also lends itself to cost-effective mosaicking with just a few images required to cover a large area.

The disadvantages include lower resolution; slow turn-around; morning image gives substantial shadows; possible off-nadir view may be undesirable; little control over acquisition date; and very sensitive to smoke and haze.

2.3.2.2 Traditional CIR Transparency Film

CIR Transparency Film is acquired in a method similar to traditional aerial photography, however IR film is used. The output product is a film roll suitable for manual analysis with a 10x zoom device using a light table or ready for digital scanning.

Vendors suggest imaging at a scale of 1:6,000 using Kodak 1443 film suitable for digital scanning. The recommended land area for this technology is a swath about 4,500 feet wide. Stereo image overlap of 60% is recommended for identifying vegetation mortality. Post processing and interpretation of this media is accomplished through digital scanning of each frame. In addition, ownership of the film product is an issue with some vendors, and they prefer to send image files from scans. North to south flight lines produce the best results.

The advantages of this technology include: simple and well-accepted technology; superior spatial detail; stereo analysis may be useful for biological issues; the film can be digitized with a scanner; and faster to georectify than raw digital images.

The disadvantages include: expensive media to acquire and scan; photograph detail is lost in scanning process; many frames to process if all photographs are to be georeferenced; manual stereo analysis may be required; spectral properties (color) are inferior to digital imagery; flight days must be sunny and the atmosphere stable; the preferred north-south flight line does not accommodate the outcrop study area; the film is delicate and scratches easily; and the film must be stored carefully for long term stability. In addition, the costs escalate with the number of images needed. Scanned images should be computer corrected for lens distortion, independently of georectification. The flight path must be higher relative to DCIR, and CIR is more sensitive to smoke or haze.

2.3.2.3 Airborne Multispectral Imagery with Complex Orthorectification

Three-band digital images are suitable for producing DCIR images and are an excellent choice for detailed mapping. This is an enhanced digital camera product using a high-quality digital Kodak camera corrected for on-chip anomalies. The pixel array is 2,000 x 3,000 (2K x 3K) or 4K x 4K depending on the particular camera assigned to the project (DCS460 or DCS7xx models). These images are corrected for lens distortion, then run through a sophisticated series of algorithms that correct for both off-nadir viewing angles and topographic influences. This "Direct Georectification" is well documented in recent scientific literature, but requires a good quality 30 m digital elevation model (DEM), or

10 m DEM if available. Accuracy is better than 10 m with the typical DEM available from the USGS. There is usually a 10-week turn around time for this product.

The advantages of this technology include the following: produces mapping quality images with very little field work; the mosaic quality is high; the technology is well respected in the scientific community; the imagery is ready for analysis using spectral techniques; and the product will ultimately provide very high quality analysis capability.

The disadvantages include: slow turn-around; competition for acquisition dates; and expensive, good quality DEMs are necessary.

2.3.2.4 DCIR - Airborne Multispectral Imagery with Georectification

This technology is acquired similar to traditional aerial photography but uses a specialized camera. Three-band digital images are suitable for producing high spectral quality DCIR images and are a good choice for vegetation imaging.

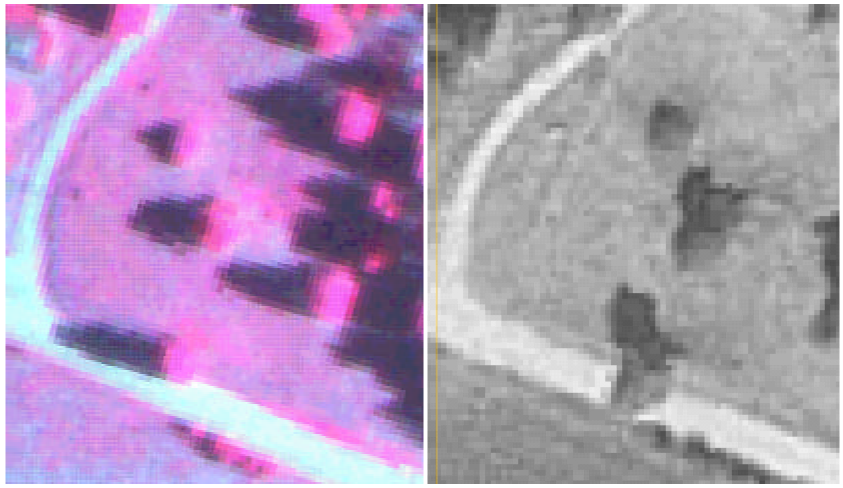
Conventional film-based infrared cameras use a set of three layers of gel-like emulsion to produce a color image on a plastic backing. Microscopic crystals, in a random pattern, activate the emulsion layers when exposed to light. This process creates very high definition spatial features, but has limited ability to capture illumination levels. The data that can be extracted from film are poor in its ability to capture a wide range of colors. In other words, conventional IR film has poor spectral resolution, but very good spatial resolution.

Digital cameras were developed to provide better spectral resolution, and provide a number of other advantages due to the digital capture of data. The camera collects narrow bands of green, red, and near-infrared energy reflected from objects. The camera model is a DuncanTech MS3100 and the photo-pixel array is composed of 1.4K x 1K chip elements (Appendix A). These images are post-corrected by the vendor for radial lens distortion only.

The advantages of this technology include the following: low cost; high quality imagery will provide good quality analysis capability; flexible acquisition dates; vendors are located near the project area; imagery is ready to analyze with spectral techniques; fast turn-around; and the most important images can be corrected first and used quickly. Quick image acquisition time will reduce the affects of turbulence above the ridges and smoky or cloudy days will be less restrictive. This imagery may be flown at a lower altitude than film. DCIR is particularly effective on overcast or hazy days.

The disadvantages of this technology include the following: a high number of images may be required depending on the resolution and study area size; georectification is more difficult; ground control data is required; positional accuracy may be lower than with some other methods; and the flight line must be defined very carefully since the field of view is smaller than most cameras.

The detail and color variation of the DCIR image (left) is more valuable as compared to the DOQQ image (right).



Based on the requirements of the project, cost and time constraints, and available technologies, LTE selected the airborne DCIR multispectral imagery with georectification to complete the pilot study.

2.3.3 Site Visit

Prior to acquiring the DCIR imagery, Mr. Hayes visited the site areas to observe ground conditions and take field notes for use in interpretation of the imagery data. Photographs were taken documenting surface condition and features. Barren areas, stream vegetation, dead trees and vegetation were recorded.

In low-lying areas with willow and cottonwood communities, denuded patches appear dark in color. This is assumed to be a combination of high organic matter and possibly moist soil. These patches have coarse woody debris and portions of dead, dry trees where firewood has not yet been recovered. The Texas Creek area appears to have had most of the dead cottonwood mass removed and has been used as a work area. A modern section of wire fence was noted wrapped around a dead tree section, possibly indicating recent mortality.

One hillside photographed had dead shrubs in a well-defined patch. Soil on this slope is markedly lighter in appearance than valley bottomlands and rock fragments are found at the surface. Travel through scrubby piñon-juniper vegetation on the hillsides is difficult, and private property boundaries are common.

Geologic parent materials vary along the pilot study area. Sandstone, shale, coal outcrops, and alluvial material are present in south-dipping structures. Valley bottoms have been used for agricultural purposes and pasture. The valley bottoms are usually low-slope features and may lead up into high slope side canyons or arroyos.

2.3.4 Other Data Utilized

Two types of mapping products were used to locate the proposed flight line. USGS 7.5' topologic quadrangles were used to locate the approximate position of the Kf on the ground. Generalized sketches of the outcrop provided an approximate area of interest or swath along the pilot study area. LTE also provided GPS coordinates of points used during previous reconnaissance surveys to assist in the development of the flight path. The Rules Hill and Ludwig Mountain quadrangles contain the test area.

New USGS DOQQs where used to provide an approximate image registration base. GPS sampled features collected during the detail seep mapping portion of this project were used to test the accuracy of the georectified images. The GPS data included a limited number of ground control reference points in addition to the features discussed in Section 2.2.1.

2.3.5 Acquisition of Aerial Imagery

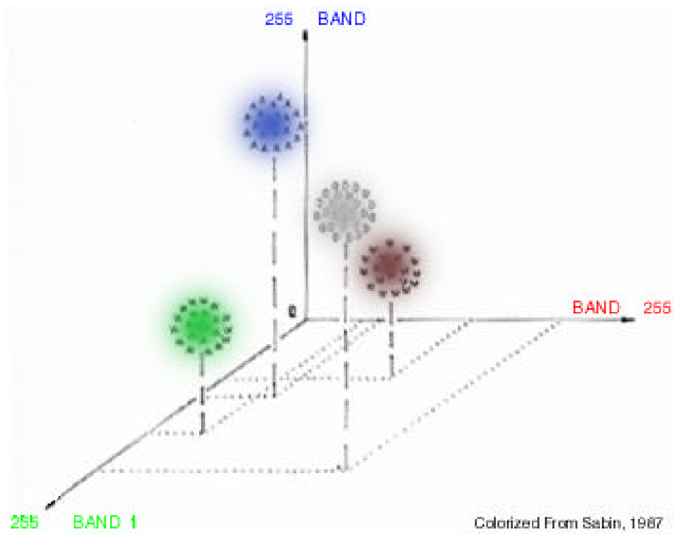
Imagery acquisition by Agro Engineering (Agro) in Alamosa, Colorado, was selected based on image quality, availability, logistical considerations, and cost. This decision was reinforced by the 2002 Missionary Ridge fire, which occurred a few miles north of the pilot study area. Agro successfully captured the test section imagery, despite flying restrictions due to the wildfire, periodic air quality problems, and turbulent flying conditions over topographic ridges. Agro was able to follow the GPS flight path supplied by LTE accurately and completely.

The proposed scope of work originally assumed imagery acquisition over the pilot study area only. At the recommendation of Agro, the entire 23-mile outcrop study area was flown since the majority of the project costs are associated with the mobilization of the field crew and not in the acquisition of the imagery. The photo-mission traversed the entire 23 mile long outcrop three times, collecting three different resolutions (0.5 meters, 1.0 meters, and 1.5 meters). Photography was acquired between 9:30 AM and 1:00 PM on August 14, 2002. Note that 1.5 meter images were taken nearly three hours before the higher resolution images. The time differences significantly affect the impact of shadows within the imagery. The flying altitude varied from approximately 10,500 to 15,400 feet, over rugged terrain with elevations between 7,300 to 8,200 feet (Appendix C). A total of 237 images were acquired and quickly reviewed for quality. The interpretation and analysis of these images were focused in the pilot study area with occasional reference to other images along the study area.

2.3.6 Analysis of Imagery

A variety of software imaging packages were used. Microsoft Photo Editor®, Adobe Photoshop®, Kodak Photo Imager®, and ACDSee® proved helpful for cursory examination on a color computer monitor. All of these imaging packages are not appropriate for viewing pixel-level detail (i.e. zoomed in or enlarged).

Digital imagery is fundamentally different than film-based photography. A photo-sensor collects numeric values that are saved as a computer file. These files are composed of three sets of values, each representing the brightness of reflected energy in a channel or band. CIR imagery requires three bands. This can be conceptualized as a single point on a three dimensional graph. Each photo-pixel value is similar to a letter in the figure below. Each band is assigned to a color gun in the computer monitor. Image software



coordinates these values as a color image on a monitor or printer. There are no inherent color values to the data. Colors or tones are selected by the analyst viewing the data and vary from machine to machine and between imaging programs. The set of values which represent a particular spot on the ground are a sample of the electromagnetic spectrum, and therefore are referred to as spectra. Manipulating these values to extract information is called spectral analysis.

Spectral analysis using ERDAS Imagine® further refines the utility of the imagery. This particular program is specialized and expensive. ERDAS Imagine® is a professional image processing program commonly used in research. Many utilities are available in this package to help an analyst investigate the content of digital images. A color level slicing (ISODATA) feature is used to mathematically class the tones in an image.

When adequate field data are present, these classes can be related to conditions on the ground with two important limitations. The first is that a careful and accurate description of surface conditions is required from field personnel and the other is that the surface condition of interest must be spectrally unique. Since these two requirements are seldom achieved perfectly, as in the idealized illustration above, some overlap or confusion will exist between classes. This class confusion may produce errors in mapping.

The images acquired within the pilot study area were evaluated by Mr. Hayes using both spectral analysis techniques as well as simple visual techniques. Heads-up digitizing of on-screen material has been accomplished in this area. Spectral signatures have been identified for dead vegetation and known methane seep areas.

All data that are presently available have been collected and are now available for analysis in an ESRI ArcView® Geographic Information System (GIS). This includes new DOQQs that have been converted to the Geographic Coordinate System (Latitude/Longitude), in the NAD83 datum, displayed in decimal degrees (DD). Ten 1.5 m resolution DCIR images, two 1.0 m, and two 0.5 m images have also been registered to the DOQQs. Previously acquired GIS coverages of methane measurements and geologic structures collected by LTE are compatible and available for overlay.

2.4 LIMITATIONS

The type of terrain that exists along the Kf outcrop presents difficulties for both the GPS unit and collection of subsurface methane samples with the slide hammer.

North-facing slopes and heavily wooded areas are difficult to obtain accurate positioning by the GPS. Satellite signals are frequently bounced among the trees or lost completely. When satellite signals are limited, positioning accuracy decreases. In some cases, it is not possible to map by GPS. Readings collected with the GPS unit can be located within one-meter radius of accuracy. However, in heavily wooded areas and north-facing slopes the unit's accuracy will decrease.

Soil probing in consolidated materials along the outcrop was limited. LTE used the slide hammer to probe to a maximum depth of 36 inches below ground surface (bgs). In some cases, probing depths of 18 inches bgs were laborious to achieve. If refusal occurred, measurements were taken at the depth bored. All probe holes were advanced to a depth ranging from 6 inches to 36 inches bgs depending on the type of surface cover present.

Methane measurements of the visible creek seeps were not recorded because of the inaccuracy associated with collecting the readings. Ambient air mixing with the methane and dispersion caused skewing of the measurement. The funnel was used in areas where gas seeps were unexpected to determine whether methane was the gas seeping through the surface water. Some portions of the waterways had too many bubbles to map separately so they were grouped together as seep areas or seep trends.

Southwestern Colorado experienced extreme drought conditions and numerous subsequent fires during the summer of 2002. The groundwater table was extremely low due to lack of precipitation at the time of the detailed mapping activities. Comparison of some of the creek seeps mapped during the extreme low flow regime to future creek seeps may show apparent increases as the rivers and creeks rise to normal levels. Regional flow summaries of daily discharge in the Animas River at Durango, Colorado and the Los Piños River at La Boca, Colorado from July 2001 through November 2002 depict the drought conditions and are included as Appendix D.

The drought conditions also resulted in an increased amount of dead and stressed vegetation, which may not be associated with subsurface methane seepage. The extensive areas of stressed or dead vegetation, particularly in the Carbon Junction area, were not completely mapped as part of the scope of work because of the drought conditions. However, comparison of this mapping program and IR imagery to vegetative rebound may be useful in the future. Again, the level of methane recorded during the drought conditions may appear to be low due to the wider vadose zone and deeper groundwater table.

Aerial imagery varies greatly depending on the type of terrain, angle of the sun, time of day, and atmospheric conditions at the time of acquisition. In some cases the full potential usefulness of the image could not be achieved due to one or more of the factors described above. In particular, north facing slopes and morning time images cast shadows that make IR interpretation difficult in some areas.

Finally, LTE was restricted by property owners from accessing several areas with noted irregularities observed on the IR images. A complete reconnaissance survey of the outcrop was not planned due to the lack of property access, increased amount of dead vegetation, and a current focus on known methane seep areas.

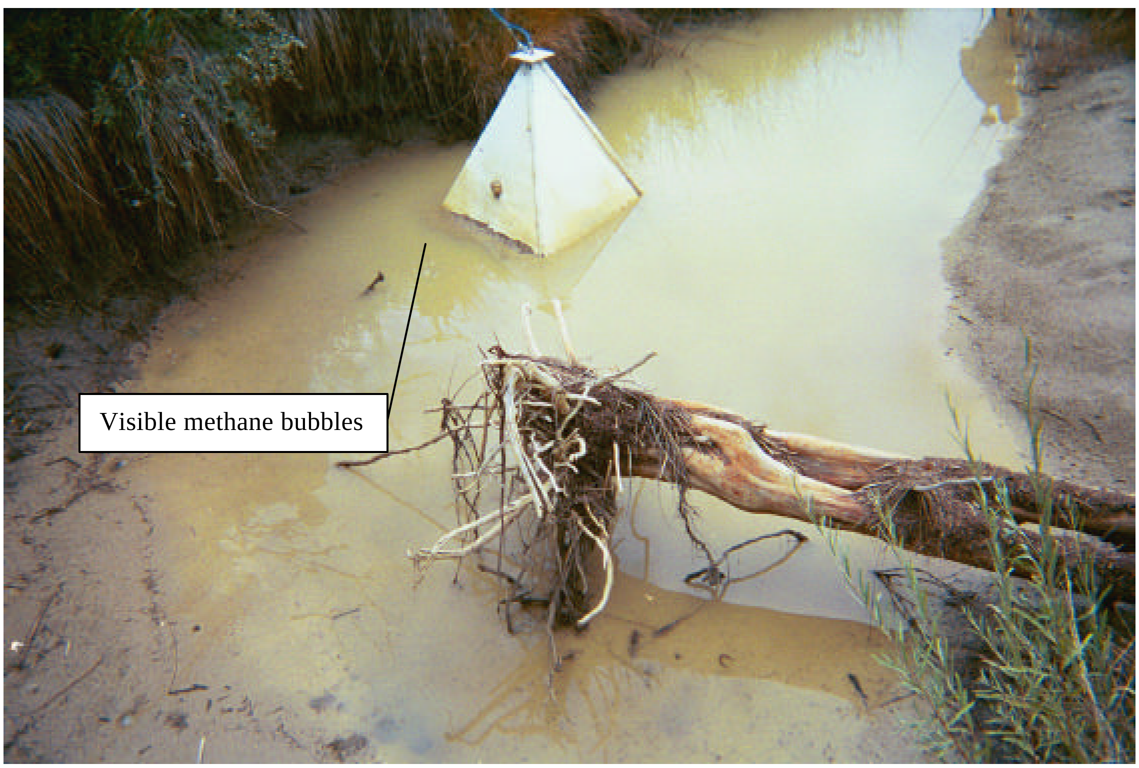
SECTION 3.0

FLUX CHAMBER MODIFICATION RESULTS

This section describes the results of the modifications made at each of the flux chamber locations. In addition, the flux chamber data collect since the June 2001 operation and maintenance (O&M) report have also been presented. The flux chamber data are included in Appendix E.

3.1 BASIN CREEK

The Basin Creek flux chamber was moved from the original site adjacent to the access road into the creek proper. The stratigraphic location of the flux chamber appears to be over the basal coal unit of the Kf based on surface geology. The creek was nearly dry during the time of installation. Only pools of water were noted at various bends within the stream. The specific area selected was based on the presence of active seeps observed within the standing water.



The Basin Creek flux chamber was set in the standing water and was therefore not buried in the soil. LTE also determined that equipping the flux chamber with poly-sheeting to extend the capture radius was not necessary based on current flow rates. In fact, the flow meter had to be re-scaled by the manufacturer to accommodate flow ranges up to 10,000 standard cubic centimeters per minute (sccm) or 10 liters per minute.

The flow data collected from the original location and previously reported indicate that flow was sporadic and rarely exceeded a flow rate of 100 sccm. No increasing or decreasing trend was observed in the flow data from the period starting in late 1997 through May 2002.

Flow data collected following modifications indicated that the current flow rate is sufficient to measure consistent gas flow and should prove to be useful in monitoring changes in gas flow over time. The current flow rate ranges from 500 sccm to 3,000 sccm with peak flows observed during the afternoon hours. This data is consistent with previous flow patterns at Basin Creek and is comparable to those flow rates observed at Texas Creek before this summer's drought conditions. The most recent data collected from the Basin Creek flux chamber indicate a considerable decrease in flow rate since May 2002.

During the most recent O&M event, LTE noted that the standing water present during the installation of the unit in May 2002 is no longer present and mudcracks have formed on the surface.

3.2 CARBON JUNCTION

The Carbon Junction flux chamber was moved from the original location near the intersection of U.S. Highway 160 and Highway 3 to an area near the boat launch into the Animas River adjacent to the Humane Society building. The station was selected based on the presence of methane bubbles within the river nearby. More active creek seeps were identified within the Animas River approximately 100 feet down stream of this location but access into the area to install the flux chamber was not feasible.

The flux chamber area was excavated to a depth of approximately 2 feet bgs. The center portion of the ground surface was raised to form a pyramid shape. Poly-sheeting (12 mil) was placed over the pyramid surface and the top of the poly-sheeting was cut open to allow gas collected by the impermeable barrier to migrate into the flux chamber which was set on top of the pyramid-shaped surface. Native soil was backfilled over the poly-sheeting and the base of the chamber.

Carbon Junction flux chamber under construction

Following construction of the flux chamber, the new datalogger was fit into the control box and the unit was setup to begin collecting flow data. A six-foot tall chain-link fence was also installed at this location to prevent vandalism to the unit.

Prior to the relocation of the flux chamber, the flow rates recorded were sporadic and rarely exceeded 100 sccm. No increasing or decreasing trend in the flow data had been noted between late 1997 and May 2002.

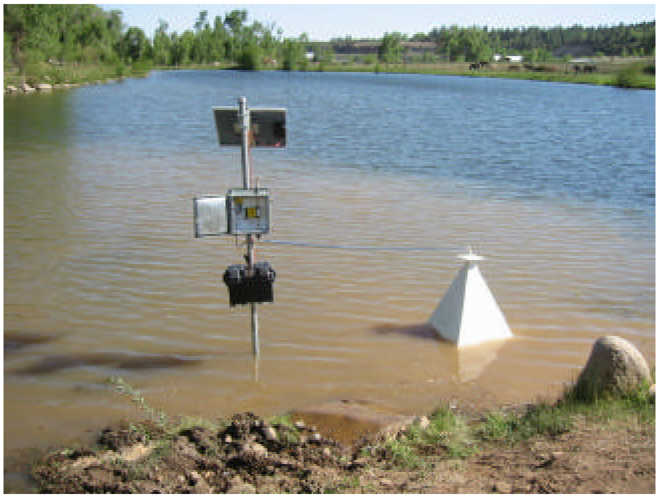
Flow data from the new location does indicate an increase in recordable flow as compared to the previous monitoring location. The current flow ranges from 20 sccm to 1,000 sccm. The flow at this new location is relatively low as compared to flow measured in the flux chambers at Basin Creek and Texas Creek. It appears that flows have decreased over the past three months since the flux chamber was relocated.

3.3 FLORIDA RIVER

The Florida River flux chamber was moved down from the hill at the intersection of County Road 234 and County Road 237 to an area where visible seeps are occurring on the north side of the Terry Palmer Ranch pond.

The flux chamber was set directly over active seeps that were observed adjacent to the edge of the pond. The flux chamber was set into the water so no excavation was needed. The new datalogger was installed into the control box and setup to begin collecting data.

Previous flow data indicated that flow was sporadic and rarely exceeded 100 sccm. Peak flows had been observed as high as 300 sccm but were not sustained. No apparent increasing or decreasing trend could be observed in the data previously collected.



Florida River flux chamber

The flow data collected shortly after relocation indicate that more sustainable flow is being recorded by the unit as compared to the previous flux chamber location. The recent data collected from the flux chamber in the new location noted sustained gas flow at a rate of approximately 50 sccm to 75 sccm. This flow rate is relatively low compared to the Basin Creek and Texas Creek flux chamber locations. In mid-August 2002, a significant drop in flow rate was observed.

During the detailed seep mapping, approximately 1.5 months following modifications to the flux chambers, it was noted that the water level within the pond had dropped below the bottom of the flux chamber. Therefore, data collected within the flux chamber when the water level is below the bottom of the chamber are not valid because the flux chamber is influenced by surface wind conditions.

3.4 TEXAS CREEK

As previously stated, the flux chamber located within Texas Creek was not modified. The flux chamber is currently measuring sustained flows, effectively allowing for monitoring changes in flow rate over time.

The flow data indicate that a significant decrease in gas flow has occurred during the past eight months. The flow rates recorded during this summer's drought are down by at least 65% as compared to the flow rates measured in early 2002. The current flow rates are less than 1,000 sccm. The South Fork of Texas Creek was noted to be dry as early as June 2002 and has remained dry since.

An additional flux chamber (TC Land) was added at the Texas Creek monitoring location for future comparison to the flux chamber measuring gas flow within the creek. This flux chamber was constructed similar to the flux chamber at Carbon Junction including the poly-sheeting skirt and the subsurface burial. The TC Land flux chamber was also surrounded by a steel fence to limit damage caused by grazing livestock.

The flow data from the TC Land flux chamber are much lower than the flow rates previously observed within the creek. Flow ranges from 10 sccm to 200 sccm. Little or no flow was recorded from late August 2002 through October 2002. Recent data suggests a slight increase in recorded flow. The recent elevated flows are likely related to the increase in precipitation that has occurred in October.

TC Land flux chamber

3.5 PINE RIVER

The flux chamber at the Pine River area was also modified to increase measurable flow within the chamber. The flux chamber was equipped with the poly-sheeting skirt and buried. During construction activities, an unmarked water line was ruptured and began to fill the excavation. The water line was immediately repaired. Prior to removal of the water within the excavation, visible seeps were noted, therefore, LTE is confident that the flux chamber is located in an area with active methane seepage.

Pine River flux chamber and weather station

The flow data prior to the modifications indicated that the flow was sporadic and ranged from 0 sccm to 800 sccm. No apparent increasing or decreasing trend in the data could be observed.

Following flux chamber modifications, sustained flow rates ranged from 10 sccm to 200 sccm. These flow rates are not much higher than the rates previously observed. However, a consistent flow rate has emerged and should assist in monitoring changes.

3.6 EAST PINE

The flux chamber at East Pine was equipped with an updated datalogger. This flux chamber was not equipped with the poly-sheeting skirt nor was it buried beneath the ground surface.

Data indicate that flow rates have ranged from 0 sccm to 400 sccm. Current flow rates are less than 50 sccm. A broad overview of the flow data indicates a slight decreasing trend over time.

3.7 FLUX CHAMBER MODIFICATION SUMMARY

In May 2002, LTE implemented the proposed modifications to the existing gas flux chamber network. The modifications included: moving three of the six existing flux chambers to more active seep areas; burying and extending the capture zone radius at the Carbon Junction and Pine River locations; installing an additional flux chamber on land at Texas Creek; and equipping each of the flux chambers with an updated datalogger.

In general, each of the modifications has provided an increase in monitored flow rate to more effectively monitor changes over time. Based on the data collected from the flow meters and field observations of groundwater table elevation, it appears that dilution and dispersion processes in the vadose zone are significant factors in evaluating seepage flow. Reduced flow, as compared to previous data, is likely a result of the increase dispersion and dilution caused by a low groundwater table observed throughout the study area. It is likely that measurable flows will increase once water levels return to normal.

The increased dilution and dispersion caused by a lowering of the water table coupled with mudcracks at the ground surface may have limited the ability of the Basin Creek flux chamber to accurately measure seeping gas.

At Florida River, it is likely that the decrease in flow rate observed in mid-August 2002 is related to the drop in pond water level, especially since the bottom of the flux chamber is exposed above the surface of the water. LTE anticipates that this unit will continue to provide sufficient flow data to monitor flow changes over time once the water levels in the pond rise.

The decrease in flow observed at Texas Creek during the past six months is likely related to the drought conditions experienced in the area and the lower groundwater table at the flux chamber. Mr. Paul Oldaker has recently observed a similar decline in measurable flow rate at the BP Pyramids.

SECTION 4.0

DETAILED SEEP MAPPING RESULTS

The following sections summarize the observations made during the detailed seep mapping study. The mapping followed the procedures outlined in Section 3.0. The sections are grouped by study area and frequently reference figures for illustration purposes. Figures are included in a separate section following the text. For each figure reference, LTE has designated a text reference label to easily identify the location discussed. Each label consists of a two letter abbreviation for the mapping area followed by a number (i.e. BC-1).

4.1 BASIN CREEK

The detailed seep mapping for Basin Creek was completed on October 3, 2002 and October 6, 2002. The mapping area was centered on Basin Creek and was approximately 0.45 miles in the east-west direction and 0.20 miles in the north-south direction. Visible methane gas seeps were mapped on the first day. Dead, stressed, and non-vegetated areas on both sides of the creek were mapped on October 6, 2002. Figure 2 illustrates the results of the mapping in the Basin Creek area.

4.1.1 Observed Methane Seeps in Surface Water

The Basin Creek flux chamber is located in the creek bed of Basin Creek (BC-1). Visible methane seeps were noted within the creek intermittently for one-tenth of a mile east of the flux chamber location. Additional methane seeps were observed within the creek approximately one-quarter of a mile downstream at location BC-2.

4.1.2 Lowland Areas

The area in Basin Creek demonstrating the highest subsurface methane concentration was encountered along the creek bed where the current gas flux chamber is located. Two large stressed vegetation areas and two dead juniper trees were noted west of the flux chamber. One of the stressed vegetation areas demonstrated a subsurface methane

Large dead tree near Basin Creek flux chamber – 350 ppm methane.

concentration of 470,000 ppm (47%). Subsurface methane concentrations of 350 ppm and 0.0 ppm were recorded at the base of the two dead juniper trees. An additional subsurface methane measurement collected outside of the stressed vegetation area demonstrated a methane concentration of 1,400 ppm. The majority of the methane seeps identified in the mapping area were stratigraphically located in the lower sections of the Kf, though direct correlation to stratigraphy is difficult due to surface coverage.

4.1.3 Upland Areas

Subsurface methane was detected at location BC-3 at a concentration of 350 ppm. All other mapped areas of dead and stressed pine, juniper, and scrub oak trees tested did not report methane seepage at the time of sampling.

4.1.4 Comparison to Previous Surveys

Reconnaissance surveys completed at the Basin Creek study area consisted of surface and subsurface measurements collected in 1995 and surface methane measurements collected in 2000 and 2001. Measurements were collected along the outcrop and the locations were mapped with the GPS unit to enable relocation during future surveys. Methane measurements recorded through the years demonstrate an overall decrease in surface methane concentrations at Basin Creek. The data collected from surface measurements in 2001 resulted in one concentration between 25 ppm and 500 ppm. The measurement was taken in an area upland and further west from the area mapped in 2002. All other surface methane concentrations were less than 25 ppm in 2001. These surface methane concentrations were generally lower than the subsurface methane concentrations collected in 2002.

The detailed seep mapping data identified subsurface methane concentrations that are similar to soil gas probe data collected between 1997 and 2001. The methane concentration detected at location BC-1 is higher than concentrations detected in the soil gas probes but many of the other measurement locations detected methane at concentrations lower than in the soil gas probes.

4.2 CARBON JUNCTION

The mapping area at Carbon Junction is centered on the Animas River by the Wal-Mart shopping center on Highway 160 and extends approximately one-mile in the northeast direction and one-quarter of a mile in the northwest direction. A portion of the area by the Gun Club was mapped on October 2, 2002; the east and west banks of the Animas River were mapped on October 5, 2002; and the area east of the river and Highway 160 was mapped on October 6, 2002. The field data are illustrated on Figures 3 and 4.

4.2.1 Observed Methane Seeps in Surface Water

The Animas River is a major river in Colorado, and therefore only the banks were mapped due to the high flow rates within the river at the time of mapping. Also, the high water flow rates and high turbidity made it difficult to observe methane bubbles as compared with similar visible methane seeps located in creeks in other study areas.

Correlation of seep location to stratigraphy is difficult due to surface coverage. The majority of the visible seep activity appears to be located over the lower portions of the Kf based on observed surface geology. Subsurface methane concentrations collected near the basal contact of the Kf ranged from 90,000 ppm (9%) to 590,000 ppm (59%).

The gas flux chamber for this study area is located on the east bank of the river (CJ-1). LTE measured a methane concentration of 900,000 (90%) and flow ranging from 30 sccm to 1,000 sccm (Appendix E).

Observable methane seeps were sparsely distributed downstream from the boat launch area for a distance of approximately 250 feet. One subsurface methane measurement collected downstream on the west bank of the river reported a concentration of 1,500 ppm. Several dead pine and cottonwood trees were mapped adjacent to these seeps but subsurface methane concentrations collected at the base of the trees were not detected at the time of sampling. An additional subsurface measurement collected adjacent to the visible seeps on the east bank reported a methane concentration of 100,000 ppm (10%). Dead cottonwood trees and tree stumps were observed near this seep area, however methane concentrations were not detected at the dead trees or the tree stumps at the time of the sampling.

4.2.2 Lowland Areas

The majority of the subsurface measurements collected from the base of dead or stressed cottonwood trees and a live juniper tree along the banks did not report detectable methane. One subsurface methane measurement collected upland from location CJ-2 reported a methane concentration of 350 ppm.

Location CJ-3 denotes a barren area visible on the IR images as irregular light green patches. A subsurface methane concentration of 21,000 ppm (2.1%) was detected at this location.

Location CJ-3

Northeast of location CJ-1, four dead scrub oak trees and one dead pine tree were mapped relatively close together. One of the scrub oak trees reported a methane concentration of

850,000 ppm (85%), and the dead pine tree reported a concentration of 60,000 ppm (6%). The remaining three dead scrub oak trees were not associated with subsurface methane gas at the time of sampling. These trees correlate stratigraphically to the lower contact of the Kf. It is difficult to correlate the location of this area to the stratigraphy due to surface coverage.

On October 6, 2002, H_2S was noted in elevated concentrations (greater than 50 ppm) in the subsurface along the west bank of the Animas River (CJ-2).

4.2.3 Upland Areas

A large dark area located in the west portion of the mapping area is visible on the IR images. The area was identified during the seep mapping and contained dead or stressed scrub oak trees, willows, sage, and other shrubs (CJ-4). Subsurface methane measurements taken in this area reported concentrations of methane gas ranging from 2,000 ppm to 175,000 ppm (17.5%). However, sample points at a stressed juniper tree and a dead cottonwood tree in the same area reported non-detectable methane.

Numerous dead, stressed, and bifurcated pine trees, juniper trees, scrub oak, and cottonwood trees were mapped immediately south of location CJ-4. Subsurface methane measurements were recorded at each of these trees and at other measurement locations. Thirteen of the fourteen measurements taken from these trees did not report subsurface methane at the time of sampling indicating that the southern extent of the seep area in CJ-4 has been broadly defined. One dead scrub oak tree in the CJ-4 area demonstrated a subsurface methane concentration of 900,000 ppm (90%). Measurements collected at four tree stumps and one stressed juniper tree located north of location CJ-4 did not produce any subsurface methane measurements. The detectable methane concentrations occurred in a trend paralleling the lower portion of the Kf based on surface geology. A large stressed vegetation area was mapped along the dirt road to the Gun Club (CJ-5). Portions of the stressed vegetation area were black, and the two subsurface measurements collected inside the area reported methane concentrations of 200 ppm and 21,000 ppm (2.1%).

Location CJ-4

Location CJ-5

The majority of the elevated methane concentrations detected in the northeast portion of the Carbon Junction mapping area are concentrated along the valley floor and appear to correlate stratigraphically with the basal portion of the Kf at the contact with the Pictured Cliffs (Kpc) Formation based on surface geology. Methane concentrations detected at dead pine trees, dead scrub oak trees, and subsurface methane measurement locations near this area ranged from 450 ppm to 990,000 ppm (99%). Nine of the 22 methane measurements collected in the valley did not record subsurface methane at the time of the sampling.

Three irregular areas consisting of dead and stressed pine trees in linear patterns perpendicular to the strike of the Kf were noted on the IR images. Few of these trees were located where subsurface methane concentrations were reported at the time of sampling. Location CJ-6 illustrates 36 subsurface methane measurement locations collected in association with dead and stressed vegetation, however only three of these locations reported detectable subsurface methane. The methane concentrations were 800 ppm, 180,000 ppm (18%), and 490,000 ppm (49%). The abundant dead and stressed vegetation coupled with the sporadic elevated methane concentrations in the area suggest that methane is present but seepage is not uniform across the entire area.

Dead trees
east of
Animas River

4.2.4 Comparison to Previous Surveys

Surface and subsurface methane measurements were collected at the Carbon Junction study area in 1995, and surface methane measurements were collected in 2000 and 2001. Subsurface methane concentrations measured in 1995 extend along the formation west of the river approximately 0.3 miles. Subsurface concentrations were detected along the formation east of the river approximately 0.75 miles.

Surface methane concentrations collected in 2000 did not extend as far from the river in the lowland areas as those collected in 1995. Elevated surface methane concentrations were detected in the upland areas approximately 0.5 miles west of the river and greater than one mile east of the river. Surface methane measurements collected in 2001 demonstrated a decrease in methane concentration over time. Although no surface methane measurements exceeded 25 ppm in the study area during 2001, elevated methane concentrations were detected from the subsurface methane measurements collected during the detailed seep mapping in 2002.

Historic probe monitoring by the BLM in this area has detected methane in the subsurface over time. The concentrations detected between 1997 and 2001 are comparable to those concentrations detected during the detailed seep mapping.

4.3 FLORIDA RIVER

The Florida River mapping area is approximately one mile in the northeast direction by 0.6 miles in the northwest direction from where the Kf is transected by the river. The mapping area included the Florida River from the bridge crossing at the Terry Palmer Ranch continuing northward to the Florida Farmers Canal headgate. The headgate is located upstream of the Kf outcrop and stratigraphically lower in geologic section of the Kf. LTE mapped the river for methane seeps on October 7, 2002. The east and west sides of the Florida River were mapped on October 8, 2002. Figures 5 and 6 illustrate the results of the detailed seep mapping performed at the Florida River mapping area.

4.3.1 Observed Methane Seeps in Surface Water

Methane seeps were identified where the river flowed directly east of Terry Palmer Ranch private pond, which stratigraphically correlates with the middle and upper portions of the Kf based on surface geology (FR-1). Methane seeps were noted approximately 0.20 miles upstream of location FR-1 where the river transects the outcrop. One methane seep was noted upstream of the Kf outcrop and stratigraphically positioned over the Kpc based on surface geology (FR-5, Figure 6).

Further upstream, at the Florida Farmers Canal headgate, numerous visible seeps were noted during the mapping activities (FR-2). Surface methane measurements were taken at the water surface to confirm the presence of methane. The concentration of methane directly above the surface of the water measured approximately 300 ppm. This location correlates stratigraphically with the Lewis Formation (Kl) based on surface geology. The Kl consists of a "dark gray, fissile shale containing thin sandstone beds at [the] top and gray, bluish-gray limey shale in the lower part…it is a reservoir for natural gas in the San

Juan Basin" (Carroll et. al, 1999). Other seeps have been observed in the Kl in other locations outside the monitoring area.

Visible Seeps at Location FR-2

Visible methane seeps were mapped as seep trends in the northern half of the Terry Palmer Ranch private pond west of the Florida River.

4.3.2 Lowland Areas

Stressed and non-vegetated areas were mapped on the west, north, and east sides of the pond. Subsurface methane was detected north of the pond with concentrations ranging from 600 ppm to 150,000 ppm (15%). One non-vegetated area located west of the pond and one stressed vegetated area located east of the pond exhibit subsurface methane gas concentrations of 6,500 ppm and 8,500 ppm, respectively. These mapped dead and stressed vegetation areas correlate relatively well with the irregular areas noted on the IR images, and correlate stratigraphically with the middle Kf based on surface geology.

4.3.3 Upland Areas

Access issues prevented the completion of the detailed seep mapping on the west side of the Florida River. Due west of Terry Palmer Ranch private pond and canal system, numerous dead pine trees were observed in a cluster (FR-3). Nine subsurface methane measurements were collected in this area both next to the dead trees and in non-vegetated areas between the trees. A subsurface probe hole next to one of the dead pine trees reported methane concentrations of 25,000 ppm (2.5%). Two subsurface methane measurements in the same area detected methane gas concentrations of 10,000 ppm (1%) and 90,000 ppm (9%). This cluster of trees is located stratigraphically on the contact of the upper Kpc and the lower Kf.

Approximately 0.20 miles southwest of location FR-3, a second cluster of dead pine trees was observed (FR-4). Sixteen subsurface gas measurements were collected from the area. One subsurface measurement reported a methane concentration of 2,500 ppm, and the methane concentration detected at one of the dead pine trees was 36,500 ppm (3.65%). The group of dead pine trees is located stratigraphically over the lower Kf.

Three dead pine trees were noted approximately 0.15 miles southwest of location FR-4. Methane was detected at one of the trees at a concentration of 70,000 ppm (7%).

Dead pine trees, cottonwood trees, juniper trees, and tree stumps were observed throughout the areas where access was granted west of the river. Subsurface methane gas was not detected at any of these locations.

Numerous tree stumps, methane measurement points, dead pine trees, dead scrub oak trees, bifurcated pine trees, and dead cottonwood trees were mapped on the east side of the river. Subsurface methane was detected at one location approximately 0.05 miles east of the river. The methane concentration detected was 47,500 ppm (4.75%). The other dead or stressed vegetation area observed did not have subsurface methane gas reported at the time of sampling.

4.3.4 Comparison to Previous Surveys

Surface and subsurface methane concentrations collected at the Florida River study area in 1995 were only collected on the west side of the river. Methane concentrations above 25 ppm in 1995 were identified in the same high concentration areas as mapped in 2002 and in upland areas approximately 0.75 miles along the Kf west of the river. Surface methane concentrations were collected on the east side of the river in 1998. Methane concentrations greater than 25 ppm were identified approximately 0.5 miles east of the river. Measurements collected in 1999, 2000, and 2001 demonstrate a decrease in surface methane concentrations. Surface methane measurements collected in 2001 did not exceed 25 ppm in the study area, however measurements collected in 2002 reported up to 50% methane in the subsurface.

The subsurface methane concentrations detected during the detailed mapping program were relatively lower than the subsurface methane concentrations detected in the soil gas monitoring probes between 1997 and 2001.

4.4 SOUTH FORK TEXAS CREEK

The Texas Creek mapping area is located where the south fork of Texas Creek transects the Kf. A large alluvial grass covered valley parallels the strike of the outcrop and eventually transects the contact between the Kf and Kpc. The detailed mapping area was approximately one mile in the east to west direction and 0.2 miles in the north to south direction. The seep mapping at the Texas Creek area occurred on October 3, 2002 and October 4, 2002. The field data are illustrated on Figures 7 through 9 (note scale changes on maps).

4.4.1 Observed Methane Seeps in Surface Water

The creek water level was extremely low during the time of mapping making visible methane seeps within the creek difficult to map. In fact, most of the creek was dry. A few methane seeps visible in some pools of standing water were noted in the center of the study area near the gas flux chamber (TC-1, Figure 9).

4.4.2 Lowland Areas

Patches of stressed vegetation and non-vegetated areas were easily identified on the IR images and during the seep mapping activities. Approximately one-half of a mile west of the main Texas Creek mapping area, a large area of stressed vegetation was mapped with the GPS unit and subsurface methane concentrations were measured (TC-2, Figure 7). No methane was discovered at this area.

Location TC-2

The west portion of the mapping area consisted of several clusters of stressed and non-vegetation patches. Linear trends can be found linking these patches in the east-southeast direction, paralleling the strike of the Kf. Subsurface methane concentrations ranged from 450 ppm to 670,000 ppm (67%) in these stressed and non-vegetated areas. Five of nine measurements collected in these areas did not exhibit detectable concentrations of methane gas.

The largest stressed and non-vegetated areas were noted in the center of the mapping area where the creek transects the Kf and Kpc contact. The linear trend of the stressed and dead vegetation follows the river abruptly north in this area which may indicate that the seepage trends along a fault in this area. These stressed and non-vegetated areas were nearly continuous along the suspected fault line and were commonly associated with subsurface methane gas. Subsurface methane concentrations ranged from 250 ppm to 940,000 ppm (94%). The majority of these vegetation patterns were irregular in shape.

Circular non-vegetation patterns, commonly containing a concentric patch of live grass, were intermingled with the irregular dead and stressed vegetation shapes but were not associated with subsurface methane. These circular shapes may be associated with a type of fungus rather than subsurface methane gas, but LTE was unable to determine the specific cause of the pattern during the field mapping.

A thin, linear non-vegetated area was mapped as a seep trend further northeast along the valley floor (TC-3, Figure 9). The trend parallels the strike of the Kf. The stratigraphic correlation of this trend appears to be to the Kpc based on surface geology. However, faulting in the area may have added complexity to the subsurface stratigraphy. A cluster of dead and stressed aspen trees located east of this trend were not associated with subsurface methane at the time of the mapping. A dead and stressed vegetated area northwest of the Kf and Kpc contact was not mapped due to access issues. This area appears to correlate stratigraphically with the Kl based on surface geology.

4.4.3 Upland Areas

Numerous dead aspen, pine and juniper trees, along with bifurcated pine trees were observed with detectable concentrations of methane in the subsurface (TC-4, Figure 9). The trees follow a trend line in an east-southeast direction from the more active seep areas. Subsurface methane concentrations ranged from 1,800 ppm to 1,000,000 ppm (100%) along this trend line. Two of the 14 measurement locations did not contain detectable methane gas concentrations at the time of sampling.

4.4.4 Comparison to Previous Surveys

Surface and subsurface methane measurements were collected at the Texas Creek study area in 1995, and surface methane measurements were collected in 1999, 2000, and 2001. Methane concentrations at Texas Creek demonstrated a continued decrease each year it was surveyed.

BP conducted detailed seep mapping at the Texas Creek study area in 2001. A figure illustrating their results is presented in Appendix F. In general, LTE's detailed seep mapping data correlate well with the BP mapping data. BP examined the study area further west in the lowland areas than LTE did during the 2002 seep mapping event. However, LTE continued the seep mapping further east than BP in the upland areas.

LTE confirmed the locations mapped by BP. LTE mapped several additional areas of dead or stressed vegetation in the lowland portion of the study area mapped by both BP and LTE. BP mapped more dead trees directly southeast of the main area of high concentrations while LTE focused more on the trees in the east portion of the study area.

The subsurface concentrations collected during the detailed seep mapping are similar to those concentrations recorded in the soil gas monitoring probes between 1997 and 2001.

4.5 PINE RIVER

The Pine River mapping area is approximately one-half of a mile in the east-west direction and 0.20 miles in the north-south direction. This area was not in the original scope of work since it is currently mapped by Paul Oldaker for BP on a regular basis. LTE conducted mapping to a limited extent on October 9, 2002 for use in comparison to the IR pilot study activities. Most of the features mapped were grouped together rather than dividing individual features due to the limited time and access within the mapping area. Access issues prevented LTE from mapping the land north of Ludwig Road. Figures 10 and 11 present the results of the detailed seep mapping for the Pine River area.

4.5.1 Observed Methane Seeps in Surface Water

The visible methane seeps are concentrated south of the bridge and north of the island located in Pine River. A methane seep was observed further upstream near the bridge (PR-1, Figure 10). The land east of the Pine River is utilized for agricultural purposes, and several canals are used to direct surface water. Visible methane seeps were noted in several of these canals. Based on subsurface geology observed in monitoring wells installed in the area, the seep trends observed in Pine River correlate stratigraphically to the transition zone between the Kf and the Kirtland Formation (Kk).

4.5.2 Lowland Areas

Numerous stressed vegetation areas were observed both on the IR images and during the mapping activities. Subsurface methane concentrations range from 400 ppm to 860,000 ppm (86%). Five of the 36 subsurface methane measurements collected did not exhibit detectable methane concentrations. Upland from the east bank, several subsurface methane measurements were collected north of the linear stressed vegetation areas. None of these measurement locations exhibited methane at concentrations greater than 25 ppm (PR-2, Figure 10).

Subsurface methane measurements were also collected south of the linear stressed vegetation areas but methane was not detected (PR-3, Figure 10). One of two subsurface methane measurement locations in the southeast portion of the mapping area detected methane at a concentration of 800 ppm (PR-4, Figure 11). LTE was unable to continue the seep mapping in the area to the east due to access issues.

4.5.3 Upland Areas

Stressed vegetation was noted along the hillside in the western portion of the mapping area. LTE attempted to map the area but complications with the GPS signal caused the stressed area to be mapped incorrectly (PR-5, Figure 10).

One subsurface methane measurement collected towards the lower elevation of the hillside east of location PR-5 detected methane at a concentration of 260,000 ppm (26%). Dead vegetation was noted on top of the hill, however subsurface methane was not detected in these areas (PR-6, Figure 10).

Location PR-5

4.5.4 Comparison to Previous Surveys

The reconnaissance survey completed in 1995 at the Pine River study was conducted in upland areas along the Kf west of the river and at the base of the upland areas east of the river. Subsurface methane concentrations greater than 500 ppm were recorded in these areas.

Surface methane measurements collected in 1999 showed concentrations greater than 500 ppm along the outcrop approximately one mile west of the river. Methane concentrations greater than 500 ppm were recorded approximately 0.75 miles east of the river along the outcrop. A continued decrease in surface methane concentrations was observed in 2000 and 2001.

Paul Oldaker conducted detailed seep mapping in the Pine River study area for BP in March 2002. The results of this mapping are included as Appendix G. The study area mapped in 2002 focused on the lowland areas where high methane concentrations were observed during the previous years.

The subsurface concentrations collected during the detailed seep mapping are similar to those concentrations recorded in the soil gas monitoring probes between 1997 and 2001.

4.6 DETAILED MAPPING SUMMARY

Detailed mapping of known seep areas occurred in early October 2002. The seep mapping areas included Basin Creek, Carbon Junction, Florida River, Texas Creek, and a limited portion of Pine River.

The seep trends observed are similar to those trends previously identified with the most active seeps occurring in the lower portions of the Kf, based on surface geology, in areas where a surface drainage feature transects the geologic contact between the Kpc and Kf.

A methane seep area was identified along the Florida River near the Florida Farmers Canal Headgate. This area was not included in previous surveys along the outcrop. This area is stratigraphically positioned over the Kl based on surface geology. The potential sources for this gas are biogenic gas from a local source; thermogenic gas from the Kl; or thermogenic gas from the Kf via subsurface fractures and preferential pathways.

The dilution and dispersion factors affect the ability to detect methane. These factors appear to be related to the elevation of the groundwater table and the thickness of the vadose zone. The extreme drought conditions observed during Summer 2002 have increased the depth to groundwater and lowered the surface water levels in the region. Therefore, the dilution and dispersion factors may have limited the detection of methane during the mapping activities. It is likely that, if water levels return to normal, subsequent mapping activities will identify more detectable methane.

Seep trends not mapped during BP's activities in the Texas Creek area in 2001 were identified, particularly in an area north of the estimated Kpc-Kf contact based on surface geology. Potential seep trends may be related to seepage through faulting and fractures which create preferential migration pathways. There is a prominent north-south seepage trend in the center of the Texas Creek mapping area that appears to follow a fault line identified by BP.

The presence of dead or stressed vegetation does not imply that methane has caused the condition. In many areas mapped, particularly west of the Texas Creek area, dead or stressed vegetation was observed with no detectable concentrations of methane noted. However, the vegetation does appear to be a good indicator to assist in identifying those areas where methane seepage is occurring or may have occurred in the past.

Based on the results of the detailed seep mapping, it appears that the mapping methodology utilized by LTE will be effective for monitoring changes over time and space since more features are being monitored. In addition, the features that were mapped have been located and defined more accurately as compared to previous surveys.

Inferences to the extent of the seep areas can be made from the results of the mapping activities, although specific boundaries are difficult to define.

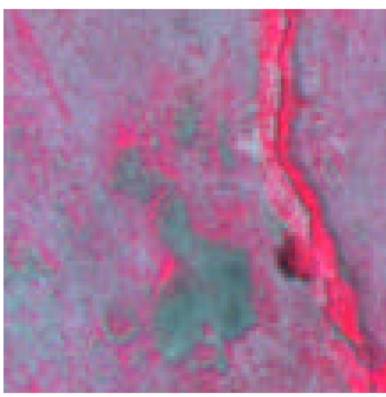
SECTION 5.0

IR IMAGERY PILOT STUDY RESULTS

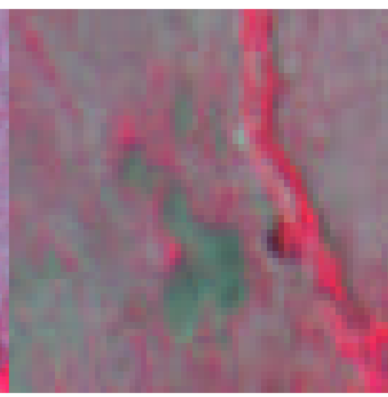
This section presents the results of the pilot study and discusses the factors that must be considered during IR imagery evaluation. This section also includes the results of the IR imagery evaluation as it relates to the identification of suspect areas and how to apply this technology to identify potential methane seep areas.

5.1 IMAGE RESOLUTION

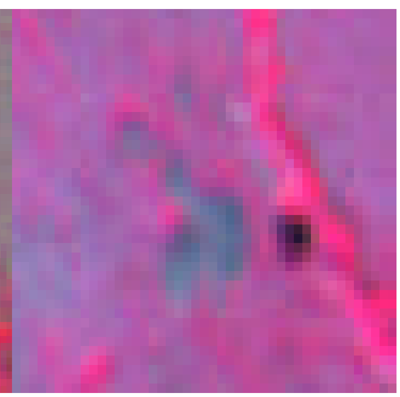
Resolutions of 0.5 m, 1.0 m, and 1.5 m were reviewed as part of this pilot study. The spectral content of each resolution appears similar, and for this reason, it appears that higher-resolution images are not absolutely required for this task. An exception to this case may be when looking for dead vegetation that has sparse or missing under layers of dead leaves or needles. Higher resolutions will provide better accuracy under this circumstance. Larger pieces of dead wood and dead branches are also identified more easily in high resolution images (0.5 meter).



0.5 m resolution (high)



1.0 m resolution



1.5 m resolution (low)

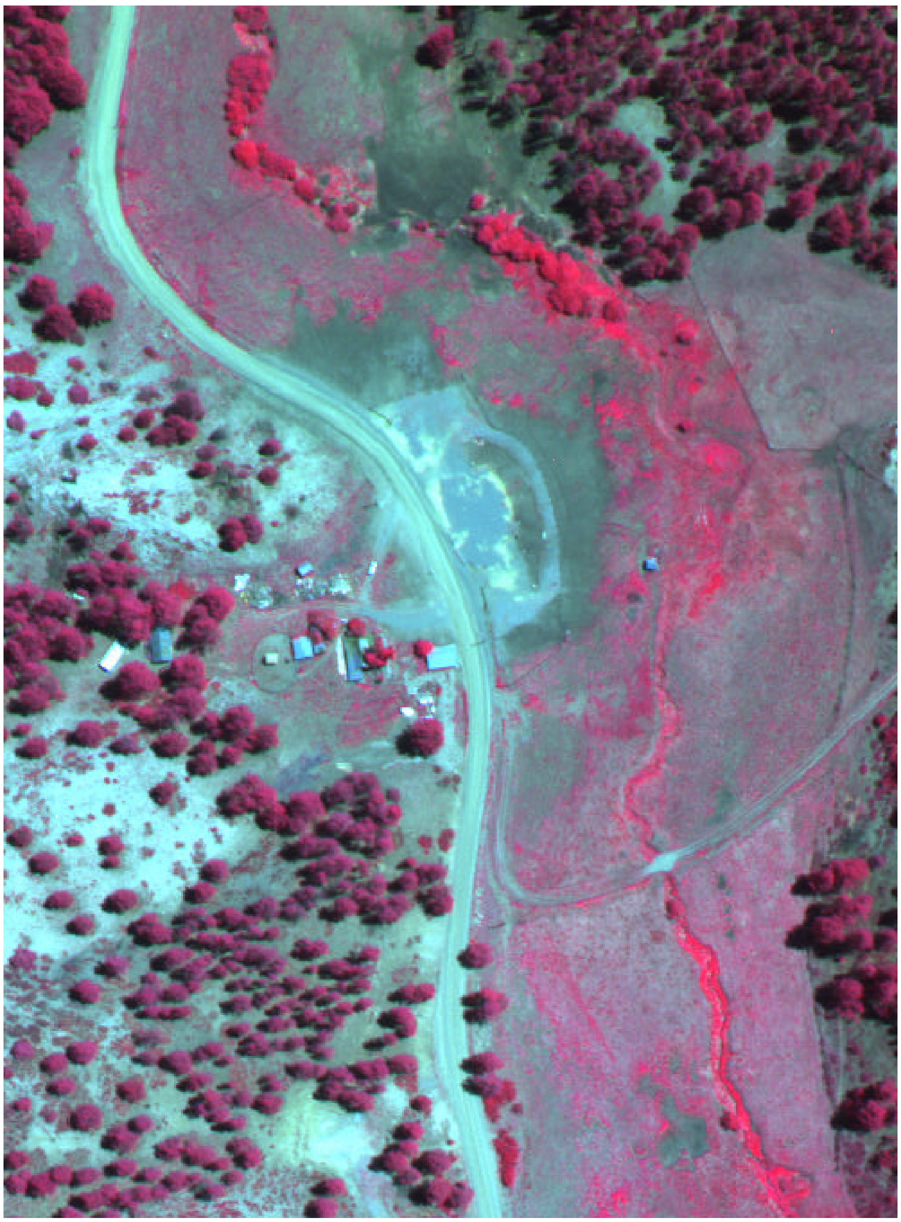
The three resolution ranges do vary the tone in each image. Color shifts are also noticeable, possibly due to variations in ambiance (sun angle and camera angle). Exact spectral comparisons from year to year may be impractical for this reason. Mortality and bare soil are unique enough to be mapped, and these maps are likely to be more comparable over time. Digital techniques can be developed to compensate for these kinds of issues and will allow tracking of changes over time. This technology is expected to provide vivid spatial documentation of changes in this arid ecosystem.

Images collected near solar noon have less shadowing, and provide the most useful data. Shadowing from trees and terrain significantly detract from image usefulness. Solar noon images had the best quality; however, these were also the highest resolution images.

5.2 GENERAL OVERVIEW

The spectral performance of the DCIR imagery acquired is adequate for the needs of this project's vegetation analysis. General vegetation types can be determined informally by an analyst familiar with this ecosystem, and with limited field experience at the site.

Viewing the images with commonly available computer software tools and on several low-end computer monitors clearly show that denuded patches of grass and forbs (vegetation other than grass) in valley bottoms is possible. Some of these areas have been identified as current methane seep locations based on the results of the detailed seep mapping activities. Healthy grasses are markedly different than those that are dry or absent, and provide contrast in the lowland images. An overview of the IR images from the Texas Creek and Pine River areas are included as Figures 12 through 19.



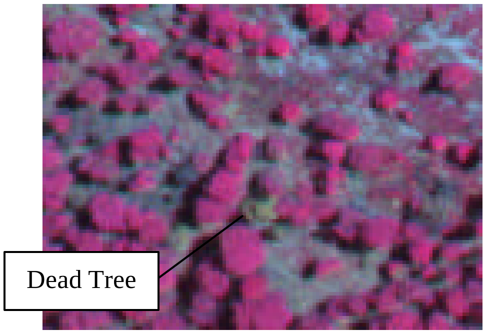
DCIR image of Texas Creek area

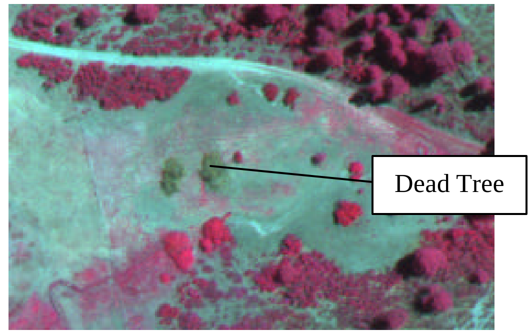
Shrubs, trees, bare soil, rock, surface water, and riparian zones (areas relating to the bank of a natural watercourse) all stand out clearly. Moisture and organic matter in soils are similar to one another, but the variations are clear in some images. Color infrared photography (whether film or digital) is interpreted in a similar way showing deciduous vegetation and lush grass as a bright red which makes riparian zones stand out.

Raw image northwest of Pine River seep area.

Gamble's oak and some other leafy shrubs have an orange tone, with much more texture. Juniper tend to appear pinkish in color with bare branches common. Dryland shrubs such as mountain mahogany tend to look a bit purple (especially when dry) and tend to occur in patches. Piñon have dense, well-defined crowns, and are usually a rusty red color, except when young. Initial review indicates that ponderosa have a feathery crown which may be an intermediate tone between juniper and piñon. Dry bare soil is a light blue or cyan color, with darker and greenish variations due to organic matter or moist soil. Water is black unless it has suspended sediment, is less than about a foot deep, or is reflecting the sun. Rock is often white. Moisture and organic matter in soils look similar to one another, but the variations are clear in some images. These 0.5 m images also show many cultural features such as small paths, fences, sheds, and individual shrubs.

Trees with crowns of yellowing or red needles are defined in even the lowest resolution images of 1.5 m. Dead vegetation is found without elaborate analysis when sufficient needle or leaf material is present on or below the plant, but dead, dry and bare branches have been best identified with a combination of spectral analysis and human visual inspection of 0.5 m imagery. Additional features observed in the IR imagery are included as a Powerpoint slideshow in Appendix H (cd-rom).





There are three feature groups that are of interest in identifying possible methane seeps within the IR imagery. All three are a variation on the basic themes of dead or absent vegetation.

The first is the most obvious; yellow or red needles still clinging to a tree that has died recently. These are rare in most areas but are easily identified by eye. The tone is unique in the images, and when it occurs in a forested area, can be confused with no other naturally occurring feature.

The second is a tree crown that has lost its needles, is showing bare wood or the dark fungus that grows on bark. This crown will cast thin shadows and in some cases may have a dark area below the tree. This dead tree has a unique texture, may show dead branches, and is fairly easy to select by eye. However, the dead tree with no foliage tends to blend in with dark backgrounds. The analyst must use the contextual information available in the image to determine what is likely to be a true crown and it is not practical to go by tone alone. In either case, dead trees are well represented by a point feature in a GIS.

The third feature group is the area of dead vegetation that appears to have a defined edge. Many polygons can be selected where some condition is producing a patch, series of blotches, or where there appear to be a contiguous area of shrub mortality. Shrub mortality cannot be assured from images taken in a record drought, but there are patches that are either very dry or dead. When grasses and trees are also dry or dead in the patch, it is more likely that a mortality agent is present.

From these basic feature groups, a selection of points and polygons were made. Many polygons were of an unusually dark color indicating an absence of grass and forb cover. Some areas had an unusually large number of dead trees. A few were patches of dead or dry shrub cover with an unusual tone in comparison to similar patches nearby.

Since the eye is misled by background tones, spectral analysis helps bring out those pixels that were identified as being valuable in previous contexts. Optical effects would encourage the eye to miss dead vegetation near shadows, wet soil, and in the spaces between healthy trees. Occasionally, attention is drawn to a small clump of pixels, as in a small crown exhibiting late stages of decline. More often, these data are clustered in patches and groups, and are especially easy to misinterpret. Human review is needed here more than in other circumstances. Grouping likely spectral targets with polygons is expedient.

With these issues in mind, a polygon coverage was made to summarize areas that were identified primarily with spectral techniques, and another acquired with relatively unaided visual analysis. A third point coverage collects crown data.

The IR imagery is also a useful photo-documentation tool to quantify changes over time. If additional photo-missions are completed, they can be compared to previous years. Changes over time can then be quantified more accurately.

5.3 SUSPECT AREAS IDENTIFIED BY HEADS-UP DIGITIZING

LTE has utilized Arcview® to display the results of the heads-up digitizing that was performed. The results are presented in Figures 12 through 19. The blue polygons represent the locations of suspect areas across the pilot study area. The yellow-black points also represent the locations of dead trees or bushes within the pilot study area.

Based on a review of the eight IR images across the pilot study area, LTE identified 97 suspect areas. These areas were selected based on the following parameters:

- Dead or stressed trees;
- Bare soil in patches, not obviously influenced by agriculture;
- Bare soil with an unusual tone, similar to that found in known methane seep areas;
- Scant vegetative cover in patches with well defined edges;
- Areas of thin vegetation with background stain of unknown origin;
- Patches with dead, dry, or unique shrub characteristics near otherwise normal shrubs;
- Areas with odd patterns in sparse grass;
- Large areas with scattered tree mortality, but with an identifiable edge;
- Patches of dry grass near otherwise healthy grasses;
- Features with characteristics like known methane seep areas;
- Patches of dark soil; and
- Small patches of dark pixels.

Once these areas were identified, LTE compared these polygons with features observed in the field and considered their position relative to stratigraphy and active seep areas.

5.3.1 Lowland Areas

In the Texas Creek portion of the pilot study area, much of the lowland areas parallel the strike of the Kf and are positioned stratigraphically on the upper Kf members, based on the surface geology. Several suspect areas were identified west of the active seep area. LTE believes that the areas were identified as suspect largely due to the drought conditions present at the time of image acquisition and not due to methane seeps.

During field mapping activities, LTE observed this lowland valley to contain large areas of senescent grass cover. Historic reconnaissance data have also not identified elevated concentrations of methane in these areas.

LTE did identify six lowland suspect areas on the imagery west of the main seep area which have been confirmed as methane seep areas or appear to follow existing seep trends (TC-5 through TC-10, Figures 12 and 13).

A peculiar vegetative pattern was identified on the IR imagery in the lowland area northeast of the active Texas Creek seep (TC-11, Figure 14). This area correlates stratigraphically with the Kl, based on surface geology. Based on recent information obtained at the Florida River study area, there is a potential for similar conditions to exist at Texas Creek. Since seep activity was not anticipated at this location, a request for property access was not made prior to field mapping activities.

It appears that the suspect areas are more frequently identified in the lowland areas. At the Pine River area (Figure 19), several suspect areas based on the criteria listed above have been identified well north and south of current seep trends. LTE did not have access to these areas during detailed seep mapping but it appears that many of these suspect areas are not associated with methane seep activity since they do not correlate to the Kf and do not look similar to those areas where known seeps are occurring.

However, there are several suspect areas that do correlate stratigraphically to Kf and known seep trends in the Pine River area. These locations have been labeled as PR-7 through PR-11 (Figure 19). Data from previous reconnaissance surveys have confirmed the presence of methane at locations PR-7 and PR-8. It is likely that methane would also be detected at locations PR-9, PR-10, and PR-11.

North of Ludwig Road, the IR imagery identified three areas in particular that may represent methane seep areas (PR-12 through PR-14, Figure 19). Property access to these areas has not been granted since the inception of the monitoring studies initiated in 1995. The color signature of these areas is relatively similar to the known seep areas.

Other study areas (Florida River and Texas Creek) have identified methane seep areas north (stratigraphically lower in the geologic section) of the Kf. The suspect areas south of the known trends at Pine River are less likely to be associated with methane seep areas but several of these areas should be investigated for confirmation purposes.

5.3.2 Upland Areas

Only 10 suspect areas were identified in the upland areas between Texas Creek and Pine River. Three additional suspect areas were identified within the pilot study area in upland areas west of Texas Creek. Figures 12 through 18 illustrate the upland areas along the pilot study area.

A suspect area identified as TP-1 (Figure 15) may be associated with an active seep area for the following reasons: the location is positioned on the Kf relatively low in the geologic section; it is positioned along a linear trend that correlates to active methane seeps at Texas Creek; it is located in close proximity to a natural drainage feature that transects the Kf-Kpc contact, based on surface geology; and dead and stressed pine trees are grouped together in a relatively small area. Additional field work can confirm the presence or absence of methane associated with this suspect area.

Location TP-2 (Figure 15) identifies an area surrounding at least 14 dead or stressed trees. The IR analyst felt that this area contained a color signature anomaly. This location is stratigraphically positioned on the Kl based on surface geology, therefore, the potential for methane seepage is low. Based on data collected from the Florida River area and observations in the Texas Creek area, the suspect area may be associated with methane seep activity through conduits such as faulting or inter-fingered coal-bearing units. Further investigation of this area is needed to confirm the presence or absence of methane.

Suspect areas TP-7 and TP-8 (Figure 18) were identified on the upland areas west of the Pine River area and may be attributed to methane seepage based on their stratigraphic position and their proximity to the active seep area. However, TP-7 may be a simple surface anomaly since this suspect area is located directly on the competent sandstone of the Kpc.

The upland suspect area west of Texas Creek (FT-1, Figure 12) is positioned on the Kf and appears to be a very large sparsely vegetated area. Historic reconnaissance data in this area have never detected methane. The potential for this suspect area to be associated with methane seep activity appears low.

The remaining suspect areas identified along the upland areas are relatively small and often positioned on gray colored surfaces. Based on LTE's experience in these upland areas, there are many land areas with sparse vegetation areas on exposed gray shale soil. Many of these upland suspect areas appear to be associated with this type of surface feature rather than methane seep activity. Historic reconnaissance data in these upland areas have not identified detectable concentrations of methane.

5.3.3 Point Features

LTE identified 192 suspect point features across the pilot study area. In general, these point features represent the locations of dead or stressed trees and/or bushes. In most cases, the suspect points were identified in groups rather than as single points across a wide area.

West of Texas Creek, the suspect points are sparsely scattered and do not appear to be associated with potential methane seep areas based on the stratigraphic position, historical data, and locations of suspect areas.

A grouping of dead trees was identified along an existing seep trend that correlates with the faulting complex at Texas Creek (TC-12, Figure 13). The trees are located within a suspect area identified during the heads-up digitizing but also follow the linear north-south trend of methane seep activity that appears to be associated with faulting. An additional grouping of dead trees was also noted at the north end of this trend line.

TC-13 (Figure 14) identifies a location with several dead trees. This area is adjacent to a suspect area identified in the lowland area. The stratigraphic position of these trees is on the Kl. Based on recent data gathered, there is a potential for these trees to be associated with methane seepage.

A grouping of trees identified at location TP-2 (Figure 15) and areas immediately east of TP-2 were identified as suspect areas. The potential for these suspect features to be associated with methane seepage is low but due to the widespread mortality, it is important to confirm the presence or absence of methane in these areas.

Several small groupings of suspect points were identified south of the Kf. Methane seepage has never been associated with these areas, therefore it is likely that the tree mortality is not related to methane seepage. It may be prudent to confirm the presence or absence of methane at a limited number of these locations.

The tree mortality identified near locations TP-8 and PR-15 (Figure 19) has the potential to be associated with methane based on field data collected nearby and their position relative to known seep trends. Further field work at these dead tree locations can confirm the presence or absence of methane.

5.4 SPECTRAL ANALYSIS

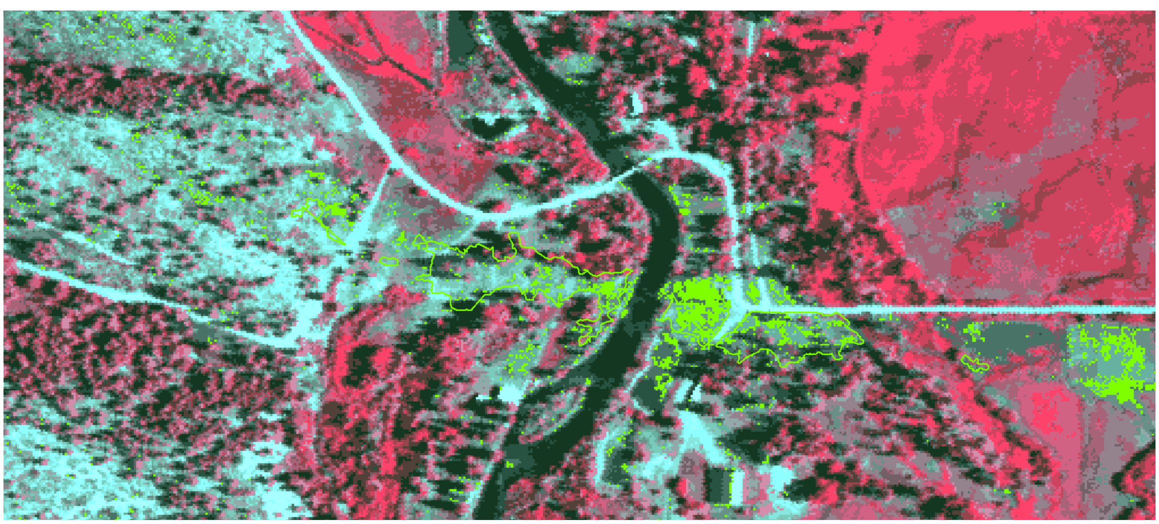
Since the eye is misled by background tones, spectral analysis helps bring out those pixels that were identified as being valuable in previous contexts. Optical effects would encourage the eye to miss dead vegetation near shadows, wet soil, and in the spaces between healthy trees. Occasionally, attention is drawn to a small clump of pixels, as in a small crown exhibiting late stages of decline. More often, these data are clustered in patches and groups, and are especially easy to misinterpret. Human review is needed here more than in other circumstances. Grouping likely spectral targets with polygons is expedient.

Spectral analysis along the pilot study area appeared to be more useful in the lowland areas relative to upland areas. The lowland areas have had more field data collected thereby allowing for more interpretation of the spectral data. In addition, there appears to be less class confusion in lowland areas.

Spectral confusion exists in several important landcover classes. Shadow (both topographic and from tall objects), organic soils, moist soils, and sage all appear similar to the methane seep areas identified in the lowland areas. Vegetation that retains yellow or red foliage is distinct, but may share spectral characteristics with several other classes. The analyst can often determine which of these pixels to ignore while viewing the imagery on-screen, but software will not provide sole discrimination.

Therefore, spectral analysis maps will need further human processing and interpretation to make the best use of input data. Digitizing with points, lines, and polygons captures the features that are clear to the human eye using intuitive pattern recognition skills.

In the Pine River area, the IR analyst attempted to identify areas through spectral analysis that are similar to areas with known methane seepage. The image below illustrates how the spectral analysis was used to identify suspect areas. One spectral class is highlighted to help direct the analyst's attention to particular pixels. These pixels are similar in tone, and their position helps determine the appropriate landcover assignment.



Spectral analysis in the Pine River area. Green pixels identify suspect areas classified by the analyst. Green lines (commonly associated with the green pixel areas) identify actual stressed areas or dead areas mapped by LTE's field team.

The spectral analysis technique may prove useful when comparing baseline IR imagery to future IR images. The computer algorithms can identify areas of change between two images. Using this technique to identify changes in mortality extents, especially over large forested areas, should be useful in this project.

5.5 SUSPECT AREAS IDENTIFIED BY SPECTRAL ANALYSIS

LTE has utilized Arcview® to display the results of the spectral analysis that was performed, which is illustrated in Figures 12 through 19. The orange polygons represent the locations of suspect areas across the pilot study area.

5.5.1 Lowland Areas

In general, the spectral analysis identified the same areas that were identified during the heads-up analysis and/or during the detailed seep mapping. In particular, the active seep areas in Texas Creek and Pine River were both identified based on the spectral analysis. Locations including TC-5, TC-6, TC-7, PR-5, PR-7, and PR-8 (Figures 12 and 13) were highlighted as suspect areas and known methane seeps have been detected in these areas. Other suspect areas in lowlands that were identified through spectral analysis, which have a greater chance of being associated with methane, include locations PR-13 and PR-14 (Figure 19). Further confirmation is needed to verify the presence or absence of methane in these two areas.

Northwest of location PR-13 (Figure 19), several suspect areas were identified through the spectral analysis. Based on factors such as stratigraphy and land use, the potential that these suspect areas are associated with methane appears low.

5.5.2 Upland Areas

The spectral analysis identified 17 suspect areas on upland topography. However, based on historical reconnaissance data, stratigraphy, and land use, many of these upland suspect features were likely identified due to class confusion. For example, location FT-2 (Figure 13) is located on Kpc. It is a relative small area and does not exhibit the same spatial characteristics of known methane seeps. It is likely that the feature identified at location FT-2 is a result of class confusion as discussed in Section 2.3.5.

In contrast, the location TP-4 (Figure 14) is relatively more likely to be associated with methane seeps since it is positioned stratigraphically near the basal Kf and near known seep areas. Field confirmation at this location is still necessary.

Locations TP-5 and TP-6 (Figure 16) were identified through spectral analysis and are associated with dead trees and shrubs identified during the heads-up analysis. These areas are likely not associated with methane because of their location, however, they may warrant field confirmation because of their size and since they were identified using multiple analysis techniques.

The spectral analysis also identified several small suspect areas immediately west of the Pine River mapping area. Based on the locations of these areas, there is a potential for these areas to be associated with methane.

5.6 IR PILOT STUDY SUMMARY

The IR pilot study was initiated to determine if the remote-sensing technology can be used to identify dead and stressed vegetation. Once suspect areas on the imagery are identified, the images can be used to assist in focusing reconnaissance efforts toward potential seep areas while maintaining a vigilant watch over outcrop areas not visited on foot.

After collecting the imagery from the pilot study area, it is apparent that this technology is effective at providing a detailed look at the condition of vegetation across a large area. The imagery is capable of identifying dead and stressed trees and bushes on upland areas and vegetative cover on lowland areas.

The use of heads-up digitizing techniques appears to be the most efficient means by which to recognize most of the suspect areas. Spectral analysis is useful for identifying more subtle differences that define a suspect area.

When the IR imagery is compared to the detailed field mapping data, it is clear that the IR imagery is capable of defining many of the areas where seeps have occurred. This comparison is illustrated in the Texas Creek and Pine River areas as shown on Figures 20 and 21. Additional field confirmation of suspect areas is still required in areas not visited during the detailed mapping activities. Depending on the results of the field confirmation, the suspect areas identified during the IR evaluation may be dropped from the reconnaissance monitoring or continued to be inspected over time. As additional IR missions are performed, additional suspect areas may be identified and require additional field inspection.

Based on the results of the pilot study, it appears that the IR imagery can accurately capture and record the condition of vegetation for comparison to subsequent photo-missions. This technique will assist in monitoring changes in methane seep activity over time and space.

SECTION 6.0

RECOMMENDATIONS

6.1 GAS MONITORING SYSTEM

LTE recommends that monitoring of the flux chamber system continue as originally planned. The new locations and increased capture zone should allow for more consistent monitoring of changes over time.

LTE recommends a review of the soil gas monitoring probe data collected by the BLM. At the time of this report, data collected after January 2001 were not available to LTE. LTE recommends review and comparison of the soil gas probe data to determine if trend decreases have been observed in the soil gas monitoring probes over the past six months due to drought conditions similar to trends observed in the flux chambers at Texas Creek and Pine River.

6.2 DETAILED SEEP MAPPING

LTE recommends continuing the detailed seep mapping program as described in this report. It appears to be effective at identifying and broadly delineating the known seeps. Over time, continued mapping should provide an indication of the changes in the seep dimensions.

LTE recommends conducting an additional seep mapping event in the spring of 2003. Historical data identify this period as having relatively more seep activities than late summer or fall. The spring runoff will elevate water table levels and allow seepage to be detected more easily.

LTE also recommends collecting a gas sample for compositional and isotopic analysis from the seep identified at the Florida Farmer's Canal headgate. This information may be useful in determining the source of the seep.

Access issues must be worked out in order to performing additional detailed seep mapping.

6.3 IR AERIAL RECONNAISSANCE

The use of heads-up digitizing techniques appears to be the most efficient means by which to recognize most of the suspect areas. Spectral analysis is useful for identifying more subtle differences that define a suspect area. Heads-up digitizing along with field verification is reproducible. Because of the wide range of color variability, spectral analysis has limited use for our application due to the lack of reproducibility.

When the IR imagery is compared to the detailed field mapping data, the results indicate that the IR imagery is capable of defining many of the areas impacted vegetation are associated with methane seepage. Additional field confirmation of suspect areas is still required in areas not visited during the detailed mapping activities. Depending on the results of the field confirmation, the suspect areas identified during the IR evaluation may be removed from the reconnaissance monitoring or continued to be inspected over time. As additional IR missions are performed, additional suspect areas may be identified that will require field inspection.

LTE recommends evaluating the IR imagery for the remainder of the outcrop area. LTE has already acquired this imagery during the pilot study activities. As part of the evaluation, LTE would identify suspect areas along the entire outcrop. A field crew can then inspect the suspect areas for the presence of methane producing a baseline for the entire outcrop. Changes in vegetation conditions can then be compared with subsequent IR missions and field verification activities allowing for a better understanding of the methane seepage across the entire outcrop.

To enhance the efficiency of IR image evaluation, LTE recommends that DEMs are purchased to rectify the remaining IR images. In addition, it may be useful to collect additional ground control points along the outcrop area for more efficient image rectification.

LTE recommends that the regional reconnaissance survey (pedestrian surveys) program be modified to incorporate the results of the detailed seep mapping and the IR aerial reconnaissance. Increasing difficulty with access to private lands must also be resolved to continue an effective field program.

Finally, both the detailed mapping and IR imagery provide better techniques to record the observable conditions along the outcrop. There are limitations primarily associated with the number of natural factors which influence the vegetation conditions and methane seepage. These conditions include, but are not limited to: disease, groundwater table elevation, drought, preferential pathways, and temperature. LTE recommends that a percentage of the suspect areas identified during the pilot study be inspected to verify the presence or absence of methane. Some of the suspect areas in the seep mapping areas have already been visited. Preferably, the field crew conducting a spring-time mapping event can perform the suspect area inspections.

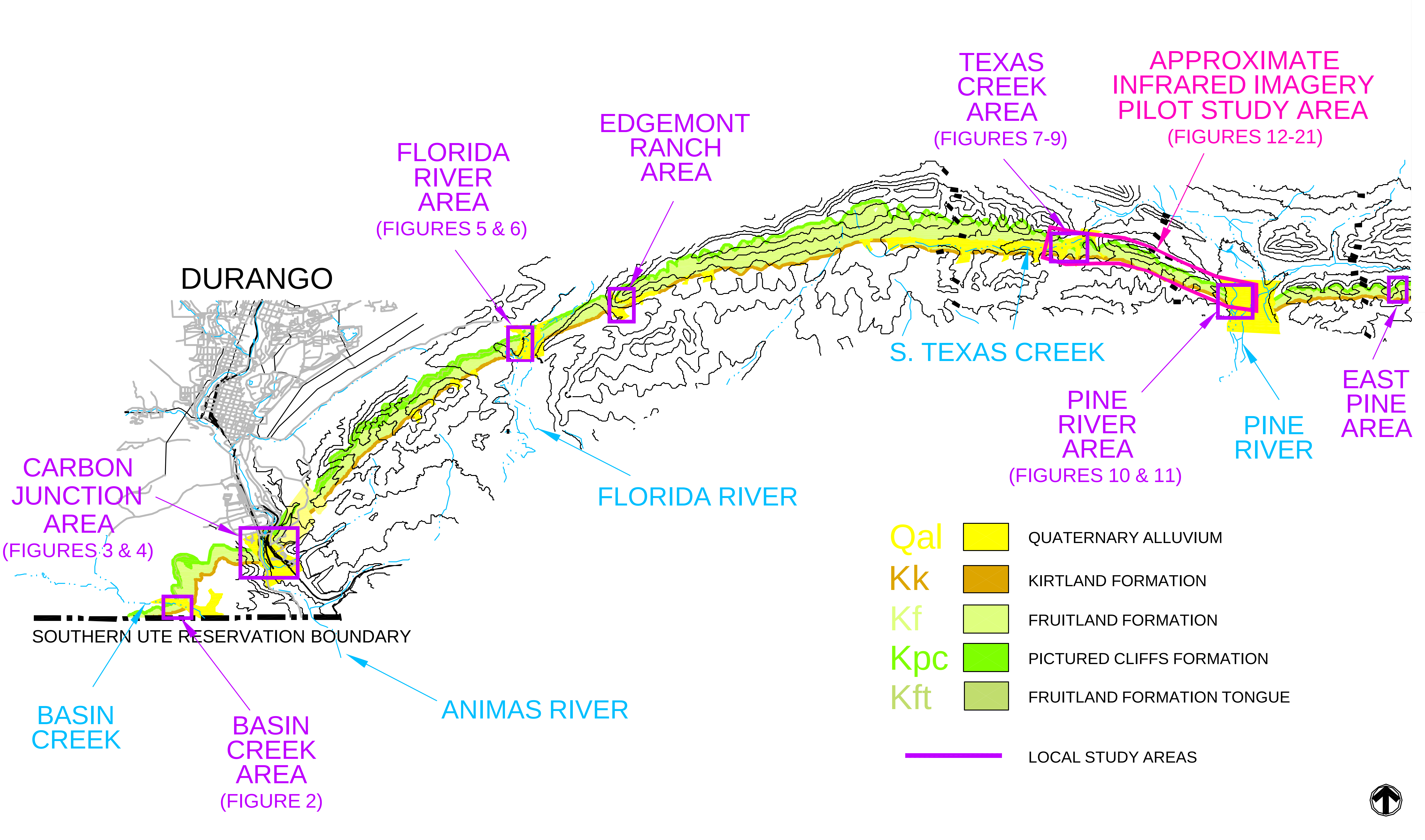
6.4 REGIONAL RECONNAISSANCE SURVEYS

LTE recommends that the regional reconnaissance survey (pedestrian surveys) program be modified to incorporate the results of the detailed seep mapping and the IR aerial reconnaissance.

Previous reconnaissance surveys were limited in effectively quantifying changes over time. The evaluation of vegetation was only a qualitative measure and the methane concentrations collected only characterized seep activity that escaped the ground surface.

By performing the detailed seep mapping, initially more than once per year until a pattern emerges, changes in methane seeps over space and time can be quantified in the areas of known seepage. In addition, spacial changes in the seep areas can be quantified by comparison of events. The IR imagery will be able to identify potential seeps on upland areas by the condition of the vegetation and field verification in those areas. The use of the IR imagery reconnaissance will accomplish the goal of observing the entire outcrop for additional potential methane seeps while allowing field crews to focus toward suspect areas rather than exhausting significant effort over large areas with no apparent methane activity. The use of IR imagery will also reduce the intrusion experienced by land owners over the past few years.

FIGURES



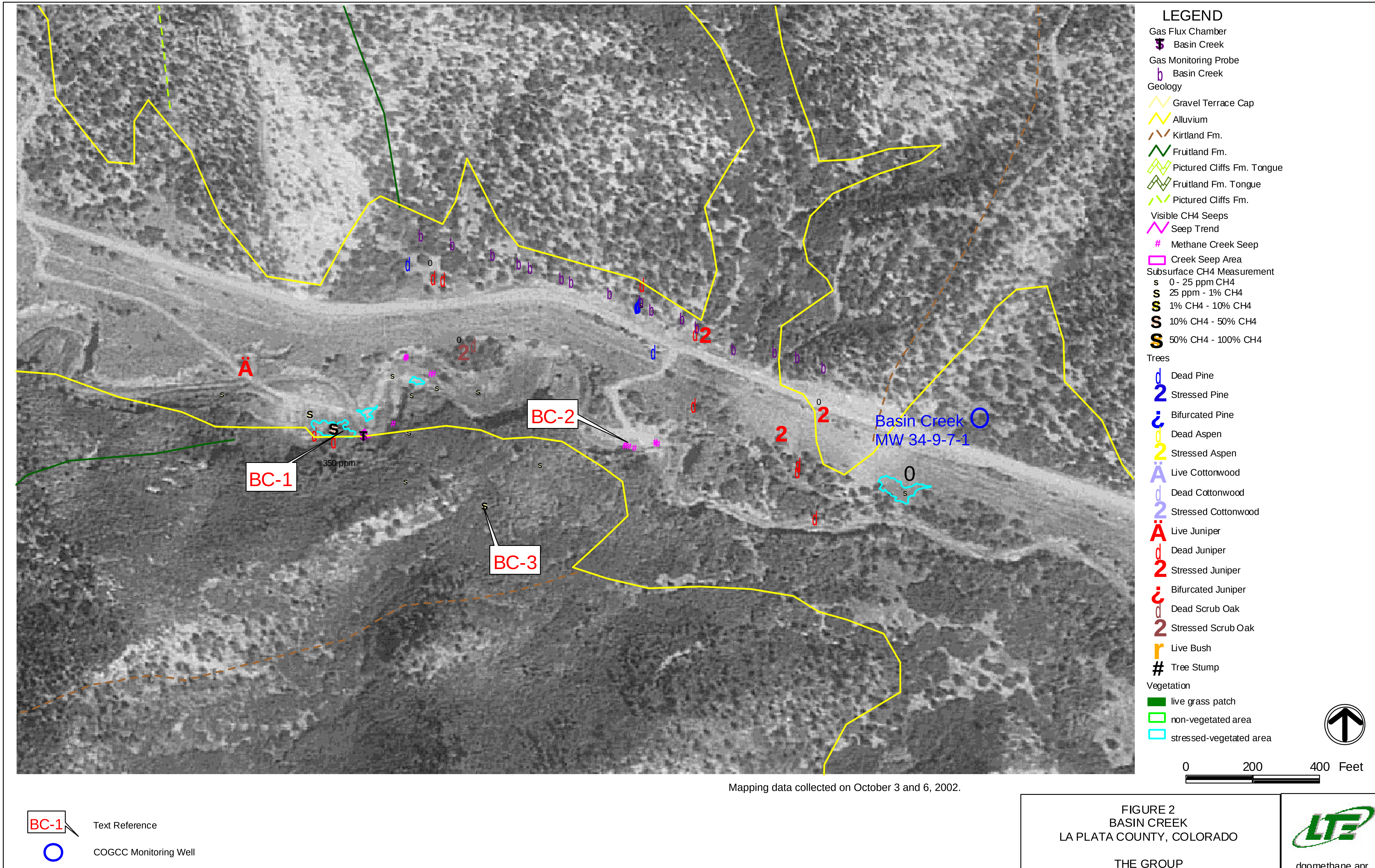
SOURCE: TOPODEPOT INC
USGS VECTOR 7.5' QUADRANGLE TOPOGRAPHIC MAPS

GEOGRAPHIC COORDINATE SYSTEM
(LATITUDE/LONGITUDE) NAD 83

FIGURE 1
METHANE SEEP MONITORING AREA
LA PLATA COUNTY, COLORADO

THE GROUP

METHANE SEEP 12/2002

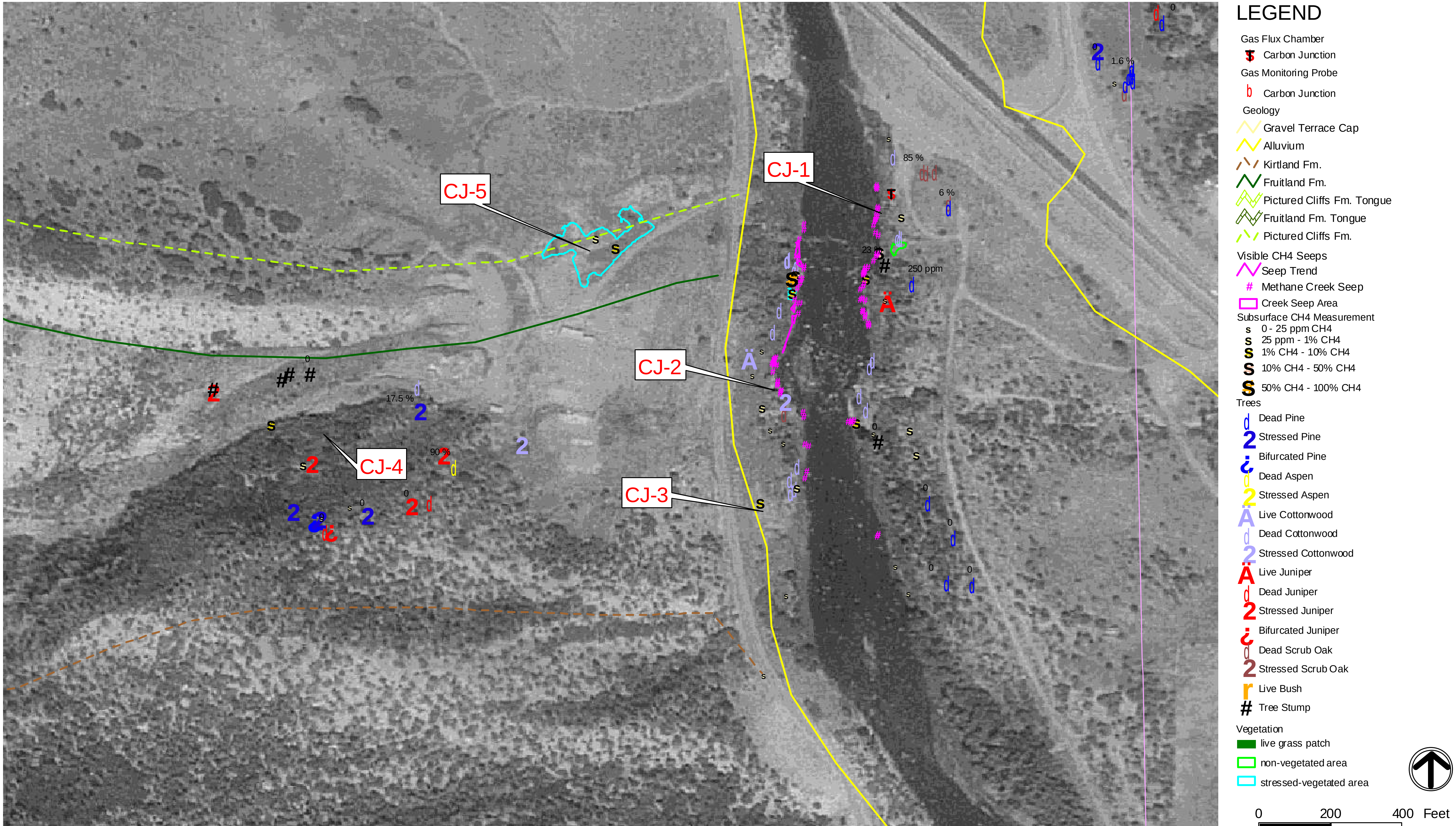


Mapping data collected on October 3 and 6, 2002.

FIGURE 2
BASIN CREEK
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



Mapping data collected on October 2, 5, and 6, 2002.

CJ-5 Text Reference

The study area east of the river is illustrated in Figure 4.

FIGURE 3
CARBON JUNCTION
LA PLATA COUNTY, COLORADO

THE GROUP

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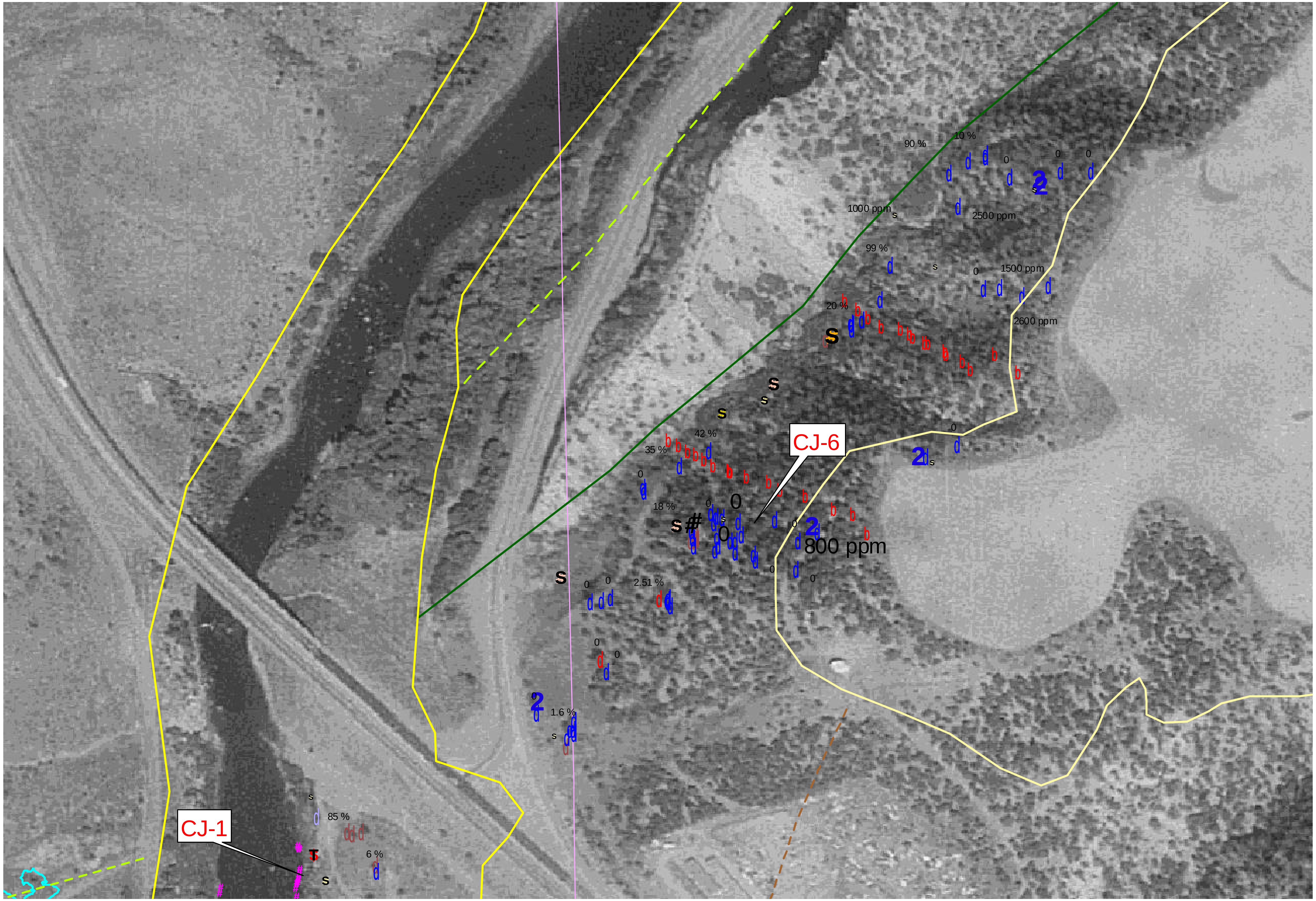


LEGEND

Gas Flux Chamber
Carbon Junction

Gas Monitoring Probe
Carbon Junction

Geology
Gravel Terrace Cap
Alluvium
Kirtland Fm.
Fruitland Fm.
Pictured Cliffs Fm. Tongue
Fruitland Fm. Tongue
Pictured Cliffs Fm.

Visible CH4 Seeps
Seep Trend
Methane Creek Seep
Creek Seep Area

Subsurface CH4 Measurement
0 - 25 ppm CH4
25 ppm - 1% CH4
1% CH4 - 10% CH4
10% CH4 - 50% CH4
50% CH4 - 100% CH4

Trees
Dead Pine
Stressed Pine
Bifurcated Pine
Dead Aspen
Stressed Aspen
Live Cottonwood
Dead Cottonwood
Stressed Cottonwood
Live Juniper
Dead Juniper
Stressed Juniper
Bifurcated Juniper
Dead Scrub Oak
Stressed Scrub Oak
Live Bush
Tree Stump

Vegetation
live grass patch
non-vegetated area
stressed-vegetated area

0 200 400 Feet

CJ-6 Text Reference

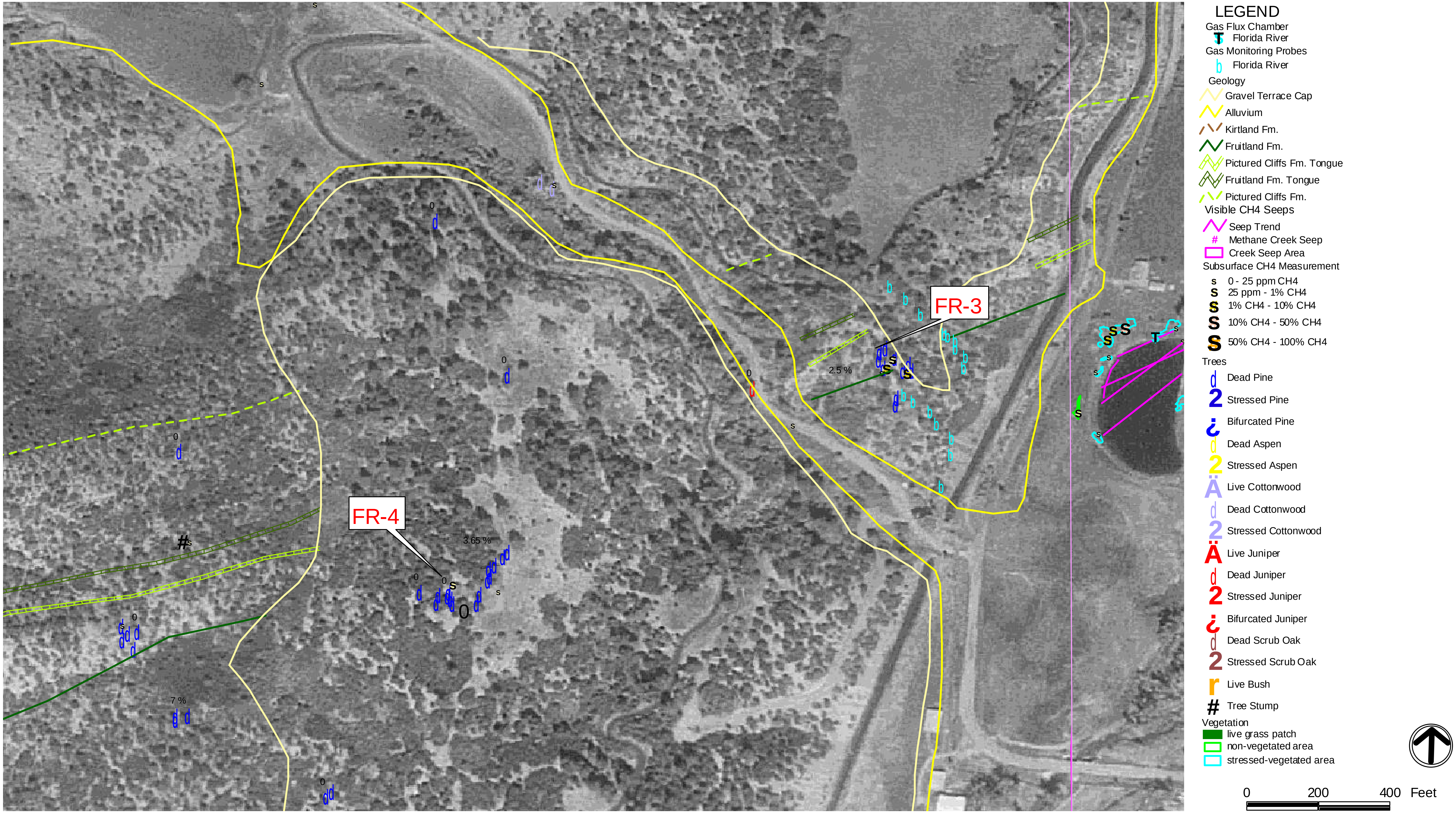
Mapping data collected on October 2, 5, and 6, 2002.

The study area west of the river is illustrated in Figure 3.

FIGURE 4
CARBON JUNCTION
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



Mapping data collected on October 7 and 8, 2002.

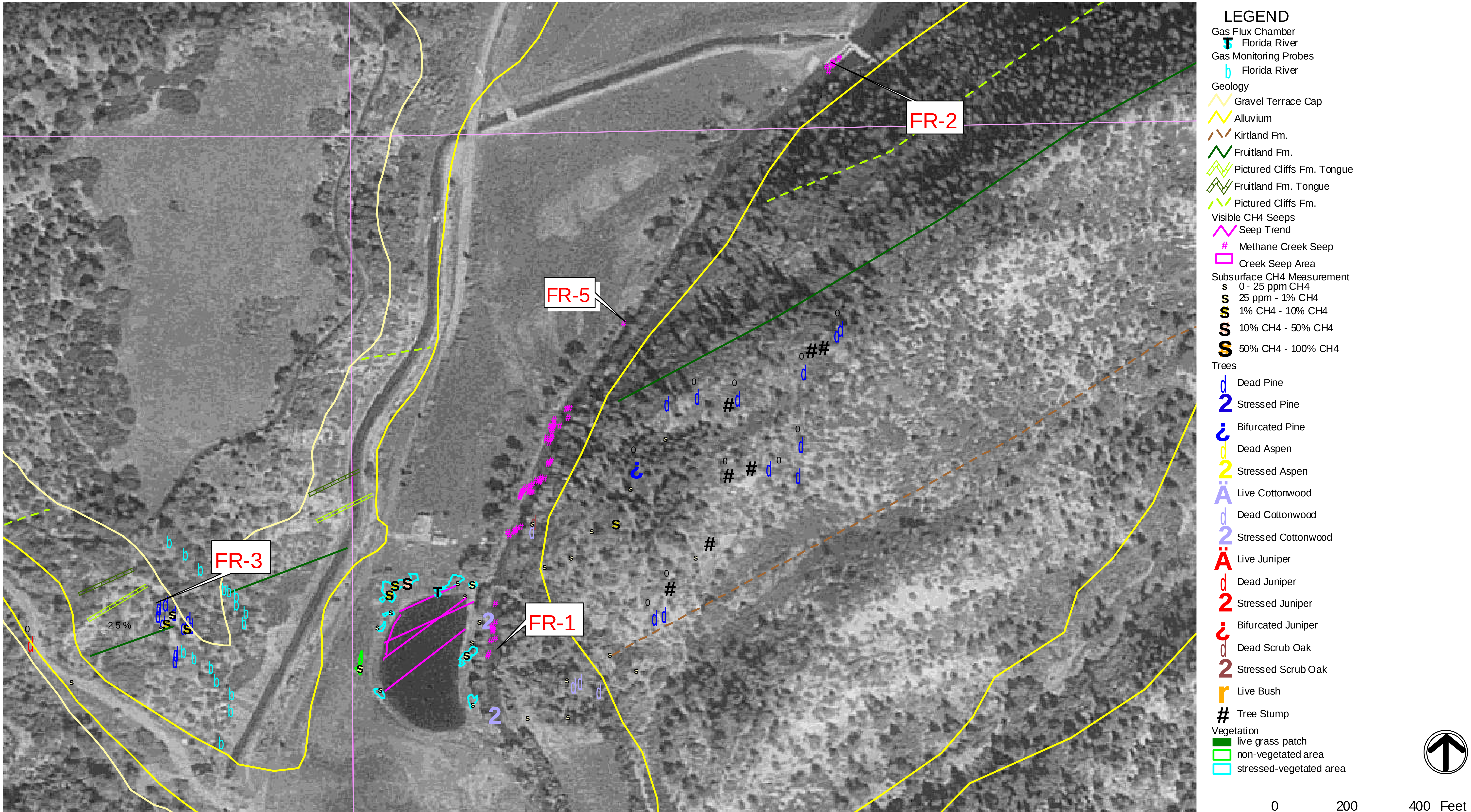
FR-4 Text Reference

The study area east of the river is illustrated in Figure 6.

FIGURE 5
FLORIDA RIVER
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



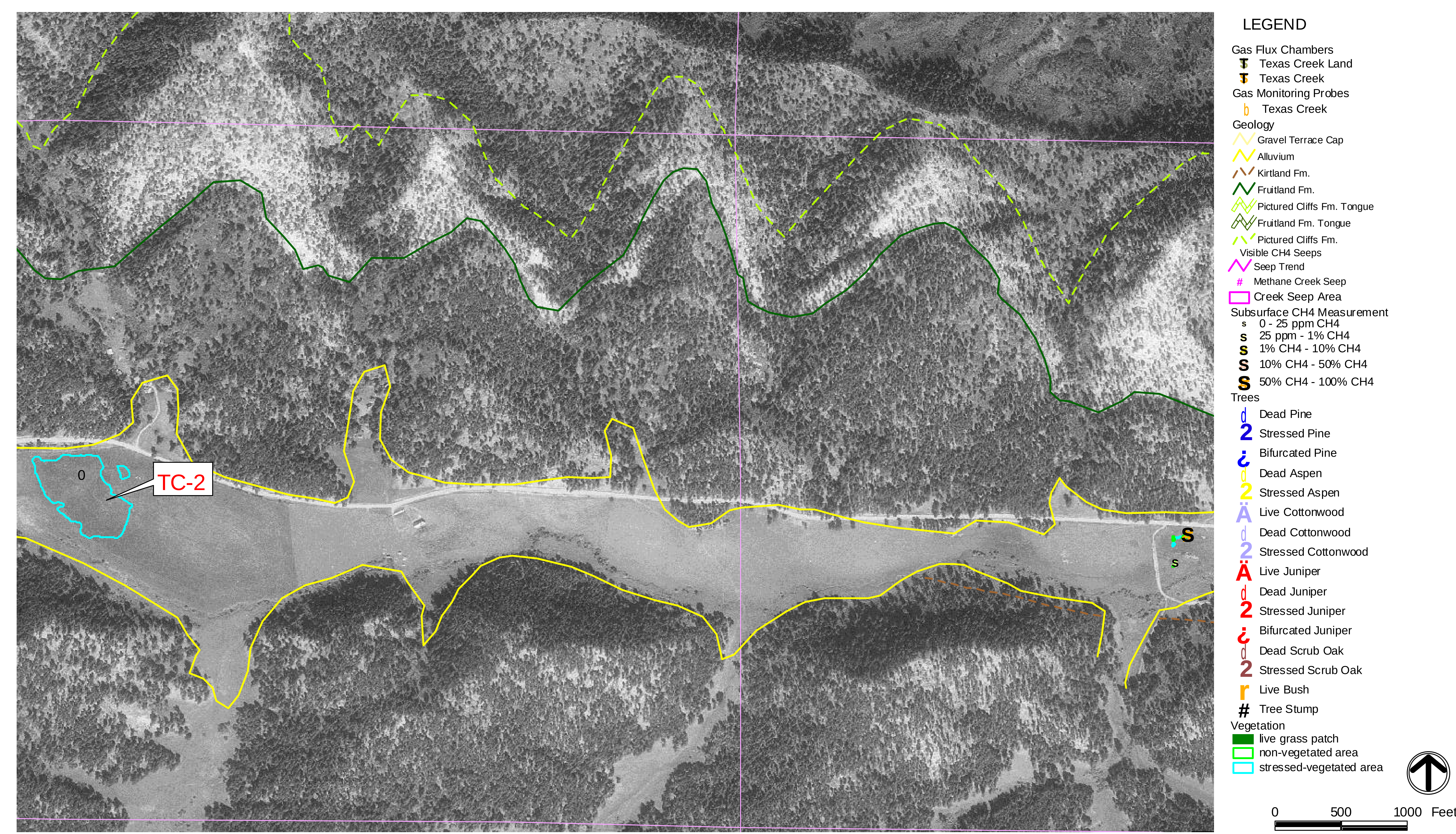
Mapping data collected on October 7 and 8, 2002.

The study area west of the river is illustrated in Figure 5.

FIGURE 6
FLORIDA RIVER
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



Mapping data collected on October 3 and 4, 2002.

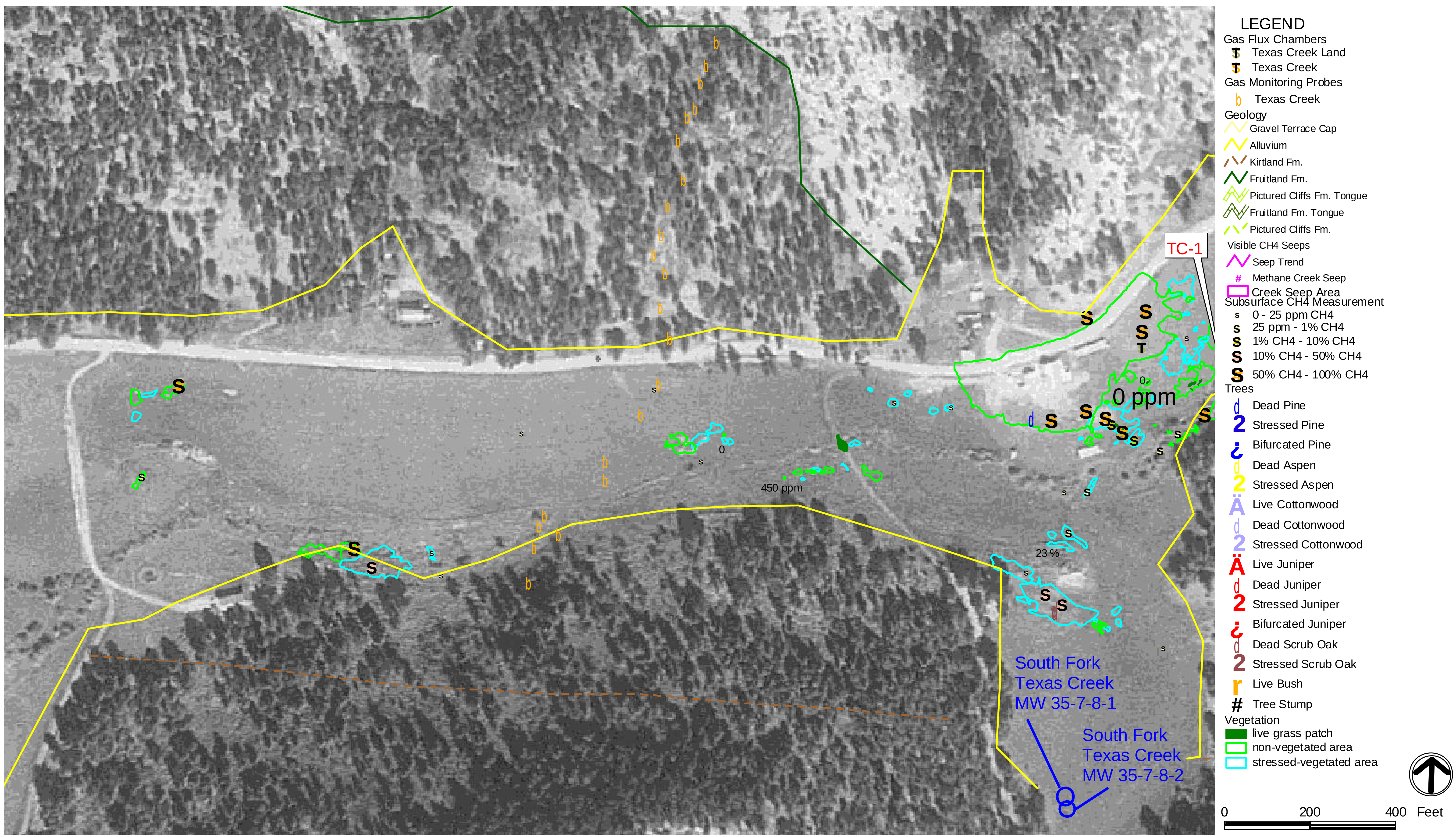
TC-2 Text Reference

The Texas Creek study area is located further east and is illustrated in Figures 8 and 9.

FIGURE 7
TEXAS CREEK
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



Mapping data collected on October 3 and 4, 2002.

TC-1 Text Reference

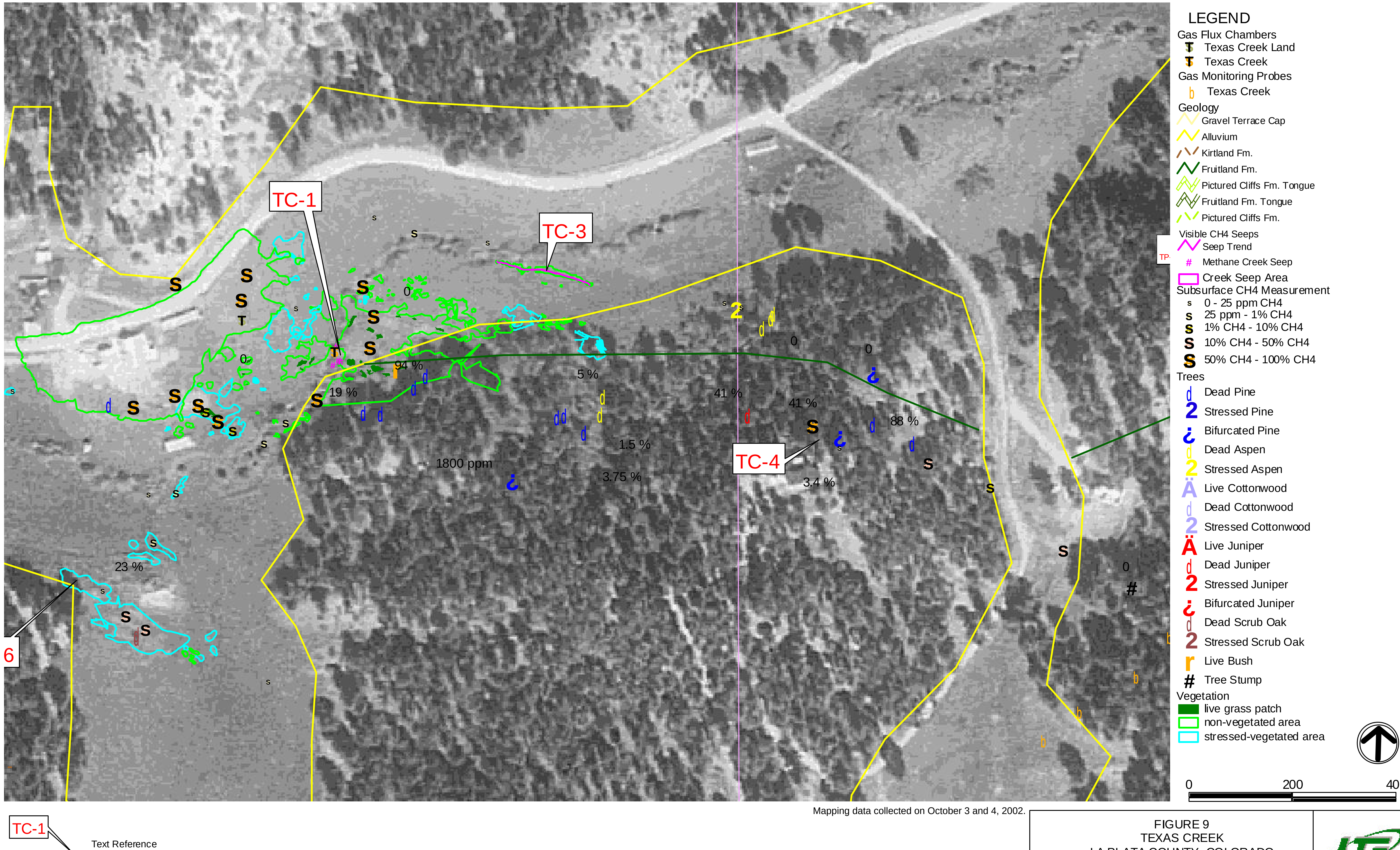
COGCC Monitoring Well

Additional Texas Creek study areas are illustrated in Figures 7 and 9.

FIGURE 8
TEXAS CREEK
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



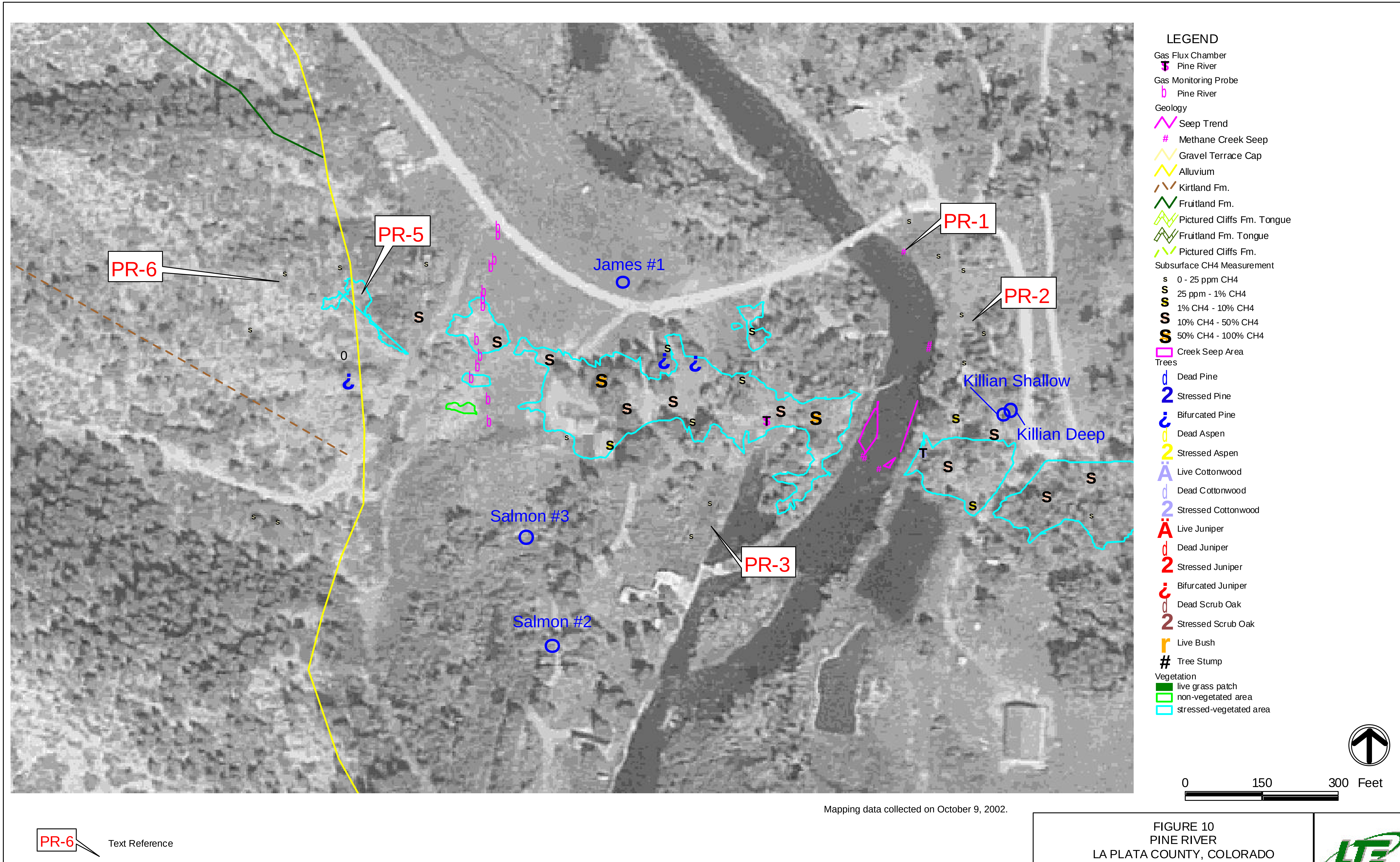
Mapping data collected on October 3 and 4, 2002.

Additional Texas Creek study areas located further west are illustrated in Figures 7 and 8.

FIGURE 9
TEXAS CREEK
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



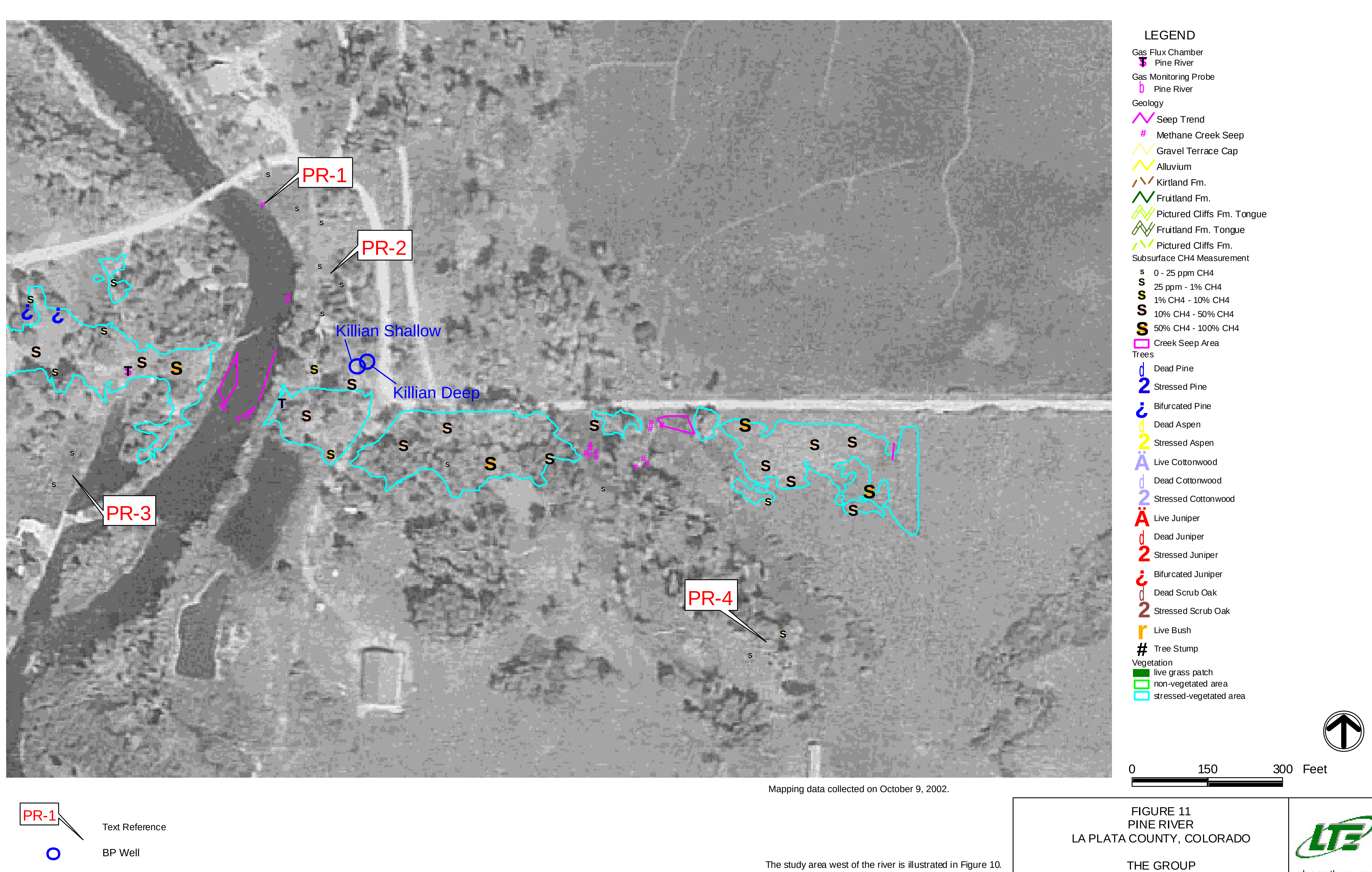
Mapping data collected on October 9, 2002.

The study area east of the river is illustrated in Figure 11.

FIGURE 10
PINE RIVER
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



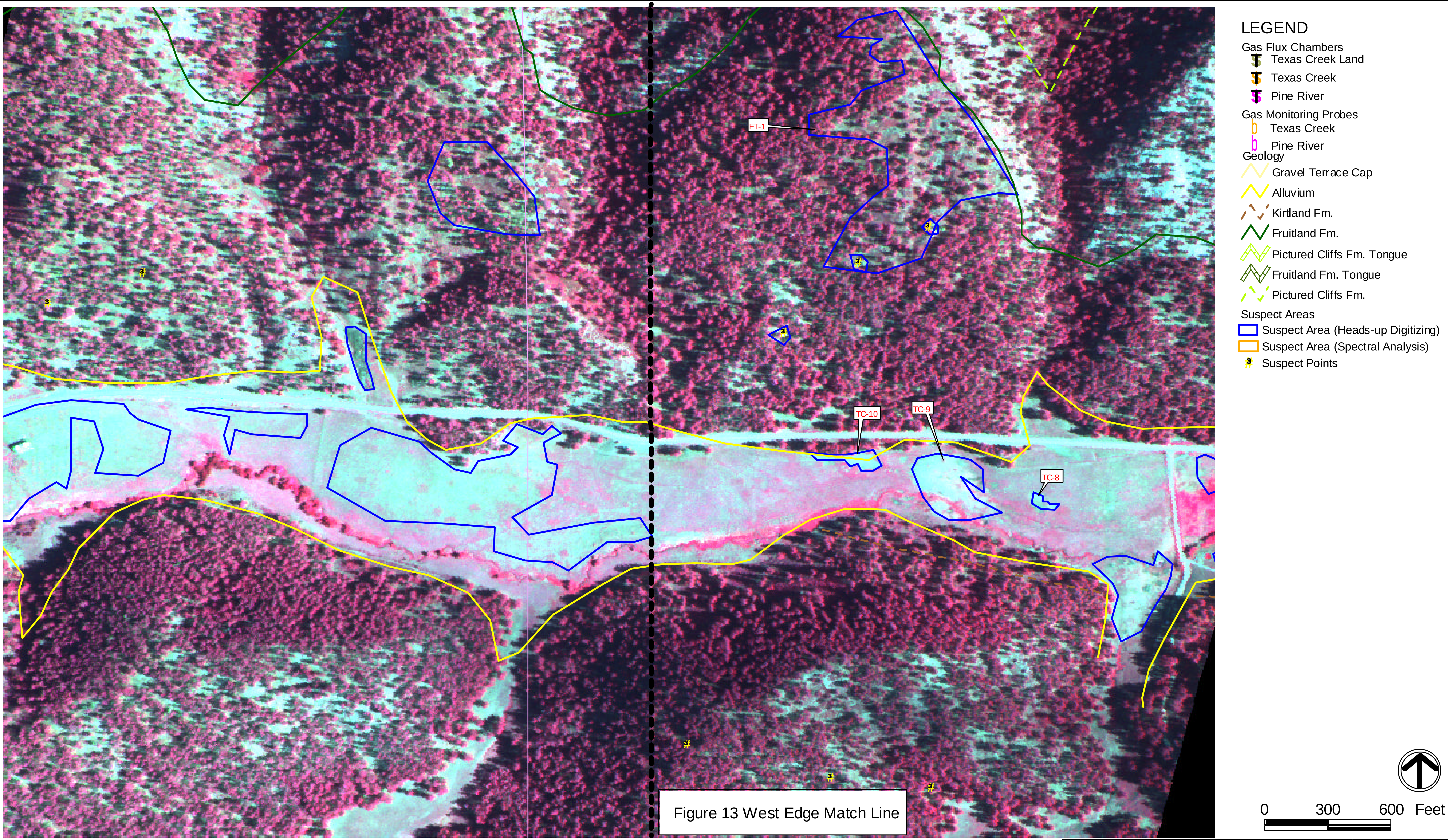
Mapping data collected on October 9, 2002.

The study area west of the river is illustrated in Figure 10.

FIGURE 11
PINE RIVER
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



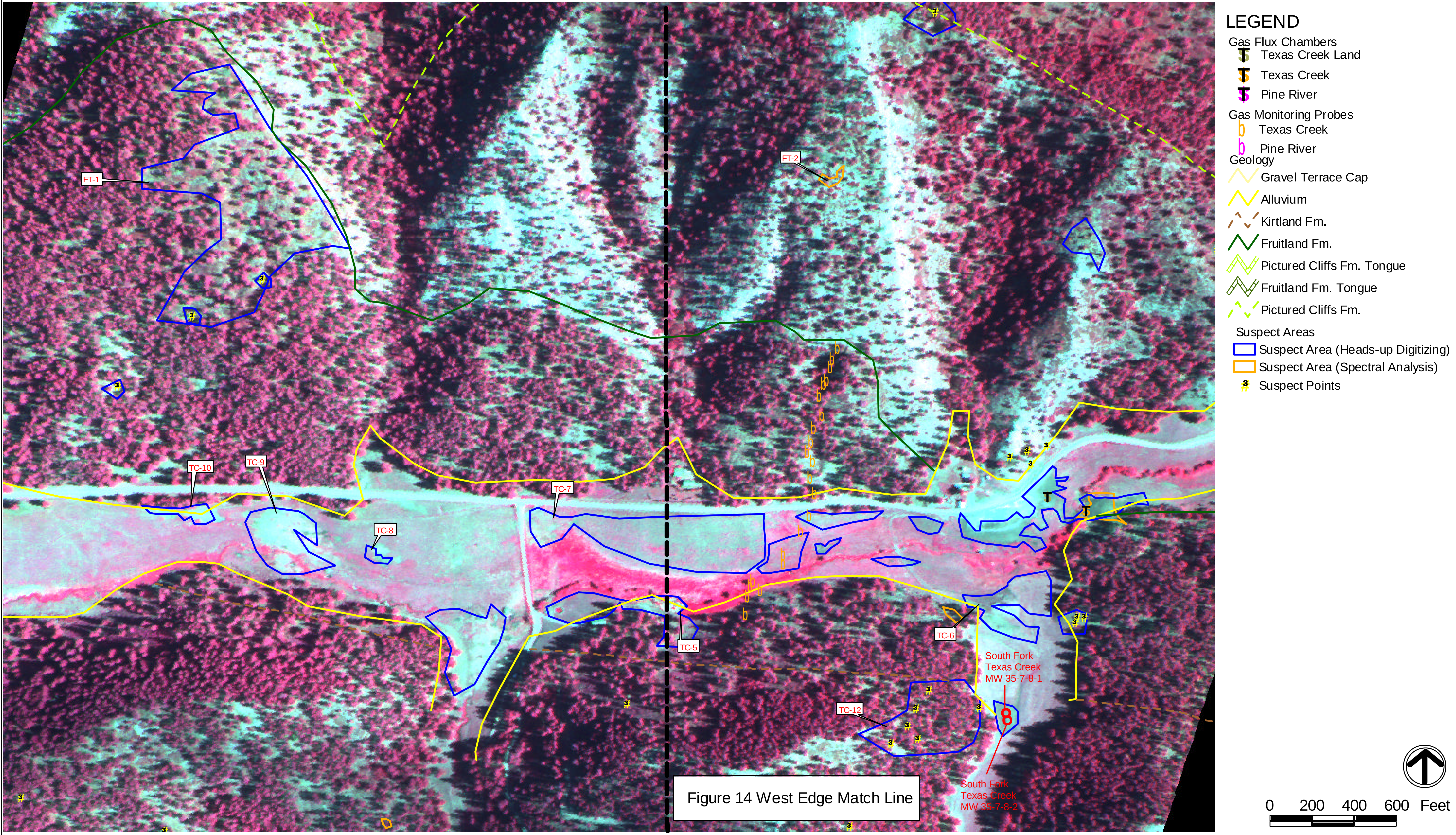
FT-1 Text Reference

IR imagery taken on August 14, 2002.

FIGURE 12
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



IR imagery taken on August 14, 2002.

FT-1 Text Reference

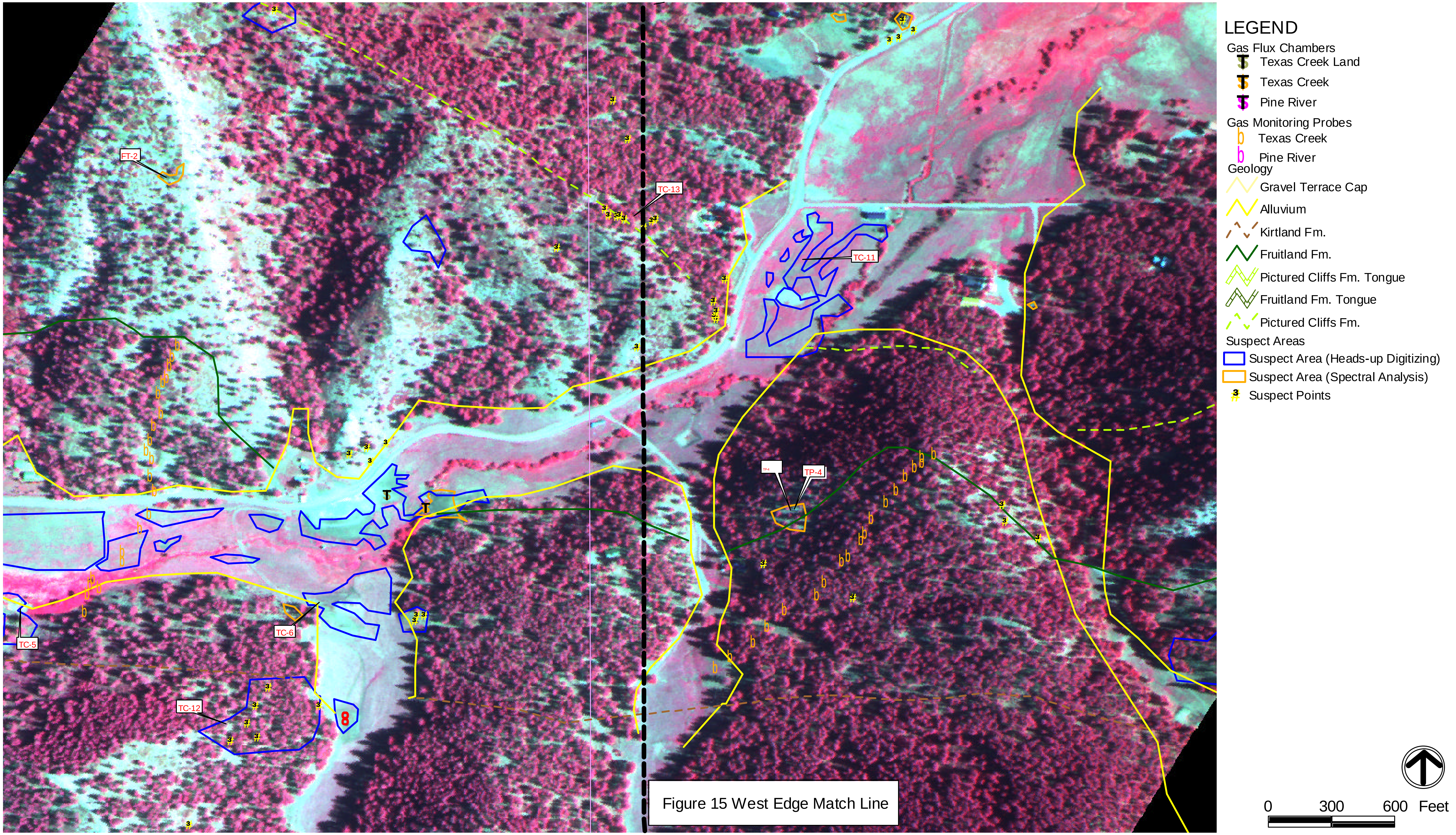
COGCC Monitoring Well

FIGURE 13
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

LTE

dgomethane.apr



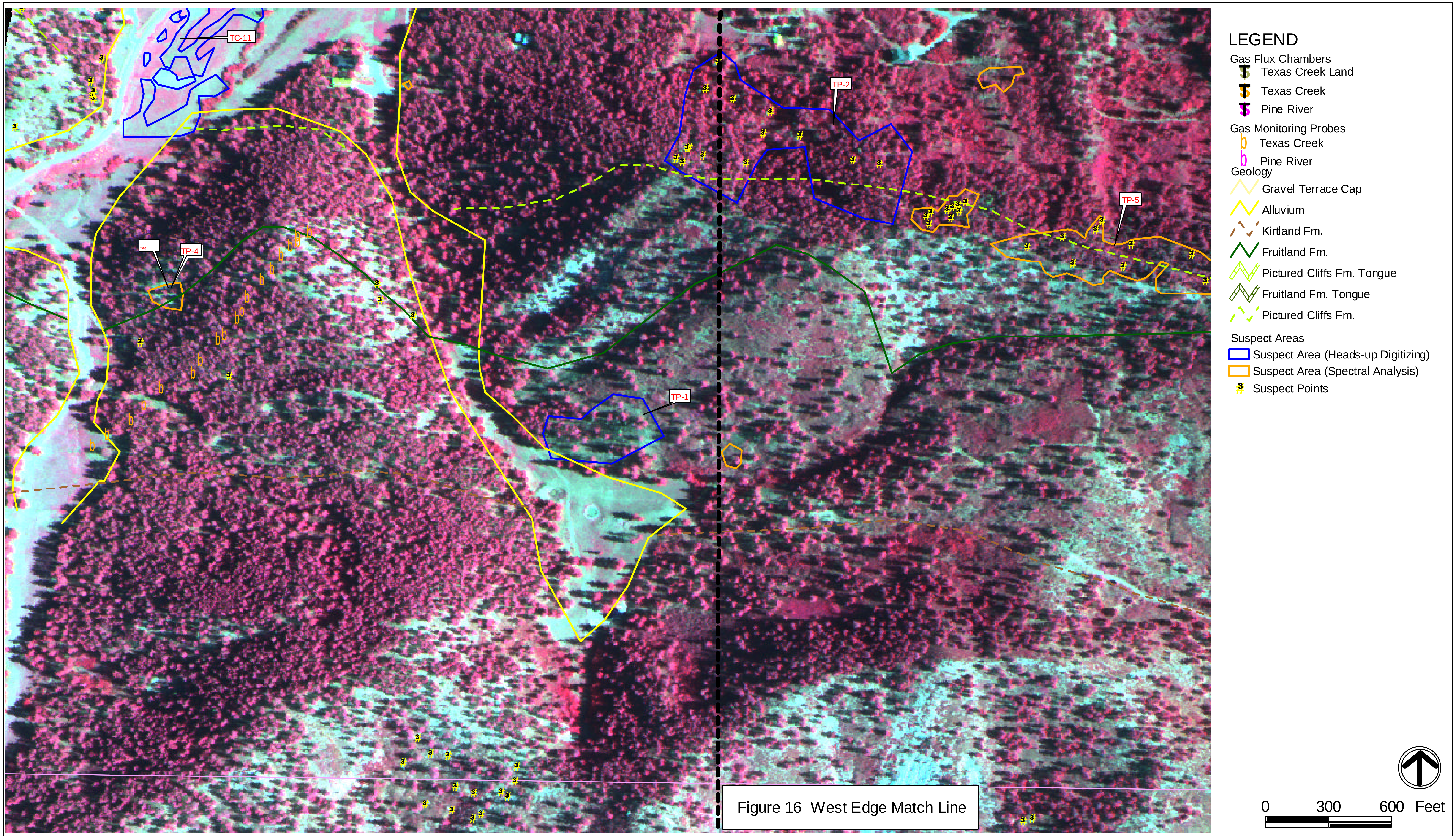
IR imagery taken on August 14, 2002.

TP-4 Text Reference

FIGURE 14
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



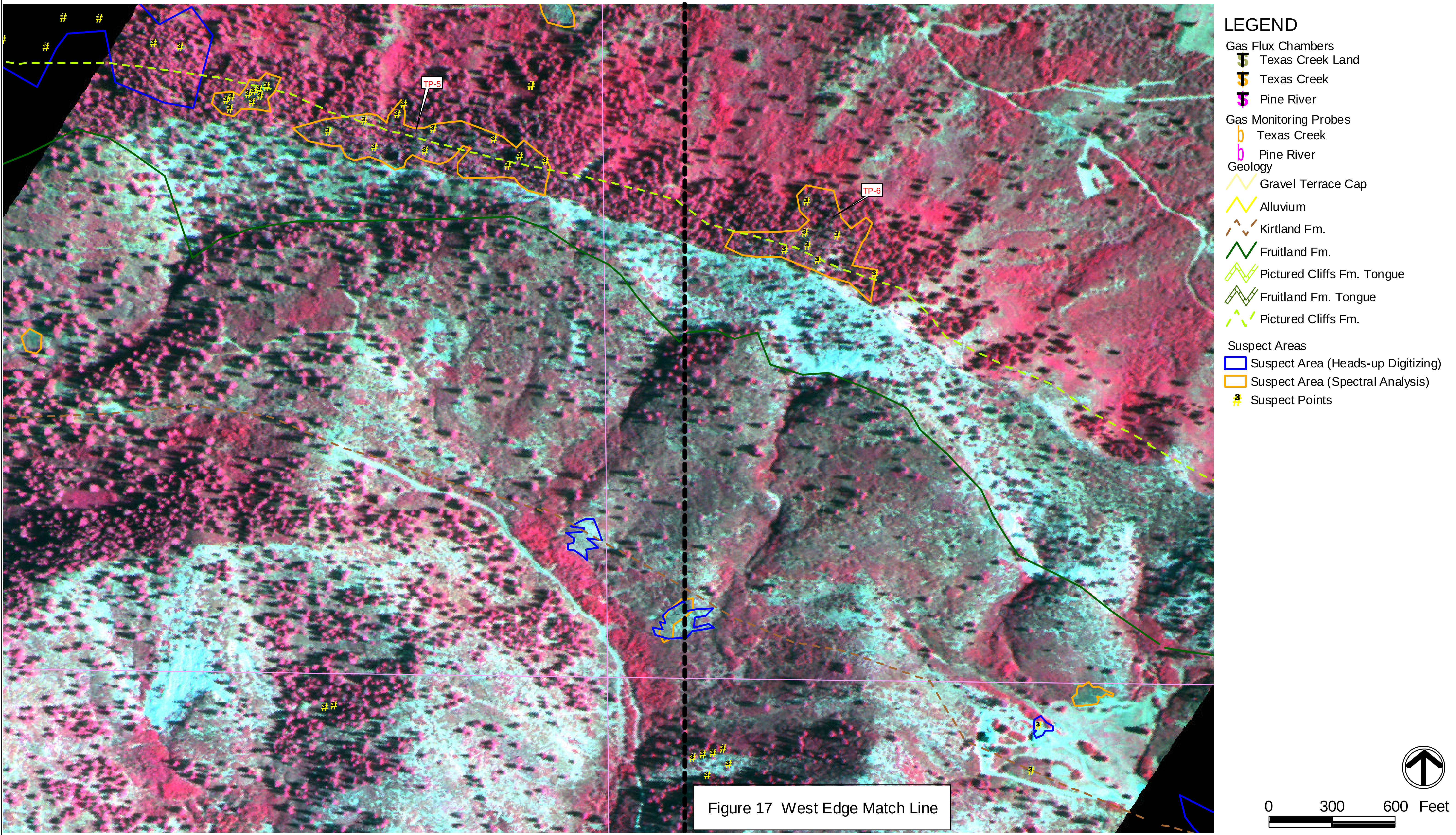
TP-4 Text Reference

IR imagery taken on August 14, 2002.

FIGURE 15
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



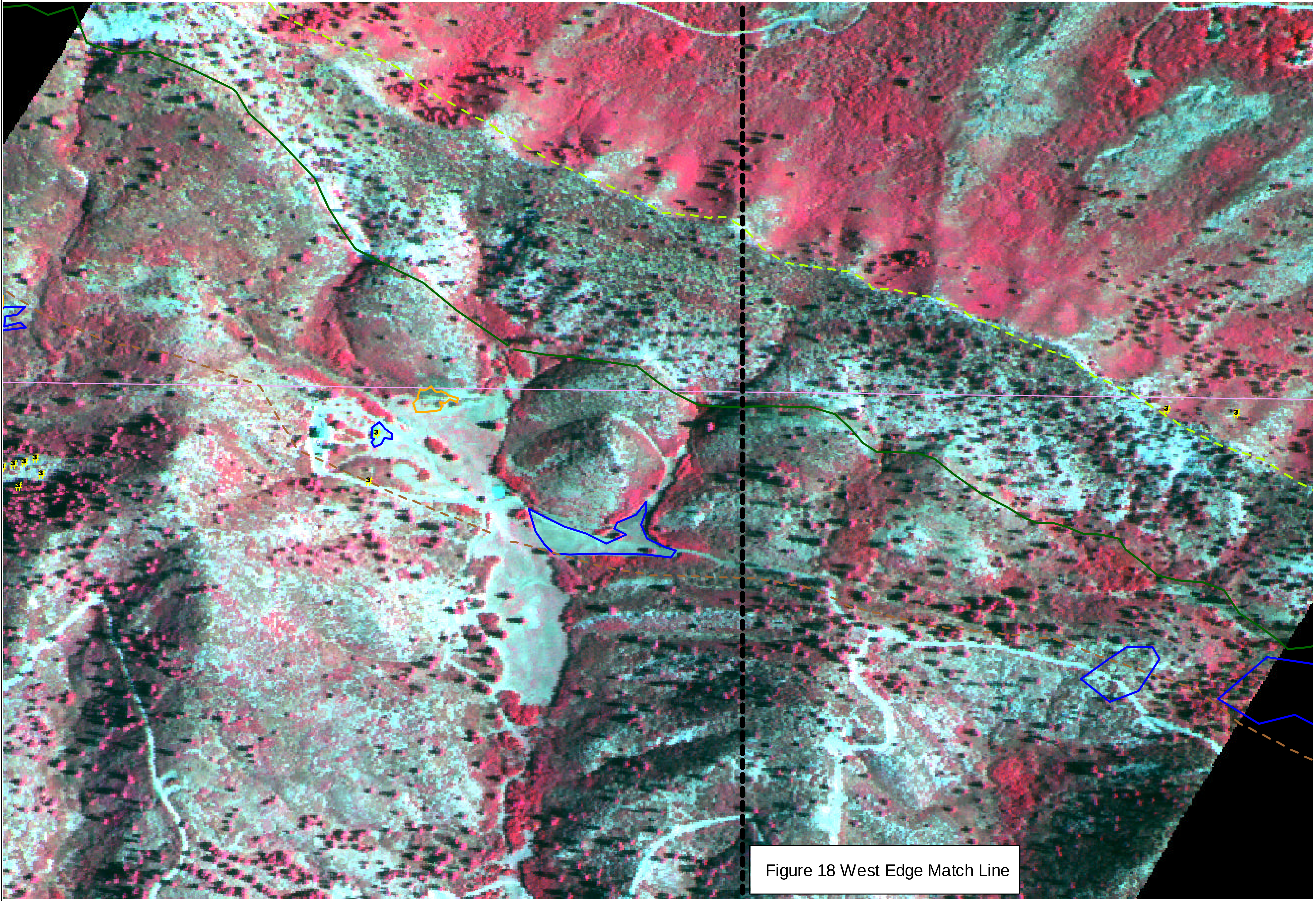
IR imagery taken on August 14, 2002.

TP-6 Text Reference

FIGURE 16
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



LEGEND

Gas Flux Chambers
- Texas Creek Land
- Texas Creek
- Pine River

Gas Monitoring Probes
- Texas Creek
- Pine River

Geology
- Gravel Terrace Cap
- Alluvium
- Kirtland Fm.
- Fruitland Fm.
- Pictured Cliffs Fm. Tongue
- Fruitland Fm. Tongue
- Pictured Cliffs Fm.

Suspect Areas
- Suspect Area (Heads-up Digitizing)
- Suspect Area (Spectral Analysis)
- Suspect Points

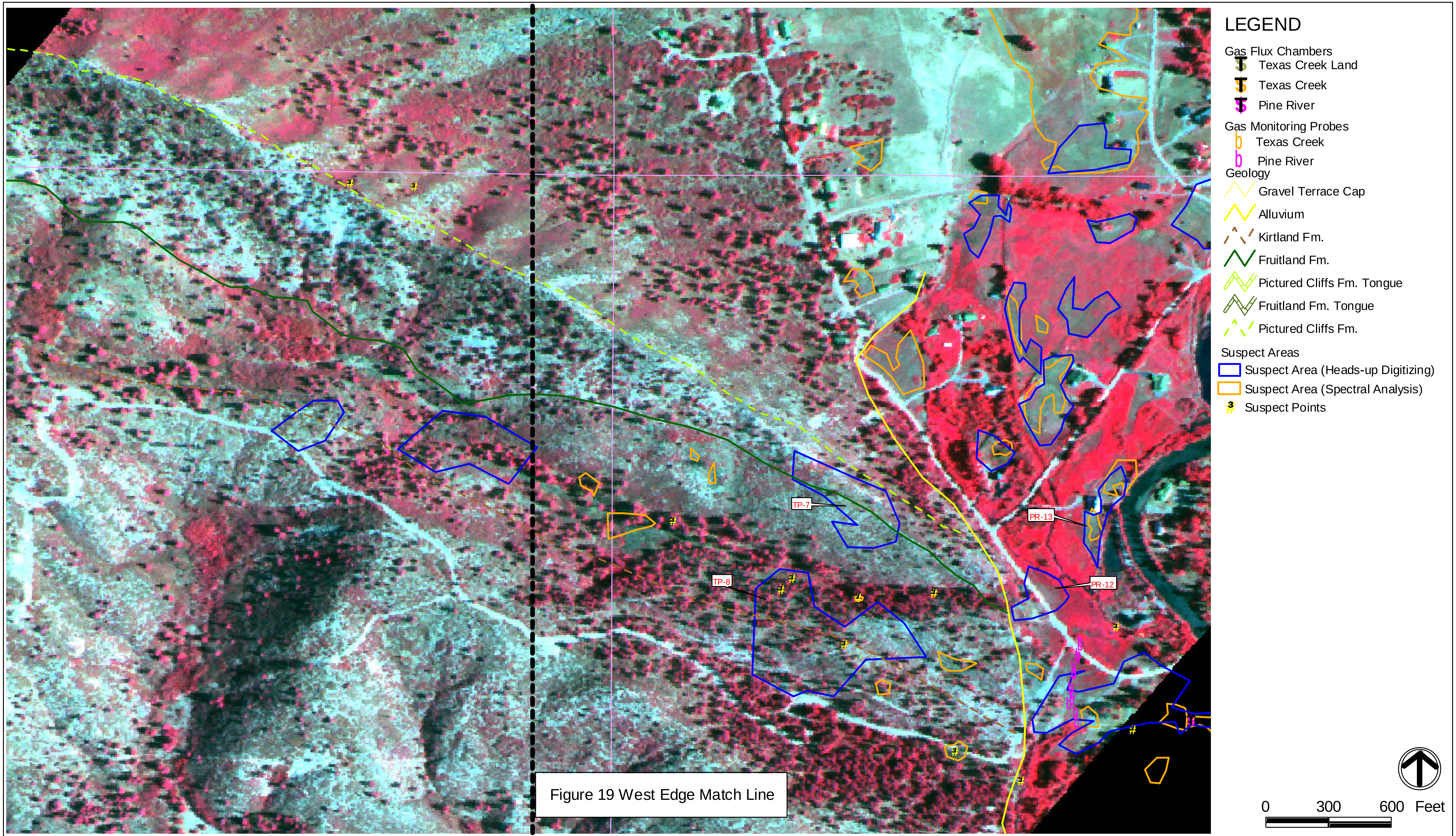
0 300 600 Feet

IR imagery taken on August 14, 2002.

FIGURE 17
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



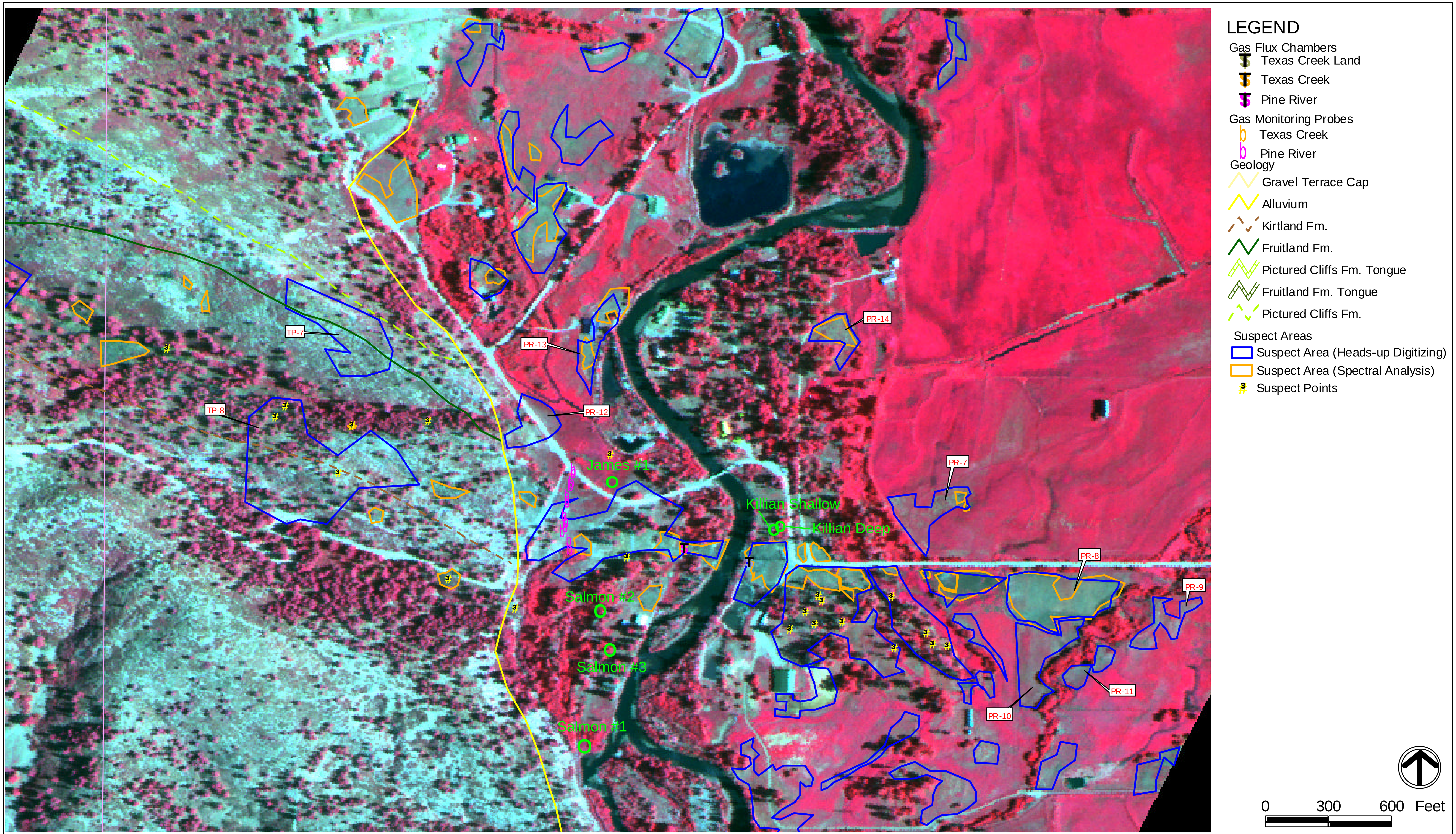
TP-8 Text Reference

IR imagery taken on August 14, 2002.

FIGURE 18
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

dgomethane.apr



IR imagery taken on August 14, 2002.

PR-11 Text Reference

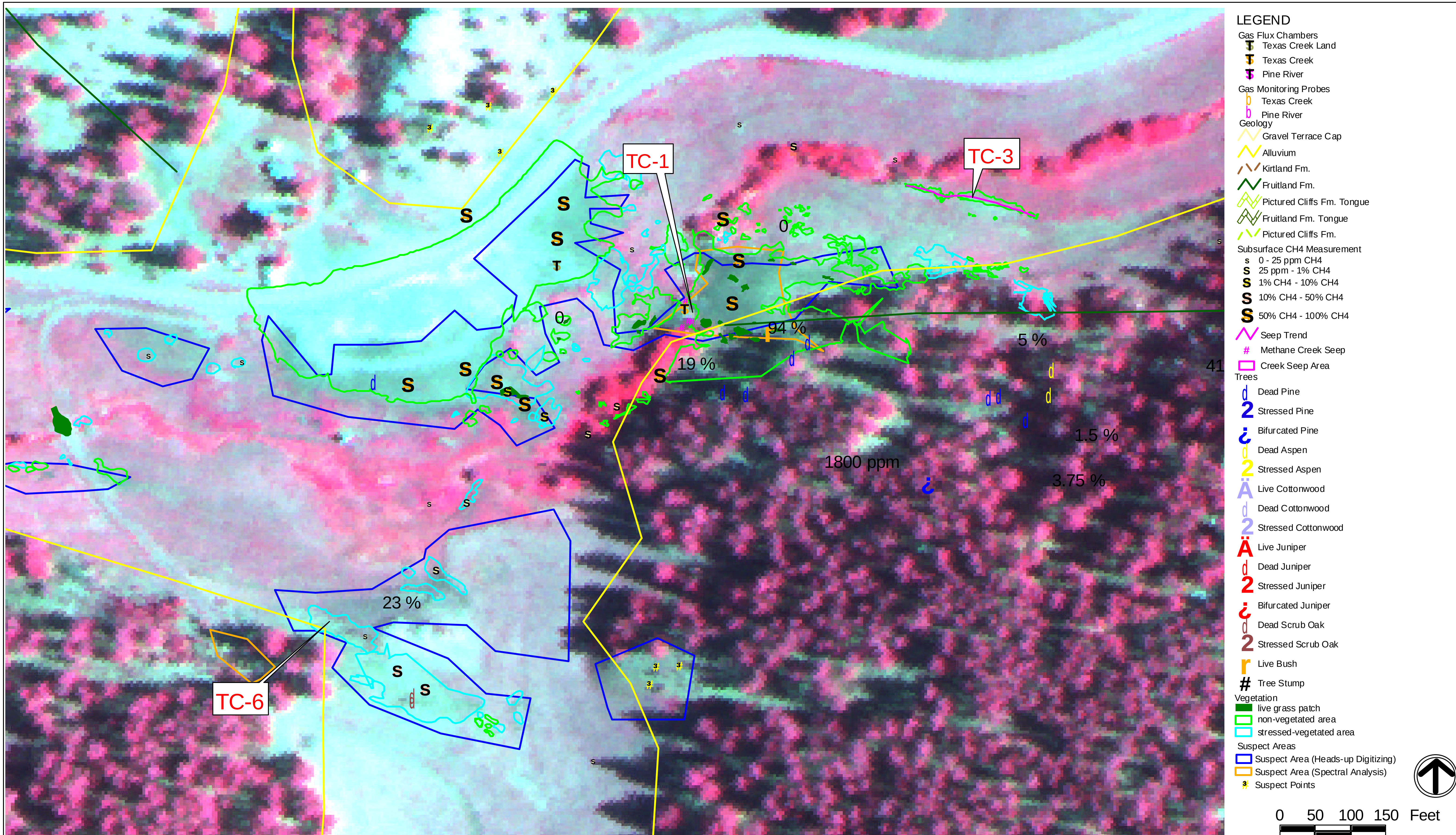
BP Well

FIGURE 19
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

LTE

dgomethane.apr



TC-1 Text Reference

IR imagery taken on August 14, 2002.

FIGURE 20
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

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IR imagery taken on August 14, 2002.

FIGURE 21
SUSPECT AREAS
LA PLATA COUNTY, COLORADO

THE GROUP

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APPENDIX A

EQUIPMENT SPECIFICATIONS

dataTaker

. . . keeping an eye on reality

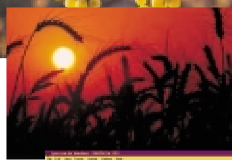
DT1000 ~ DT4000 Series

Data Acquisition and Data Logging Systems

- **Palm-Sized and Self Powered Convenience**
- **Ease of Operation**
- **Simple yet Powerful Software**
- **Reliable and Secure Performance**
- **Ten Year Battery**
- **Industry Leading Precision and Accuracy**

Specifications

www.dataTaker.com



DataTaker's Extensive Range

DataTaker's extensive range of data acquisition and data logging systems are stand alone or real time units, enabling users to log a diverse range of events and measurements. With over 30,000 data loggers in use in over 55 countries, the *dataTaker* range is used for a diverse range of applications in science, aerospace, mining, manufacturing, petro-chemical, meteorology, utilities, transportation, research & development and agriforestry.

DataTaker's Precision Palm-Sized Series

The *dataTaker* range of Precision Palm-Sized data loggers consists of four models, each with several variants:

- *DT1000* Temperature Loggers - Thermistor: 1 or 2 Channels
- *DT1700* Temperature Loggers - Thermocouple: 1, 2 or 4 Channels
- *DT2000* Temperature and Humidity Loggers: 2 Channels
- *DT4000* Voltage or 4-20mA Loggers: 1, 2 or 4 Channels

The *dataTaker* Palm-Sized range is self-powered with a battery life of up to 10 years. All data is stored in non-volatile EEROM memory so that your data is secure.

Traceable Accuracy

The *DT1000* and *DT2000* models are validatable. This certification option allows the tracing of temperature and humidity accuracy to international standards.

Simple yet Powerful Windows Software

The Windows based software is powerful yet easy-to-use. Set-up is simply a matter of completing a dialogue box. Once data is gathered, detailed charts, graphs and print outs can be produced with only a few key strokes. The graphing facilities enables users to "zoom" in on areas of interest, as well as overlay data for comparisons.

Applications

Applications for the *dataTaker* Palm-Sized Series include:

- Process Verification & Trouble Shooting
- Oven Temperature Profiling
- Monitoring of Perishable Goods
- Research and Development
- Health and Safety Compliance
- Food Storage Monitoring and Control
- Ultra Low Temperature Measurements
- Monitoring in Pharmaceutical Production
- Quality Compliance
- Blood and Organ Storage Monitoring

For your unique application contact your nearest *dataTaker* office or local dealer.

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United Kingdom
Tel: 01 462 481291
Fax:01 462 481375
sales@dataTaker.co.uk

DT1000 ~ DT4000 Series

Common Specifications

Size: 71 x 53 x 18mm
Enclosure: injection-molded beige ABS Plastic
Mounting: magnetic strips, Velcro
Operating range: –40°C to 80°C and 0 to 85% RH
Power source: internal lithium battery, 3.6V
Battery life: 10 year life at 15 minute sampling interval
A/D conversion: 12-bit (one part in 4,096)
Memory: non-volatile 32k x 8 EEROM
Data capacity: 21,500 samples, 70,000 with memory expansion option
Sample rate 10s to once per day
Memory retention: >20 yrs without power
Clock accuracy: ±1 minute per month (–40°C to 80°C)
PC interface: serial port, half-duplex, 19,200 baud
EMC: meets FCC Part 15 for digital devices, meets CE requirements for radiated emissions, ESD and susceptibility
PC software: Spectrum for Windows Software
Data inputs: refer to individual model specifications

Spectrum for Windows Software

Support software for the *DT1000 - DT4000* Series of data loggers. Not included with data loggers.

PC-SFW-IC: Spectrum for Windows Software with comms. cable and electronic manual
Functions: set loggers scan interval and start time,
download data from logger,
plot data,
overlay plots for comparison tabulate data
Compatibility: windows 95,98, NT and 2000

DT1000 Temperature Data Loggers

Temperature data loggers using thermistor temperature sensors over –40°C to +80°C or –40°C to +150°C for the external sensor

Channels: one internal temperature, one external temperature
Internal sensor: precision calibrated NTC thermistor –40°C to +80°C
External sensor: general purpose temperature probe: –40°C to +150°C range, flat ended aluminium tip 3m (10ft) leads
Resolution: ±0.05°C at 25°C
Response time: <1 min. in slowly moving air
Accuracy: ±0.25°C at 25°C
±0.15°C at 25°C (XP Versions)
±0.5°C at –40°C (LT Versions)
DT1000: two channels temperature logger (100kΩ thermistor)
DT1000-LT: two channels low temperature logger, calibrated at –40°C to ±0.5°C
DT1000-XP: two channels enhanced accuracy temperature logger: ±0.15°C at 25°C

Validatable Data Logger Versions

DTV1000: two channels validatable temperature logger (100kΩ thermistor)
DTV1000-LT: two channels validatable Low temperature logger calibrated over –40°C to ±0.5°C
DTV1000-XP: two channels validatable enhanced accuracy temperature logger: ±0.15°C at 25°C

DT1700 Temperature Data Loggers

For use with J, K, T, E, R and S thermocouples

Thermocouple - Wide Range

(–100°C to +1250°C with 1.3°C accuracy)

DT1700-20W: two channels - one thermocouple input plus ambient temperature
DT1700-30W: three channels - two thermocouple input plus ambient temperature
DT1700-50W: five channels - four thermocouple input plus ambient temperature

Thermocouple - Narrow Range

(–200°C to +240°C with 0.4°C accuracy)
DT1700-20N: two channels - one thermocouple input plus ambient temperature
DT1700-30N: three channels - two thermocouple input plus ambient temperature
DT1700-50N: five channels - four thermocouple input plus ambient temperature

Internal Ambient Sensor (Reference)

Sensor: precision calibrated NTC thermistor
Accuracy: ±0.25°C at 25°C
Resolution: ±0.05°C at 25°C
This sensor is used as the cold junction reference temperature sensor for thermocouple correction

DT2000 Temperature and Humidity Data Loggers

Resolution: ±0.05%RH
Repeatability: 0 to 75%RH: 0.5%
Stability and drift: ±1%RH (typ.) at 50%RH in 5yrs
Hysteresis: ±0.8% of span (max.)
DT2000: temperature and humidity logger (2%RH Accuracy)
DT2000-LRH: temperature and humidity logger (special calibration for increased accuracy in 0 -10%RH range)

Validatable Data Logger Versions

DTV2000: temperature and humidity validatable logger (2%RH Accuracy)
DTV2000-LRH: temperature and humidity validatable logger (increased accuracy in 0 -10%RH range)

Internal Ambient Temperature Sensor

Sensor: precision calibrated NTC thermistor
Response time: <1 minute in slowly moving air
Accuracy: ±0.25°C at 25°C, 0.5°C over 30°C to 50°C
Resolution: 0.05°C at 25°C, 0.2°C over –30°C to 50°C

Internal Relative Humidity Sensor

Sensor: temperature compensated capacitive polymer-base monolithic integrated circuit
Range: 0 to 100%RH
Accuracy:
DT2000: ±2%RH (over 10 to 90%RH at 25°C)
DT2000-LRH: ±2%RH (over 0 to 10%RH at 25°C)

DT4000 Voltage and Current Data Loggers

Number of Channels
DT4000: five, two switchable 0–1V or 1–10V, two 4–20mA (one with XPS), one internal ambient temperature
DT4000-101: one switchable 0–1V or 0–10V
DT4000-1CW: one 4–20mA with XPS
DT4000-411: four: two 0–10V and two switchable 0–1V or 0–10V
DT4000-4CW: four 4–20mA with XPS switch on two channels
DT4000-4A1: four 0–1V
DT4000-4R5: four 0–5V

Internal Ambient Temperature Sensor

Sensor: precision-calibrated NTC thermistor
Accuracy: 0.5°C over –30°C to 50°C
Resolution: 0.2°C over –30°C to 50°C

Analog Voltage Inputs

Input ranges: 0–1V, resolution 0.24mV
0–5V, resolution 1.2mV
0–1V, resolution 0.24 mV
0–10V, switchable, resolution 2.4mV
0–10V, resolution 2.4mV
Input impedance: >1MΩ
Overload protection: ±30V, reverse polarity protected

Current Loop Inputs

Range: 0–22mA
Input impedance: 50Ω
Overload protection: 60mA max, reverse protected

XPS Excitation Power-Saver Switch

The XPS Excitation Power-Saver Switch is an internal software-controlled switch in certain *DT4000*-Series models that controls loop power for circuits containing one or more 4–20mA transducers. The switch works by opening the measurement circuit in between readings then closing just prior to each reading to conserve power in battery operated systems.

Optional Accessories

Oven Temperature Profiling Enclosures

Provide protection for the Palm-Sized data loggers in high temperature environments.

Spectrum for Windows Software

Simple but powerful software that allows you to setup your Palm-Sized *dataTaker*, then to download and plot your data.

Warranty

The *dataTaker DT1000 - DT4000* range is covered by a 1 year warranty on workmanship and parts.
For further information on the *dataTaker* range, or for useful downloads,visit the *dataTaker* web site at www.dataTaker.com or contact your nearest *dataTaker* office or dealer.

dataTaker
. . . keeping an eye on reality

Your local dealer

UKAS QUALITY MANAGEMENT 001

dataTaker
Certified to ISO9002
TOTAL QUALITY COMMITMENT

BR-0016-A7

GPS Pathfinder Systems

GPS systems for better data management and decision-making

Key features and benefits

- **Fast map display**
- **Easy to use graphical interface**
- **High-performance DGPS receivers**
- **Better accuracy with postprocessing**
- **Rugged and field proven**

Trimble's GPS Pathfinder® Systems are effective tools for data collection, update, and processing. This versatile family offers a variety of software, data collector, and GPS receiver options that are powerful, easy to use, and integrate seamlessly with industry-standard GIS databases. With a GPS Pathfinder System, you'll have the most accurate, current, and reliable data you need to make the best decisions.

Productive field software

Timesaving field software is essential for productive GIS data collection and data maintenance.

With Trimble's field software options, you can quickly and easily collect point, line, and area features, along with customized attribute information. Our field software makes it easy to take existing data from your GIS into the field for verification and update. In the field, your productivity will be enhanced by better graphics. A fast map display allows you to display background data and imagery, to ensure you're working in the right location, with the right data. And flexible map symbology enables you to tailor your data display to match your GIS.

Trimble offers two field software solutions for collecting and maintaining quality data:

TerraSync™ software operates on Trimble's rugged GIS TSCe™ field device, or any Windows field computer.

Asset Surveyor® software runs on Trimble's rugged, field-proven TSC1™ data collector.

Trimble GPS Pathfinder Systems are rugged and field-proven

Accurate and reliable data

Trimble's GPS Pathfinder System receivers offer real-time differential GPS (DGPS) and postprocessing options. Real-time DGPS provides you with immediate results in the field—great for navigation, and relocation of existing assets. Postprocessing enables you to improve the reliability and accuracy of your data when you're back in the office.

The **GPS Pathfinder Power** receiver integrates GPS, real-time satellite differential, and Wide Area Augmentation System (WAAS) capabilities into a single, lightweight unit.

The **GPS Pathfinder Pro XR** system integrates GPS, real-time beacon, and WAAS capabilities.

The **GPS Pathfinder Pro XRS** system integrates GPS, real-time beacon, satellite differential, and WAAS capabilities.

The best data for your GIS

The GPS Pathfinder Office software gives you the tools to manage your GPS projects from start to finish. With it, you can define your field data collection requirements and control the quality of your data. The result is more consistent, reliable, and accurate data for your GIS.

The GPS Pathfinder Systems family offers you a variety of software, data collector, and GPS receiver options. Choose the solution that meets your requirements, and realize the benefits of better decisions based on better data.

GPS Pathfinder Systems

Versatile GIS data collection and maintenance

FEATURES AND OPTIONS

GPS Pathfinder Systems Standard Features

- GPS Pathfinder Office software
- Choice of GPS receiver
- Choice of field software
- Ergonomic backpack carrying system
- Rechargeable system batteries (provide 8 hours of field use)
- Battery charger and AC power supply

Optional Receiver Accessories

- Vehicle kit: includes cigarette lighter power adapter, quick release, 2 quick-release adapters, and magnetic mount
- GPS Pathfinder Centimeter Processing option

Available Receivers and Standard Features

- GPS Pathfinder Pro XRS receiver
- GPS Pathfinder Pro XR receiver
- GPS Pathfinder Power receiver

- 12-channel GPS receiver
- EVEREST™ multipath rejection technology
- WAAS differential correction capabilities

Available Field Software

- Asset Surveyor software for Trimble TSC1 data collector
- TerraSync software for Trimble GIS TSCe field device, and Windows field computers

GPS PATHFINDER POWER RECEIVER / ANTENNA SPECIFICATIONS

- Integrated GPS/Satellite Differential receiver and antenna
- RTCM input

General:	12 channel, L1/CA code tracking with carrier phase filtered measurements.
Update rate:	1 Hz
Power:	3.1 Watts, 9 to 32 VDC
Accuracy (RMS) (Note A):	
MCORR400 differential correction:	Submeter + 1 ppm on a second-by-second basis (horizontal) Submeter + 2 ppm on a second-by-second basis (vertical)
Carrier phase processing:	30 cm + 5 ppm with 5 minutes tracking satellites 20 cm + 5 ppm with 10 minutes tracking satellites 10 cm + 5 ppm with 20 minutes tracking satellites 1 cm + 5 ppm with 45 minutes tracking satellites (with Centimeter Processing option)
RTCM satellite differential correction:	Better than 1 meter (Note B)
Time to first fix:	30 seconds (typical)
Size:	15.2 cm diameter x 12.7 cm high (6" x 5")
Weight:	0.625 kg (1.38 lbs)
Temperature:	–30°C to +60°C (–22°F to +140°F) (operating) –40°C to +80°C (–40°F to +176°F) (storage)
Humidity:	100% fully sealed
Casing:	Fully sealed, dustproof, waterproof, shock resistant

GPS PATHFINDER PRO XR AND PRO XRS RECEIVER & ANTENNA SPECIFICATIONS

GPS Pathfinder Pro XR

- Integrated GPS/Beacon receiver
- Integrated GPS/Beacon antenna
- RTCM input/output
- 3 meter antenna cable
- Base datalogging mode

GPS Pathfinder Pro XRS

- Integrated GPS/Beacon/Satellite Differential receiver
- Integrated GPS/Beacon/Satellite Differential antenna
- RTCM input/output
- 3 meter antenna cable
- Base datalogging mode

GPS Pathfinder Pro XR receiver

General:	12 channel, L1/CA code tracking with carrier phase filtered measurements and multibit digitizer
Update rate:	1 Hz
Power:	6 Watts (maximum), 10 to 32 VDC
Accuracy (RMS) (Note A):	
MCORR400 differential correction:	50 cm + 1 ppm on a second-by-second basis (horizontal) Submeter + 2 ppm on a second-by-second basis (vertical)
Carrier phase processing:	30 cm + 5 ppm with 5 minutes tracking satellites 20 cm + 5 ppm with 10 minutes tracking satellites 10 cm + 5 ppm with 20 minutes tracking satellites 1 cm + 5 ppm with 45 minutes tracking satellites (with Centimeter Processing option)
RTCM beacon radio transmissions:	Better than 1 meter (Note B)
Time to first fix:	30 seconds (typical)
Size:	11.1 cm × 5.1 cm × 19.5 cm (4.4" × 2.0" × 7.7")
Weight:	0.76 kg (1.68 lbs)
Temperature:	–30°C to +65°C (–22°F to +149°F) (operating) –40°C to +85°C (–40°F to +185°F) (storage)
Humidity:	100% fully sealed
Casing:	Dustproof, splashproof, shock resistant; sealed to 5 psi

GPS Pathfinder Pro XRS receiver

Specifications for the Pro XRS receiver are the same as for the Pro XR receiver with the following exceptions:

Power:	7 Watts (maximum), 10 to 32 VDC
Accuracy (RMS) (Note A):	
RTCM satellite differential correction:	Better than 1 meter (Note B)

GPS Pathfinder Pro XR antenna

General:	Right-hand, circular polarized; omnidirectional; hemispherical coverage
Size:	15.5 cm diameter × 10.8 cm high (6.1" × 4.2")
Weight:	0.49 kg (1.08 lbs)
Temperature:	–30°C to +65°C (–22°F to +149°F) (operating) –40°C to +85°C (–40°F to +185°F) (storage)
Humidity:	100% fully sealed
Casing:	Dustproof, waterproof, shock resistant

GPS Pathfinder Pro XRS antenna

Specifications for the Pro XRS antenna are the same as for the Pro XR antenna with the following exceptions:

Size:	15.5 cm diameter × 14 cm high (6.1" × 5.5")
Weight:	0.55 kg (1.2 lbs)

TRIMBLE GIS TSCe FIELD DEVICE SPECIFICATIONS

Screen:	320 x 240 color touch screen: 1/4 VGA reflective color TFT
Size:	25.8 cm x 13 cm x 5.2 cm (10.2" x 5.1" x 2.1")
Weight:	0.99 kg including internal battery
Temperature:	–20°C to +60°C (+14°F to +140°F) (operating) (Note C) –30°C to +60°C (–22°F to +140°F) (storage)
Environmental:	Meets IEC 68, EN61000, MIL-STD-810E standards for temperature, moisture and immersion, dust and sand, drop test, shock, vibration and altitude. IP 67 sealed against temporary immersion.
COM ports:	9-Pin serial port: RS232 (COM 1) 26-Pin MultiPort: (COM 2, Ethernet, USB client, power in/out, and audio in/out) Infrared: IrDA Type 1 (COM 3)
Memory:	128 MB (storage) 64 MB (RAM)
Batteries:	NiMH rechargeable pack, 3800 mAh gives continuous operation for over 30 hours recharges to 90% of capacity in 1 hour (Note D)

TRIMBLE TSC1 DATA COLLECTOR SPECIFICATIONS

Screen:	240 x 200 extended temperature graphics STN LCD monochrome display
Size:	26.7 cm x 11.7 cm x 4.2 cm (10.5" x 4.6" x 1.65")
Weight:	0.85 kg including internal battery
Temperature:	–30°C to +65°C (–22°F to +149°F) (operating)
	–30°C to +80°C (–22°F to +176°F) (storage)
Environmental:	100% fully sealed against sand, dust and moisture, buoyant, waterproof against accidental immersion
COM ports:	Two RS232 7-pin lemo ports
Memory:	2 MB (storage), memory extension through user accessible Type II ATA PC card slot (Note E)
Batteries:	The internal Li-ion battery will last for at least 10 hours. In the field the TSC1 will draw power from the GPS receiver's power source when possible.

(footnotes)

Note A: At least 5 satellites, PDOP ≤6, signal to noise ratio ≥6, satellite elevation mask at 15 degrees.

Note B: RTCM SC-104 standard format broadcast from a Trimble reference station.

Note C: Frontlight has an operation temperature of >0°C.

Note D: 30 hours of operation is achievable without using the frontlight.

Note E: Memory extension through user-accessible Type II PC card slot. 16 MB PCMCIA Data Cards are available (33050-16).

Trimble follows a policy of continuous product improvement. Specifications are therefore subject to change without prior notice.

For further information, contact your nearest Trimble Authorized Distributor or Trimble Office. Please visit our web site at www.trimble.com

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011-44-1-256-760-148 Fax

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Singapore
011-65-348-2212
011-65-348-2232 Fax

TRIMBLE AUTHORIZED DEALER

Gasport® Gas Tester

The Gasport Gas Tester is designed for gas utility workers to detect methane and certain toxic gases. It is a reliable, simple, versatile tool to help your service technicians get the job done quickly! With multiple ranges and sensing capabilities built into one rugged housing, the Gasport Tester simplifies your work by reducing the number of meters you have to carry on the job.

Applications

The Gasport Tester's poison-tolerant methane sensor provides three measurement ranges for your daily service needs:

- Open air, safety sampling
- Small, in-home leak detection
- Street/outdoor service line leak detection

Features and Benefits

- **Proven in field use–rugged and reliable**
  Less costly to maintain, less time in repair
- **Multiple functions in one instrument**
  No need to buy, carry & maintain multiple instruments
- **New, poison-tolerant combustible gas sensor**
  Reduces meter ownership costs
- **User-selectable, "silent" operation mode**
  Reduces customer disturbances and worries
- **Fast warm up time**
  Fastest warm up time in industry saves time
- **Can monitor up to four gases at a time**
  Fewer instruments to carry
- **Show all gas concentrations simultaneously**
  Eliminates guesswork on what reading is displayed
- **Autoranging methane sensor**
  Automatically switches between 0-5% and 5-100% methane ranges
- **Gas readings recorded for later retrieval**
  Can double check readings after job is done
- **Simple manual or automated calibration options**
  Reduces training time and helps ensure accuracy
- **Intrinsically safe**
  Meets safety standards for work in hazardous areas
- **Lifetime warranty on case and electronics**
  Reduced maintenance and lifetime costs

Specifications

Gas	Range	Resolution
Methane	0–5000 ppm	50 ppm
Methane	0–100% LEL or 0–5% CH_4	1 % LEL or 0.1% CH_4
Methane	5–100% CH_4	1% CH_4
Oxygen	0–25%	0.1%
Carbon Monoxide	0–1000 ppm	1 ppm
Hydrogen Sulfide	0–100 ppm	1 ppm

Battery types:	NiCd and Alkaline
Case material:	Impact resistant, stainless-steel-fiber-filled polycarbonate
Operating temperature:	normal -10 to 40°C; extended -20 to 50°C
Operating humidity:	Continuous: 15-95% RH, non-condensing Intermittent duty: 5-95% RH, non condensing
Warm up time:	Less than 20 seconds to initial readings
Datalog capacity:	12 hours
Input:	3 clearly marked, metal domed keys
Warranty:	Case and Electronics: Lifetime Sensors and consumable parts: 1 year

The answer for gas utilities' gas detection needs

Ordering Information

Battery Chargers

Part No.	*Description*
494716	Omega 120 VAC 50/60Hz
495965	Omega 220 VAC 50/60Hz
801759	Omega 110/220 VAC, Five Unit, 50/60Hz
800525	Omega 8 - 24VDC for vehicle use

Battery Packs

Part No.	*Description*
496990	Standard NiCd Rechargeable
800526	Alkaline, Type C
711041	Alkaline, with Thumbscrews
800527	Heavy Duty NiCd Rechargeable

Sensors

Part No.	*Description*
813693	Combustible Gas
480566	O_2
812389	CO
812390	H_2S

Protective Boots

Part No.	*Description*
804955	Black, for NiCd Battery Packs
802806	Orange, for NiCd Battery Packs
806751	Black, for Alkaline Battery Packs
806750	Orange, for Alkaline Battery Packs
806749	Black, for HD NiCd Battery Packs
806748	Orange, for HD NiCd Battery Packs
812833	Yellow Soft Carrying Case with Harness
711022	Black padded Vinyl Carrying Case with Harness

Sampling Equipment

Part No.	*Description*
800332	Probe - 1 ft., plastic
800333	Probe - 3 ft., plastic
803561	Probe - 3 ft., plastic (holes 2" from end) (bar hole probe)
803962	Probe - 3 ft., plastic (holes 2" from handle) (solid probe)
803848	Probe - Hot Gas Sampler
710465	Sampling Line - 5 ft., coiled
497333	Sampling Line - 10 ft.
497334	Sampling Line - 15 ft.
497335	Sampling Line - 25 ft.

Sampling Accessories

Part No.	*Description*
801582	Replacement Filter, Probe, pkg. of 10
801291	External Filter Holder
014318	Charcoal Filter
711039	Line Scrubber Filter Holder
711059	Line Scrubber Replacement Cartridges, Box of 12
808935	Dust Filter, Pump Module
802897	Water Trap (Teflon) Filter, Pump Module

Calibration Check Equipment

Part No.	*Description*
477149	Calibration Kit Model RP with 0.25 lpm Regulator
491041	Calibration Gas - methane, 2.5%
473180	Calibration Gas - 300 ppm CO
813718	Calibration Gas - methane, 2.5% oxygen, 15%60 ppm CO
813720	Calibration Gas - methane, 2.5% oxygen, 15%300 ppm CO 10 ppm H_2S
710288	Gasmiser™ Demand Regulator 0 - 3.0 lpm

Accessories

Part No.	*Description*
804679	Data Docking Module Kit. Includes the Data Docking Module, MSA Link Software and Instruction Manual

Approvals

The Gasport Gas Tester has been designed to meet intrinsic safety testing requirements in certain hazardous atmospheres.

The Gasport Gas Tester is approved by MET (an OSHA Nationally Recognized Testing Laboratory [NRTL]) for use in Class I, Division I, Groups A, B, C, D; Class II, Division I, Groups E, F, G; and Class III Hazardous locations. Gaspor tGas Testers sold in Canada are approved by CSA for use in Class I, Division I, Groups A, B, C, and D locations.

Contact MSA at 1-800-MSA-2222 for more information or with questions regarding the status of approvals.

Gasport Gas Tester Kits

	LEL Display	O_2	CO	H_2S	Alarms Always	Alarms Optional	Leak Detect Page	Peak	Alkaline Battery	NiCd Battery	5ft Coiled Line	1ft Probe	Part No.
4-Gas, Selectable, NiCd	•	•	•	•		•	•	•		•	•	•	711489
4-Gas, Selectable, Alkaline	•	•	•	•		•	•	•	•		•	•	711490
3-Gas, Selectable, NiCd	•	•	•			•	•	•		•	•	•	711493
3-Gas, Selectable, Alkaline	•	•	•			•	•	•	•		•	•	711494
2-Gas, Selectable, NiCd	•		•			•	•	•		•	•	•	711495
2-Gas, Selectable, Alkaline	•		•			•	•	•	•		•	•	711496
4-Gas, Alarms On, NiCd	•	•	•	•	•		•	•		•	•	•	711491
4-Gas, Alarms On, Alkaline	•	•	•	•	•		•	•	•		•	•	711492

Assemble-to-Order (ATO) System: You Make the Choices

The ATO System makes it easy to "custom order" the Gasport Gas Tester, configured exactly the way you want it. You can choose from an extensive line of base instrument components and accessories. To obtain a copy of the "ATO System and Price Information for the Gasport Gas Tester," call toll-free 1-800-MSA-2222, and request Bulletin 0804-28. **To obtain a copy of the ATO via FAX, call MSA QuickLit Information Service at 1-800-672-9010. At the prompt, request QuickLit Document #2345 (ATO for Gasport Gas Tester).**

Note: This Data Sheet contains only a general description of the products shown. While uses and performance capabilties are described, under no circumstances shall the products be used by untrained or unqualified individuals and not until the product instructions including any warnings or cautions provided have been thoroughly read and understood. Only they contain the complete and detailed information concerning proper use and care of these products.

ID 08-04-27-MC / May 2000

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Phone (412) 967-3000
www.MSAnet.com

U.S. Customer Service Center
1-800-MSA-2222

MSA International
Phone (412) 967-3354
FAX (412) 967-3451

Offices and representatives worldwide
For further information:

MS3100

3-CCD Camera
1392(H) x 1040(V) Pixels

HIGH RESOLUTION 3-CCD DIGITAL MULTISPECTRAL CAMERA

High Resolution 3-Chip Digital Smart Camera Available in Multiple Spectral Configurations:

Color-Infrared
RGB
RGB/CIR
Multispectral

The MS3100 acquires three channels of crisp 1392 x 1040 images for your most demanding applications. A common aperture and acurate alignment provide true color fidelity and optimum image quality. Multispectral configuration options, smart camera features, and DirectView analog preview complete this unbeatable instrument.

FEATURES

- Color separating prism with three CCD imaging sensors
- 1392(H) x 1040(V) resolution (x3) for 4.3 Million pixels of data
- Image 3-5 spectral bands from 400-1100 nm
- Standard models for RGB, CIR, and RGB/CIR
- Custom multispectral configuration to meet your needs
- Frame rates up to 7.5 fps
- ”Smart Camera” features for advanced control and processing
- Display composite, false color, or individual color plane images
- Digital Image Output - EIA-644 or RS-422
- Compact, rugged package
- Independent gain, offset, and exposure control for each channel
- External trigger input with three operating modes
- RS-232 input for configuration and control
- Optional *DirectView* video preview via NTSC/PAL or Progressive Scan
- Optional on-board image processing
- OEM Customization Available

APPLICATIONS

- Machine Vision
  - Food Processing
  - Textiles
  - Plastics
  - Lumber
  - Pharmaceuticals
- Remote Sensing
  - Precision Agriculture
  - Environmental Assessment
  - Archaeology
  - Geology
  - Oceanography
- Reconnaissance
- Advanced Surveillance
- Medical/Scientific Imaging
- Robotics

DuncanTech
A SPECTRUM OF SOLUTIONS

3100-2-02/25/00

SPECIFICATIONS - MS3100

Image Device:	(3-ea) 1/2 inch Interline Transfer CCD
Picture Elements:	1392(H) x 1040(V)
Pixel Size:	4.65 x 4.65 micron
Pixel clock rate:	14.318 MHz Max
Sensing Area:	7.6 x 6.2 mm (1/2 inch format)
Frame Rate:	7.5 frames per second max
Digital Image Output:	8 bits x 4 taps or 10 bits x 3 taps (32 bits max). EIA644 or RS422
Signal/Noise:	60 dB
Lens Mount:	F-Mount or Canon ENG
Electronic Shutter:	Independent shutter time per channel. Range: 1/8,000 - 1/7.5 sec
Gain Selection:	Independent gain per channel. 0-36 dB
Offset Selection:	Independent offset per channel. 0-127 counts
External Trigger Input	Edge or level, Three modes
External Trigger Source:	Optically isolated BNC or Frame Grabber
Command/Control Input:	RS-232 port
Operating Temperature:	0-50 C
Operating Voltage:	12 VDC
Power Consumption:	10 Watts
Weight:	1.62 kg
Programmable Functions:	Offset, gain, exposure time, multiplexing, trigger modes, custom processing.
Options:	
Analog Video Output:	NTSC/PAL and Progressive Scan RGB (1280x1024 max display resolution)
Signal Processing	Thresholding, Ratios, Multipliers, Look up Tables, False Color Mapping, Custom Firmware Available

SPECTRAL CONFIGURATIONS

DuncanTech's multispectral cameras use a beam splitting prism and three CCD sensors to acquire images in 3-5 spectral bands within the 400-1100 nm sensitivity of the sensors. Standard configurations are available for RGB, CIR, and RGB/CIR. Custom spectral configurations are available to meet customer requirements. For more information on spectral configuration, ask for our *Spectral Configuration Guide*.

RGB RGB CONFIGURATION

Acquires separate Red, Green, and Blue image planes for outstanding color fidelity.

CIR CIR CONFIGURATION

Color Infrared imaging acquires Red, Green and Near Infrared bands approximating Landsat satellite bands. These images are mapped to the Blue, Green, and Red color planes to create false color images similar to color-infrared film for remote sensing applications.

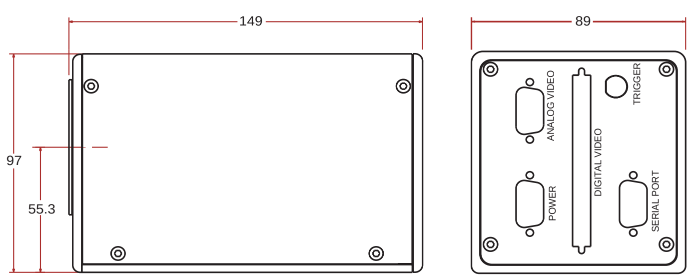
RGB CIR RGB/CIR CONFIGURATION

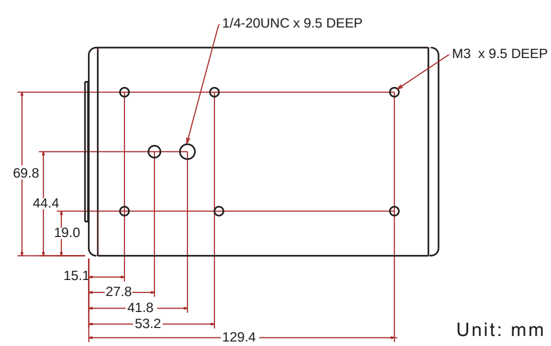
Acquires red, green, blue, and near infrared bands which can be displayed as standard color, color infrared, or single color images.

MS CUSTOM MULTISPECTRAL

Specify the wavelengths and bandwidths required for your application. This configuration is tailored to meet your needs.

DIMENSIONS





Unit: mm

DuncanTech
A SPECTRUM OF SOLUTIONS

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Email: info@duncantech.com
Web: www.duncantech.com

APPENDIX B

DCIR IMAGERY EXPERT QUALIFICATIONS

KEVIN LEE HAYES

1010 McHugh Street
Fort Collins, CO 80524
kevinlh@cnr.colostate.edu
970-472-9251 Home
970-391-4351 Cell

OBJECTIVE: Contribute to the creation, management and use of Geographic Information Systems at county and regional scales. Make it easier, faster, and more cost effective to do a good job of planning for the future, while remaining sensitive to human needs and the local ecosystem. Current interest is in Digital Infrared Photograpy for forest health assessment.

EDUCATION:

M.S. Geomatics (Geographic Information Systems and Remote Sensing), CSU
B.S. Computer Information Systems, Business Administration, CSU
A.S. Earth Science, CMC, Phi Theta Kappa, GPA 3.6
Minor: Spatial Information Management Systems, CSU
Graduate Certificate: GIS and Remote Sensing, CSU

CLASSES AND STUDIES

NR695 Team Leader for undergraduate **GIS** independent studies
NR621 Design of **Geographic Information Systems (GIS)**
ST511 Experimental Design and Data Analysis for Researchers
NR506 Applications in **GIS**
NR505 Concepts in **GIS**
NR504 Computer Processing of **Remotely Sensed Data** (2x)
NR503 **Remote Sensing and Image Interpretation**
NR440 **Land Use Planning**
NR424 **Forest Fire Management**
NR422 Applications of **GIS**
NR493/793 Seminar in **GIS** (3x)
NR322 Introduction to **GIS**
NR495 Application Project : **Global Positioning System (GPS)**
ER416 **Watershed** Management

SC442 **Forest and Range Soils**
CS200 **Algorithms and Data Structures Using C++**
CS151 Introduction to **C++ programming**
BD355 **Database Systems**
IS261 **Surveying**

OTHER EMPLOYMENT, VOLUNTEER EXPERIENCE, CLASSES

- **ARC/INFO**, **ARCView,** SML, and Arc Macro Language **(AML) Programming**
- **HTML, and Web Page Design**
- **SAS Statistical Programming**
- **Erdas Imagine**
- **Colorado State Forest Project Manager ***
- **United States Forest Service Contractor** remote sensing and GIS *
- **Larimer County GIS Contractor *** same project
- **Instructor** for CSU Lifestyles Program for 3 years
- **Red Card:** completed wildland fire crew training (1997)
- **Database** Applications in dBASE, dBASE III+, MS Access, Info
- **GPS Technician:** USFS Volunteer
- Volunteer Wilderness Ranger and other
- "**Weather Watcher**": Mountain States Weather Service
- Land Use Hydrology, Hydrogeology, Meteorology, Chemistry, Geology
- **Wilderness First Responder** (WFR, 1998), and past holder of lifesaving certificates

APPENDIX C

AERIAL IMAGERY FLIGHT ALTITUDES

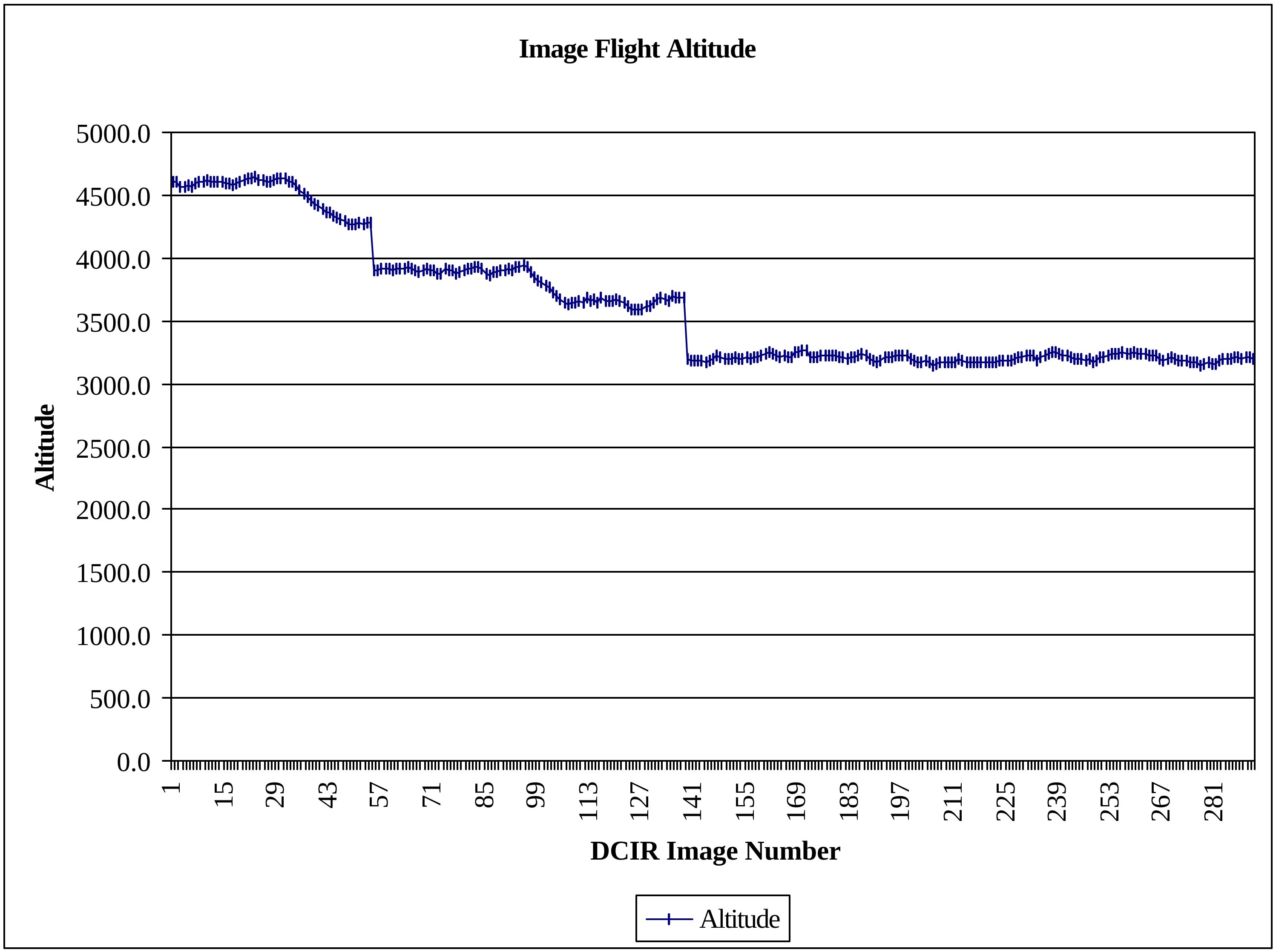

Image Flight Altitude
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4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
Altitude
1
15
29
43
57
71
85
99
113
127
141
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211
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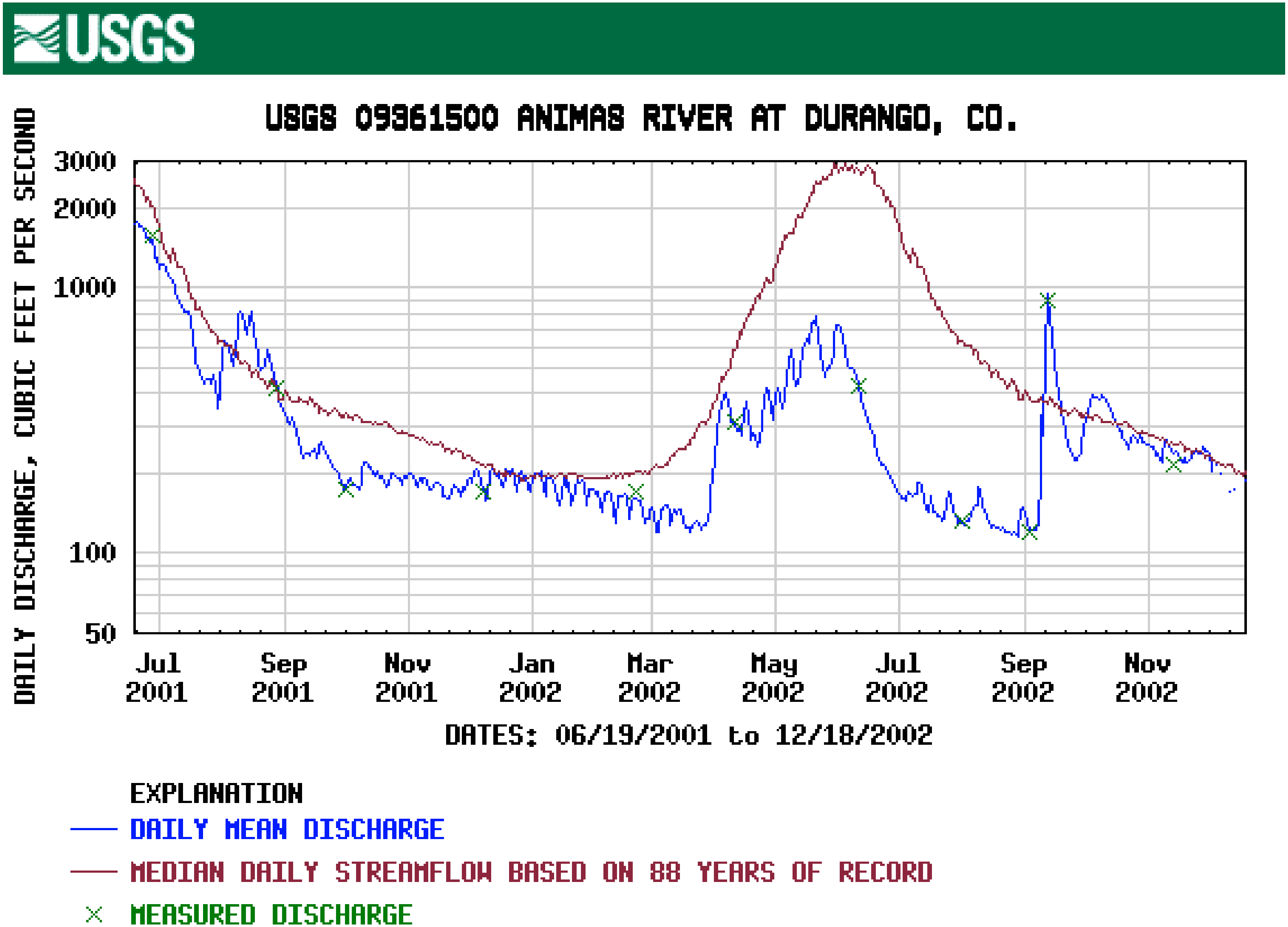
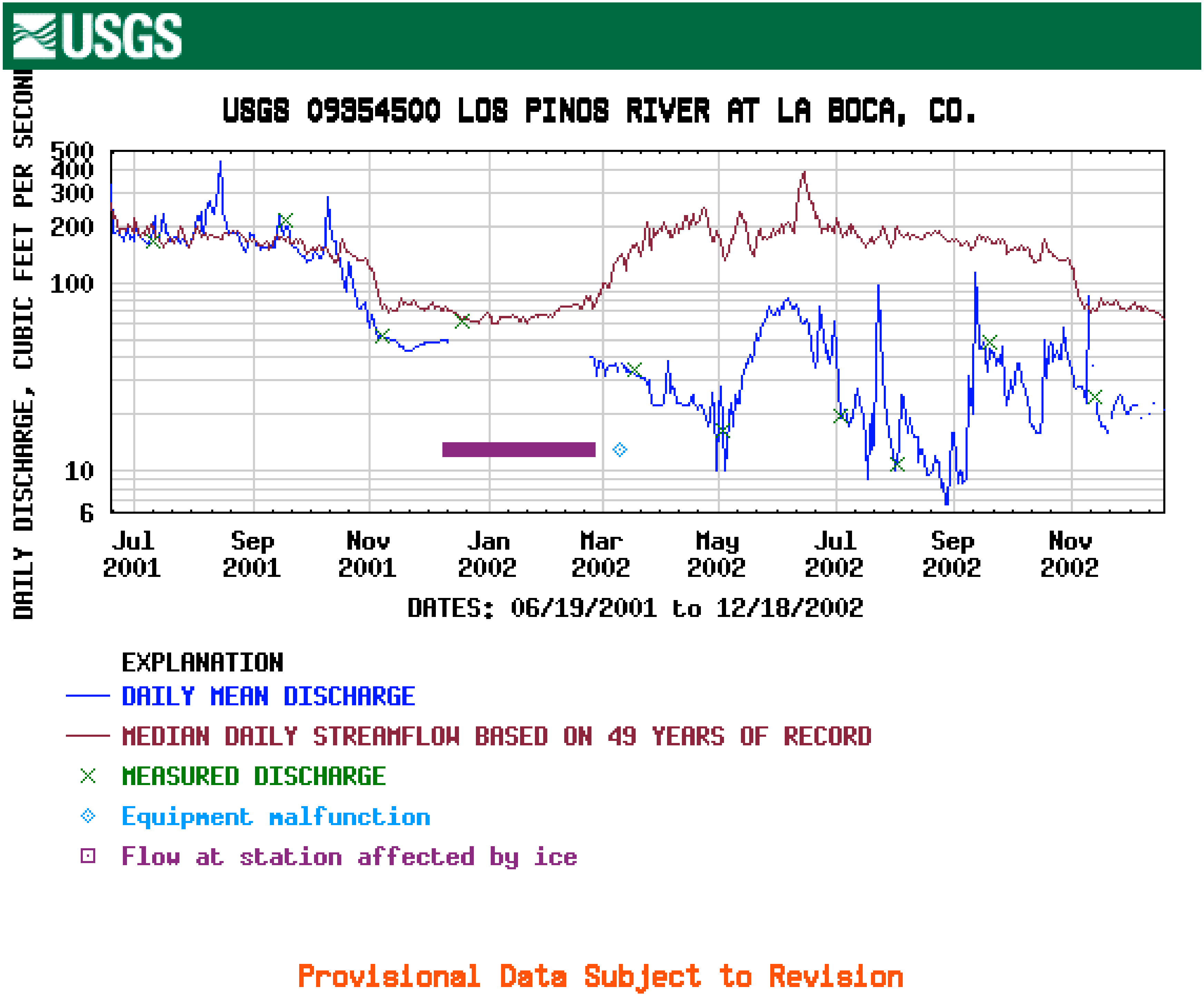
239
253
267
281
DCIR Image Number
Altitude

APPENDIX D

USGS RIVER FLOW DATA

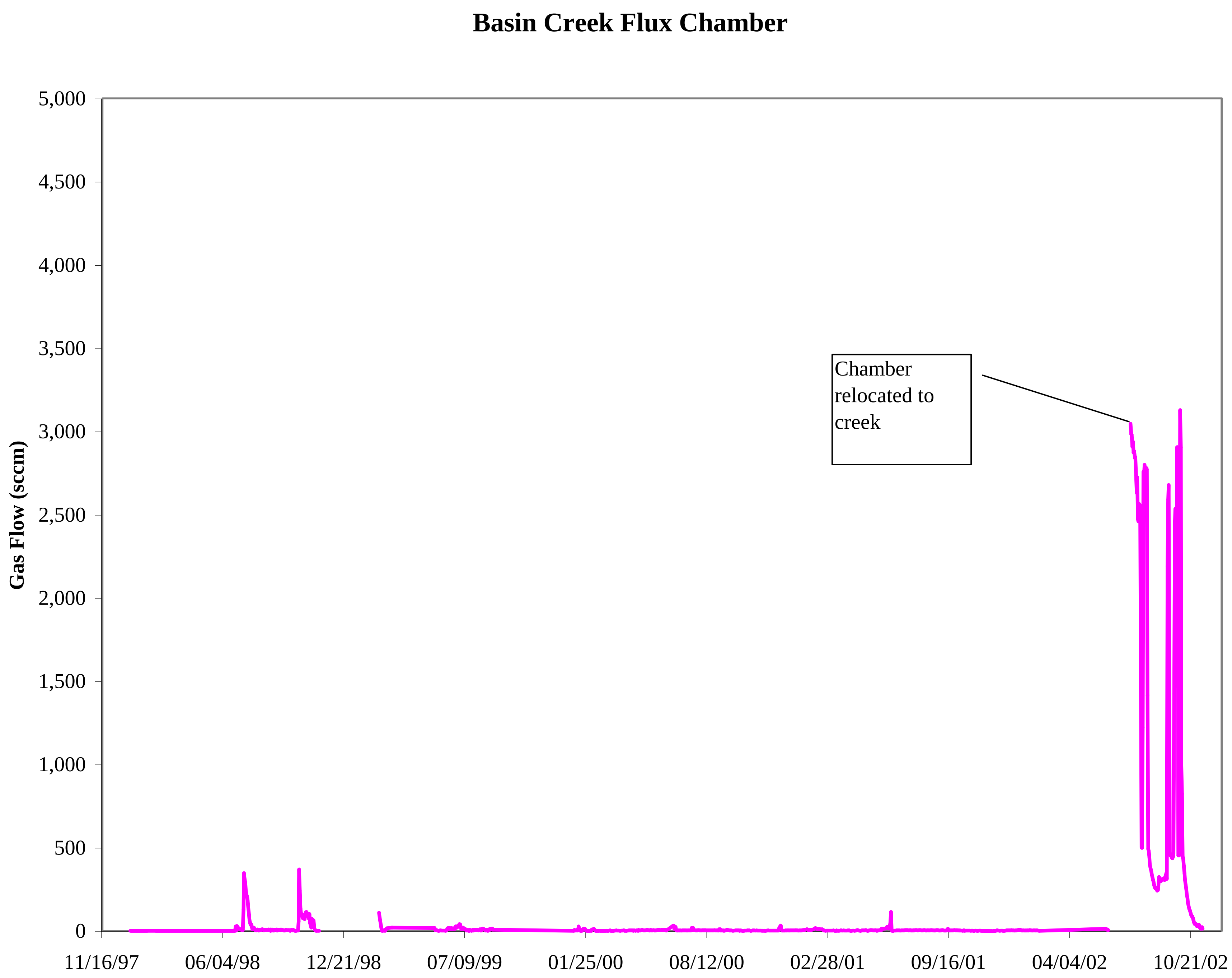


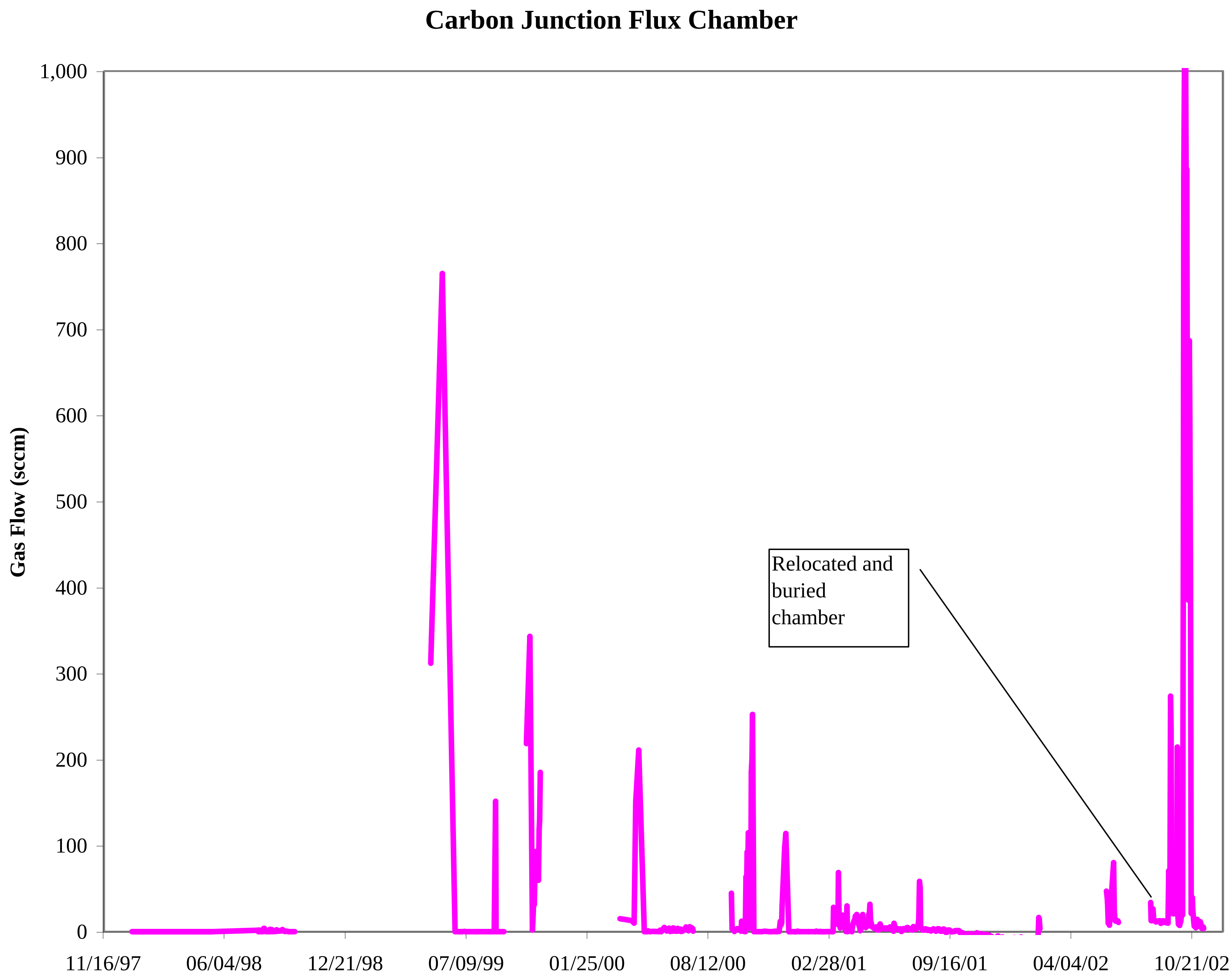
Provisional Data Subject to Revision

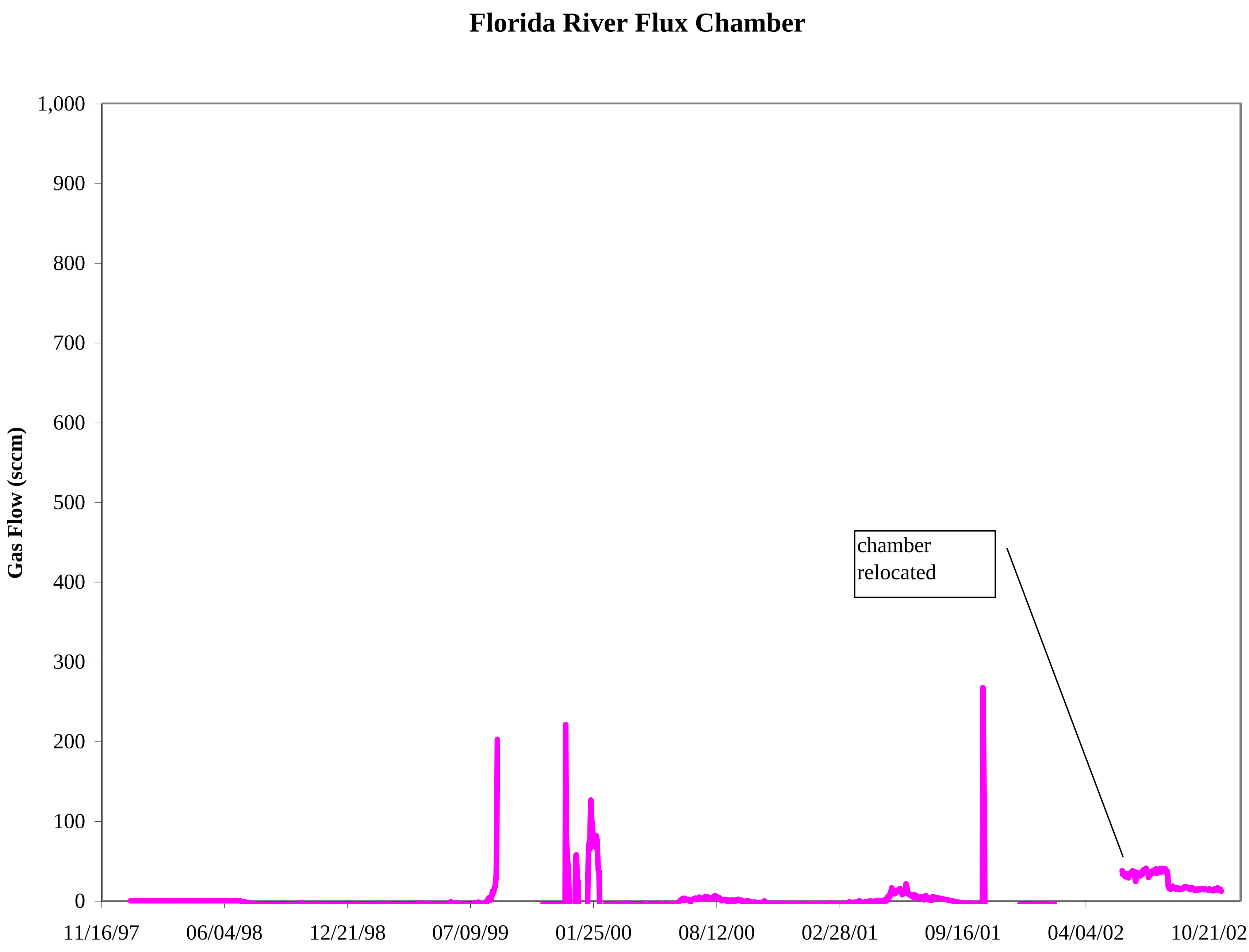

USGS
USGS 09354500 LOS PINOS RIVER AT LA BOCA, CO.
DAILY DISCHARGE, CUBIC FEET PER SECOND
500
400
300
200
100
10
6
Jul 2001
Sep 2001
Nov 2001
Jan 2002
Mar 2002
May 2002
Jul 2002
Sep 2002
Nov 2002
DATES: 06/19/2001 to 12/18/2002
EXPLANATION
DAILY MEAN DISCHARGE
MEDIAN DAILY STREAMFLOW BASED ON 49 YEARS OF RECORD
MEASURED DISCHARGE
Equipment malfunction
Flow at station affected by ice
Provisional Data Subject to Revision

APPENDIX E

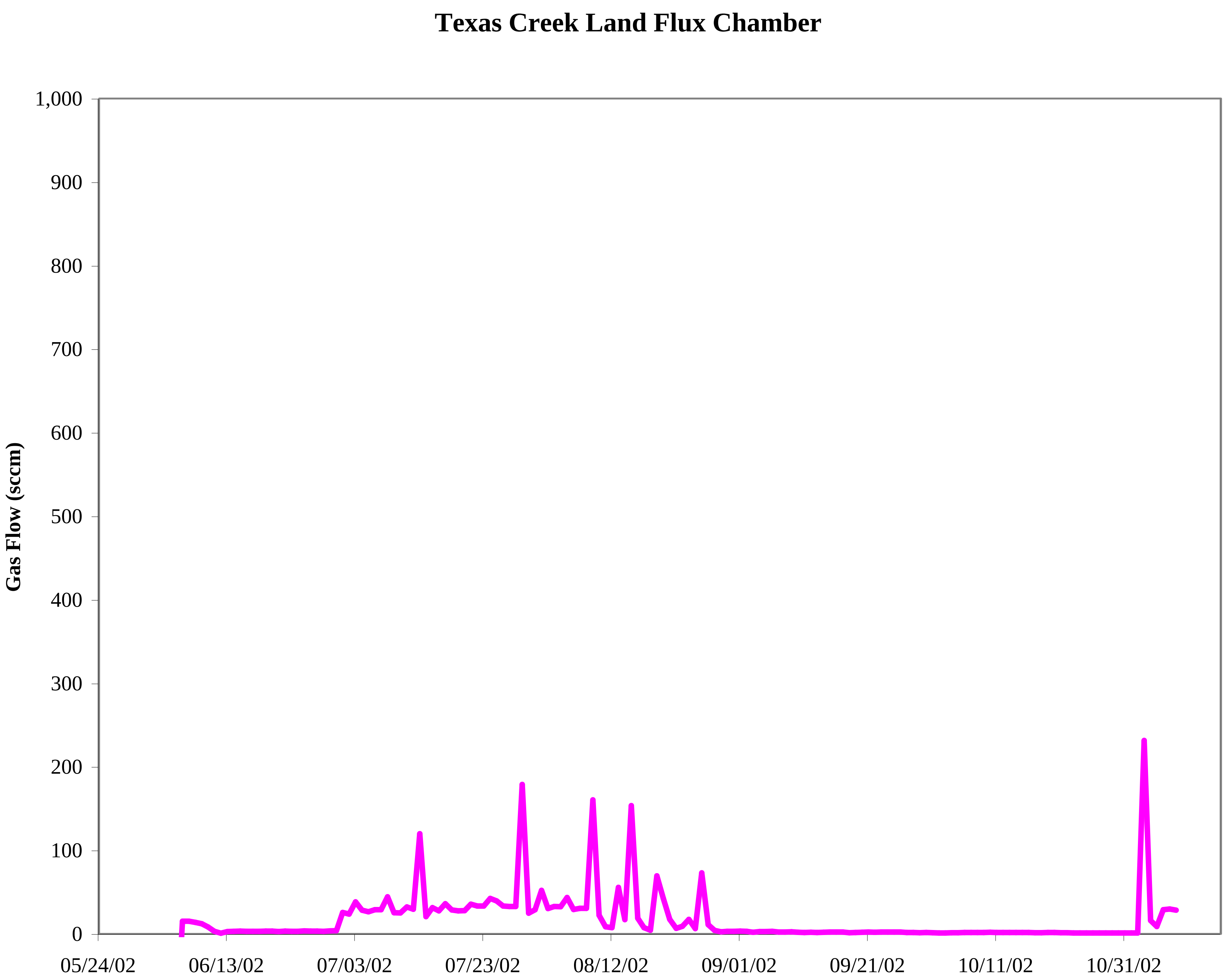
FLUX CHAMBER DATA

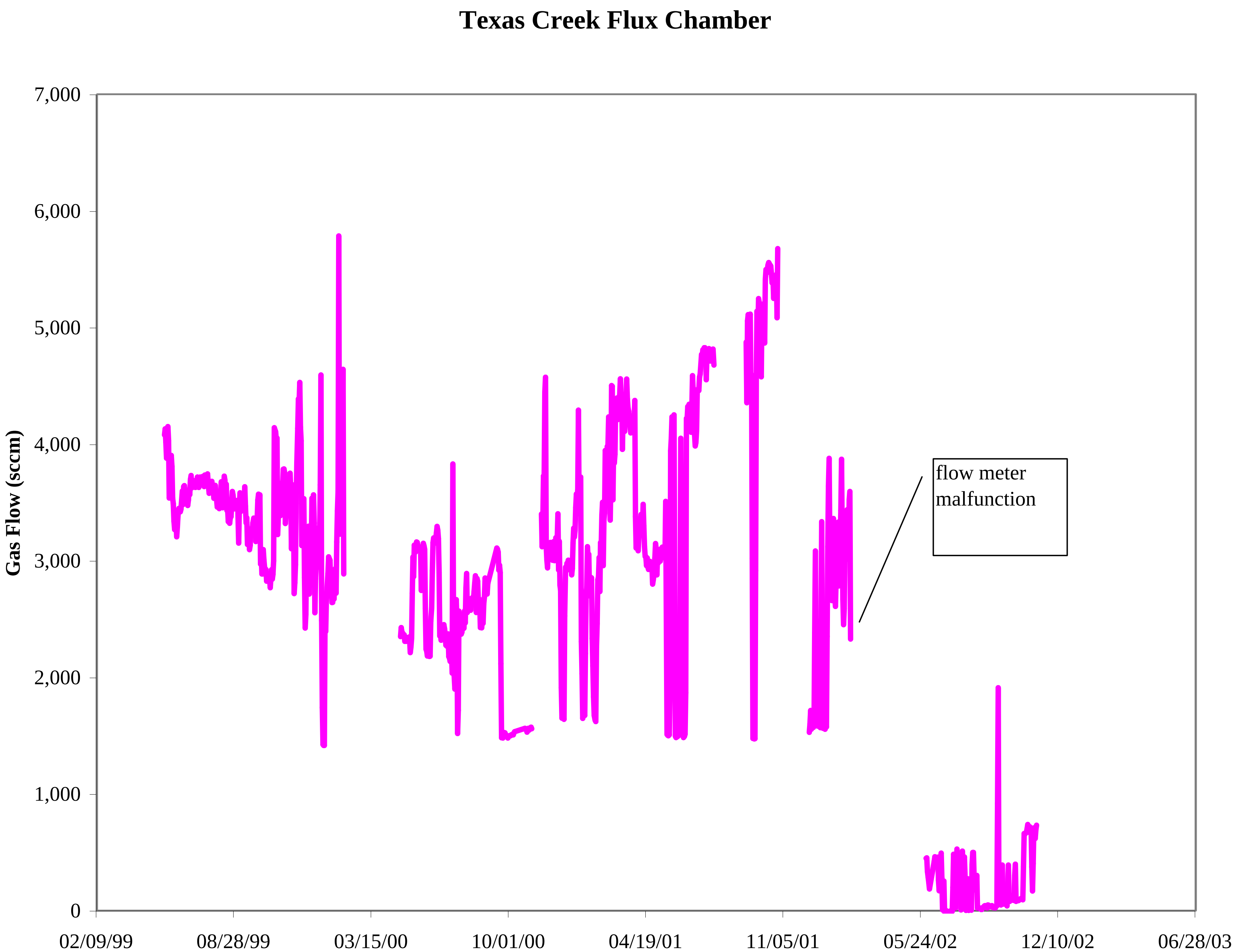

Basin Creek Flux Chamber
Gas Flow (sccm)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
11/16/97
06/04/98
12/21/98
07/09/99
01/25/00
08/12/00
02/28/01
09/16/01
04/04/02
10/21/02
Chamber relocated to creek


Carbon Junction Flux Chamber
Gas Flow (sccm)
1,000
900
800
700
600
500
400
300
200
100
0
11/16/97
06/04/98
12/21/98
07/09/99
01/25/00
08/12/00
02/28/01
09/16/01
04/04/02
10/21/02
Relocated and buried chamber

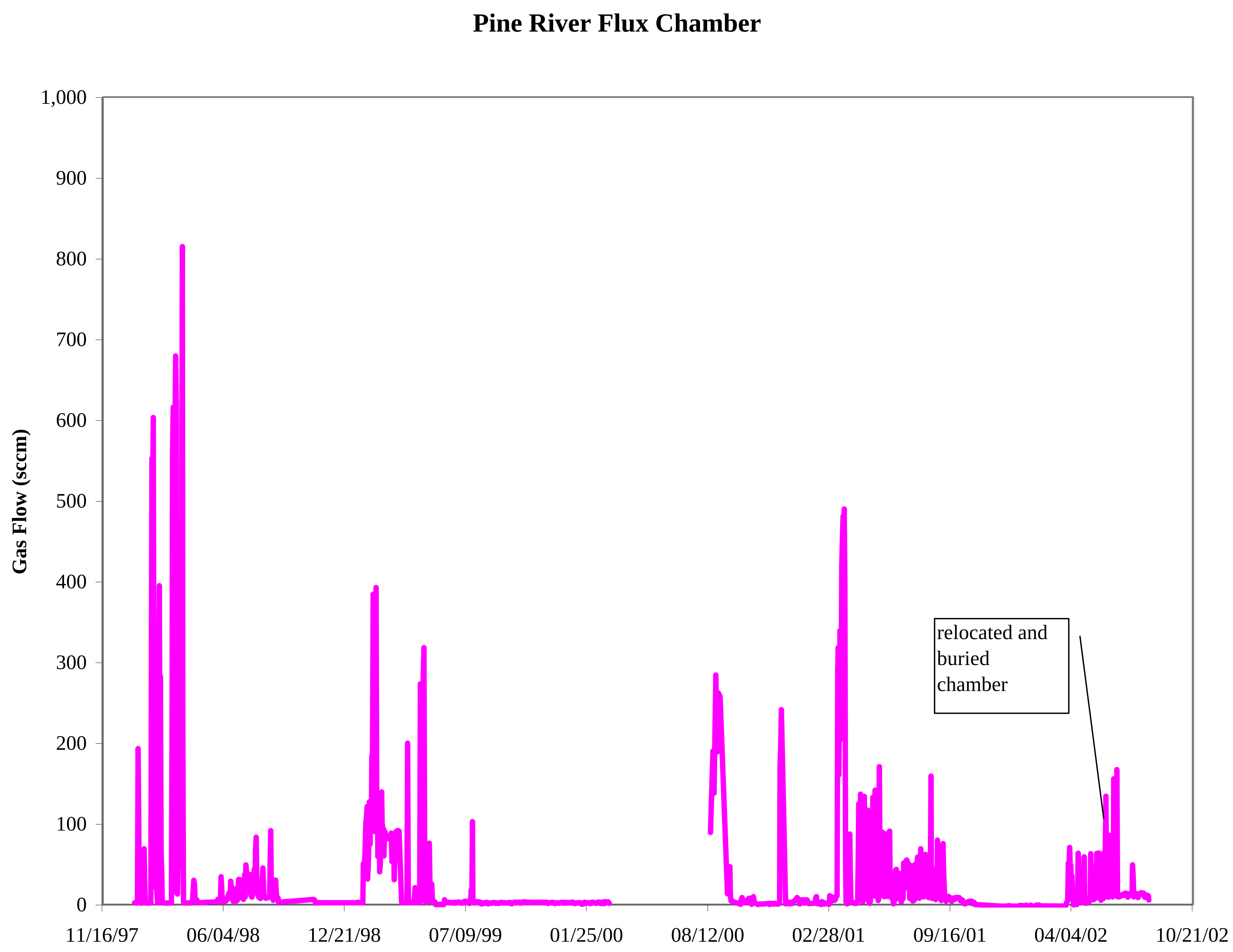


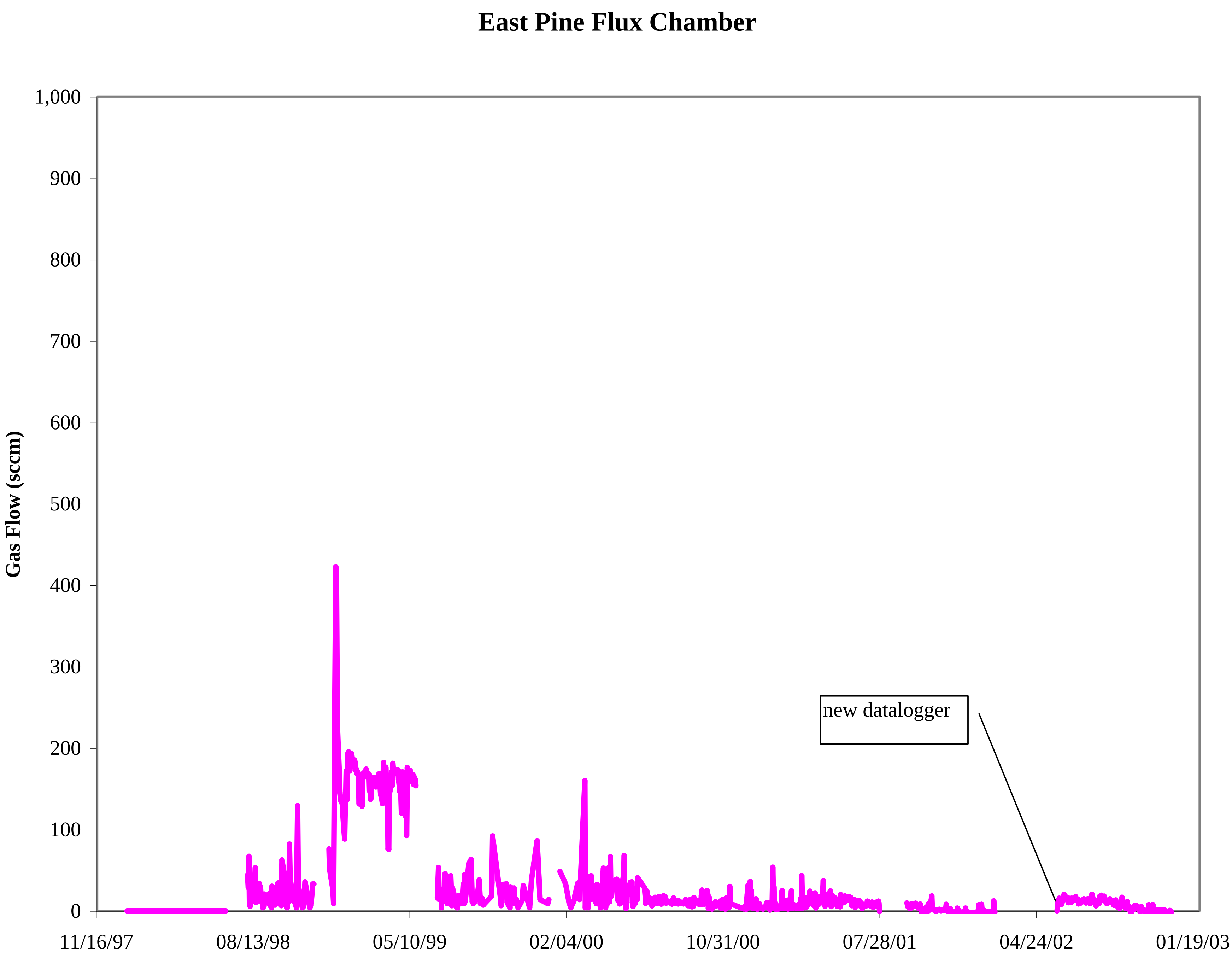
Florida River Flux Chamber
Gas Flow (sccm)
1,000
900
800
700
600
500
400
300
200
100
0
11/16/97
06/04/98
12/21/98
07/09/99
01/25/00
08/12/00
02/28/01
09/16/01
04/04/02
10/21/02
chamber relocated


Texas Creek Land Flux Chamber
Gas Flow (sccm)
1,000
900
800
700
600
500
400
300
200
100
0
05/24/02
06/13/02
07/03/02
07/23/02
08/12/02
09/01/02
09/21/02
10/11/02
10/31/02



Texas Creek Flux Chamber
Gas Flow (sccm)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
02/09/99
08/28/99
03/15/00
10/01/00
04/19/01
11/05/01
05/24/02
12/10/02
06/28/03
flow meter malfunction


Pine River Flux Chamber
Gas Flow (sccm)
1,000
900
800
700
600
500
400
300
200
100
0
11/16/97
06/04/98
12/21/98
07/09/99
01/25/00
08/12/00
02/28/01
09/16/01
04/04/02
10/21/02
relocated and buried chamber


East Pine Flux Chamber
Gas Flow (sccm)
1,000
900
800
700
600
500
400
300
200
100
0
11/16/97
08/13/98
05/10/99
02/04/00
10/31/00
07/28/01
04/24/02
01/19/03
new datalogger

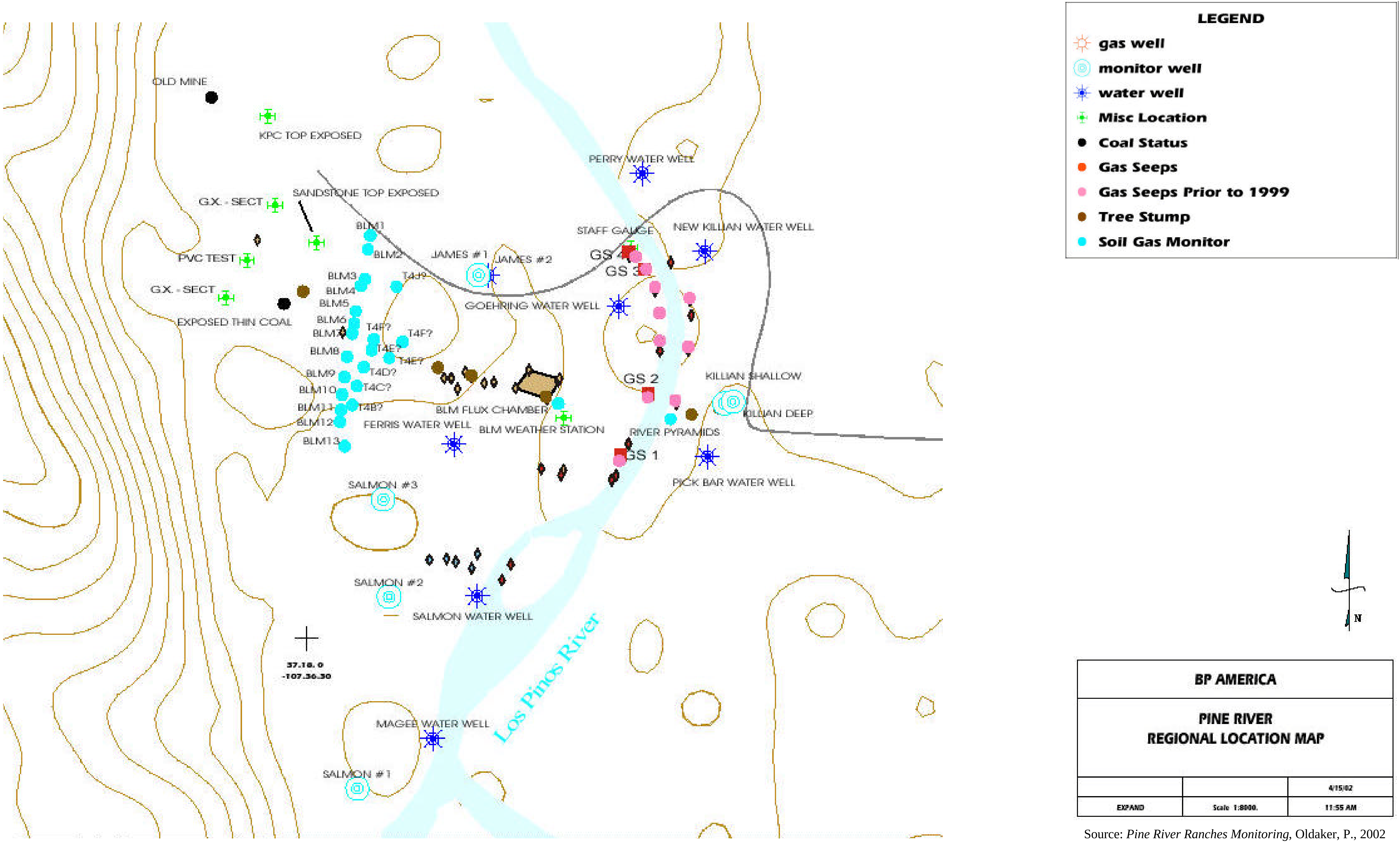
APPENDIX F

2001 TEXAS CREEK MAPPING – BP


TEXAS CREEK AREA
Source: BP Texas Creek Mapping,
Rusty Riese, 2001.
Area Extension
West Side of Creek
Aspen Tree
tree tx 13
tree tx 14
tree tx 11
tree tx 10
tree tx 15
tree tx 9
tree tx2
tree tx 3
tree tx 3
tree tx 4
tree tx 7
tree tx 8
tree tx 6
benchmark
tree tx 5b
tree tx 5a

APPENDIX G

2001 PINE RIVER MAPPING – BP



Source: *Pine River Ranches Monitoring*, Oldaker, P., 2002

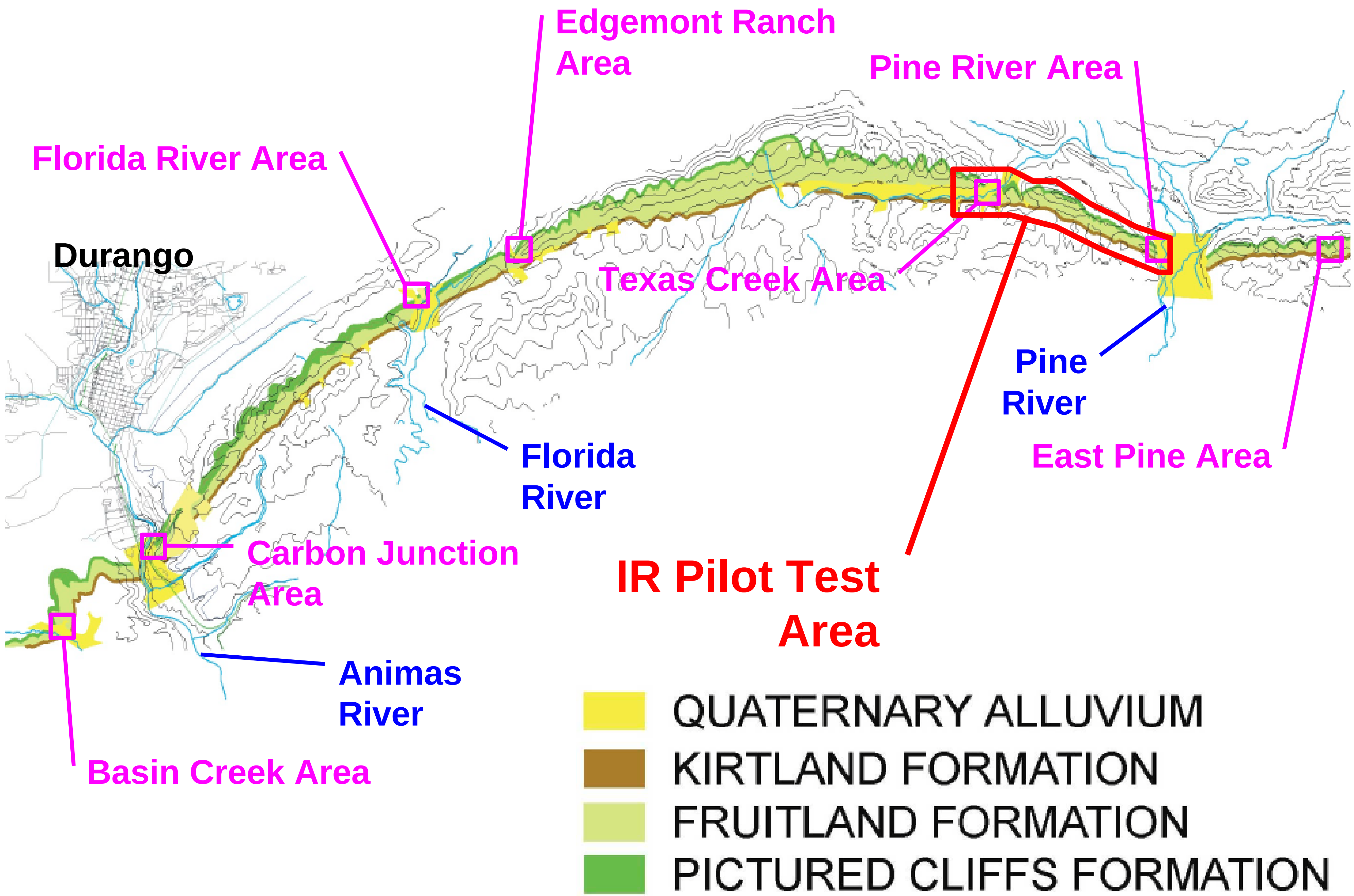
APPENDIX H

INFRARED IMAGERY MS POWERPOINT® SLIDESHOW – CD-ROM

INFRARED IMAGERY PILOT STUDY

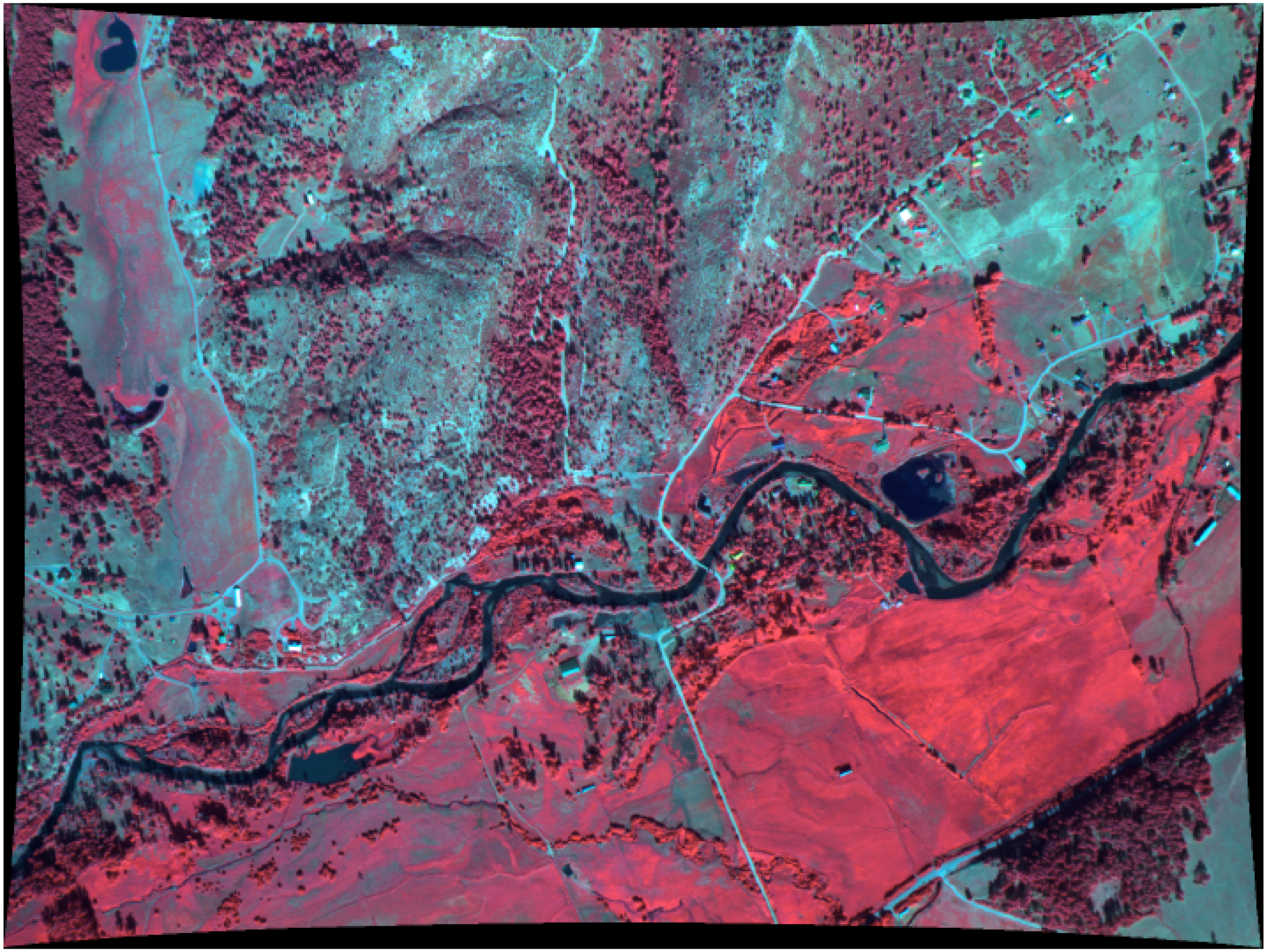
METHANE SEEP MONITORING STUDY
NORTHERN RIM OF THE SAN JUAN BASIN
LA PLATA COUNTY, COLORADO

The Study Area

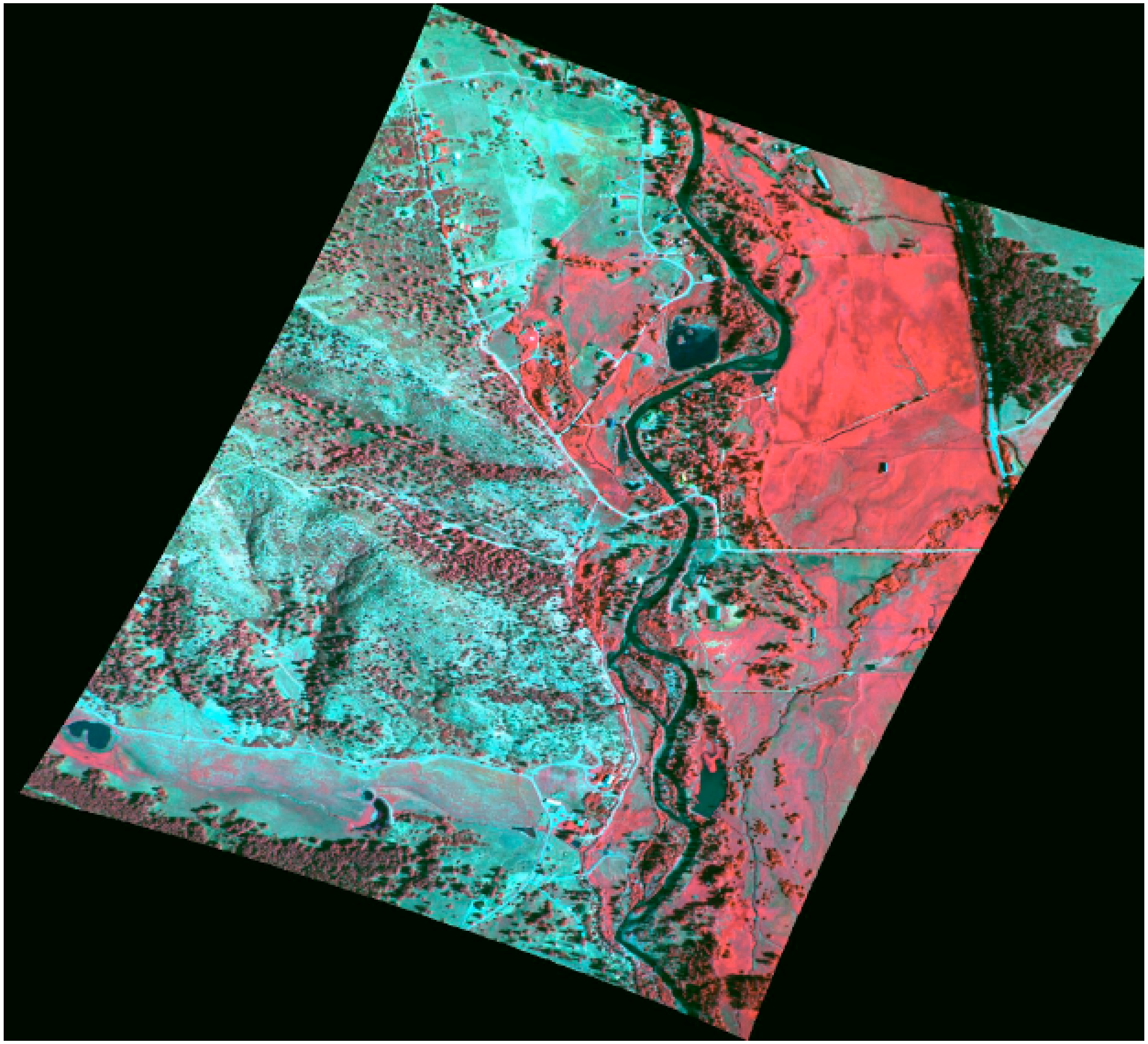


Digital Color near-InfraRed = DCIR

- Similar to conventional CIR photography, but has less spatial detail, and better spectral detail (color)
- Usually displayed in a color combination that simulates traditional CIR
- Can be analyzed with modern digital techniques, and by simple visual means
- It is described by the size of a pixel (i.e. 1.5 meter resolution)
- Similar to satellite imagery but acquired from a plane. It has distortion that must be corrected (georectification).

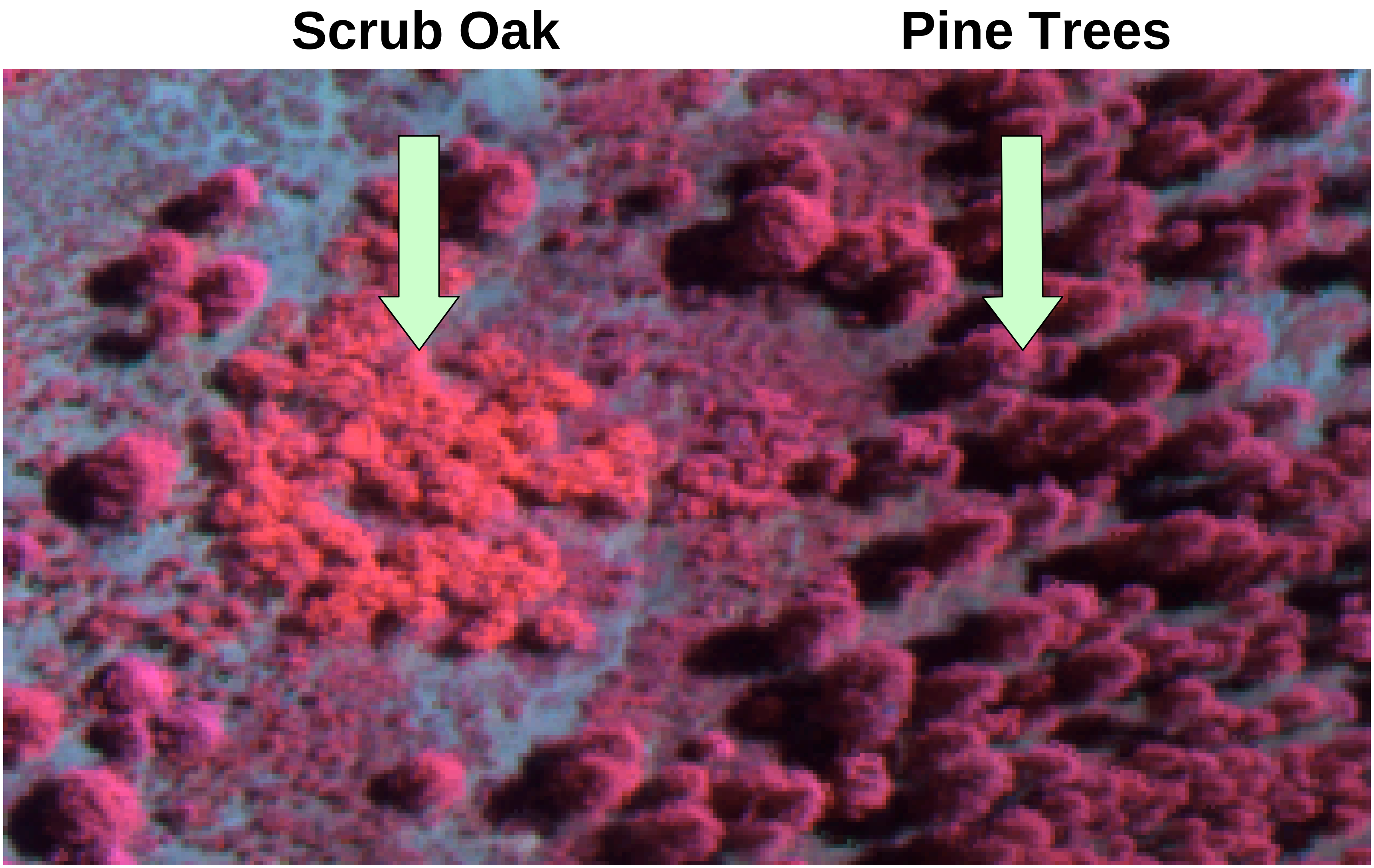


Original image is corrected for lens distortion

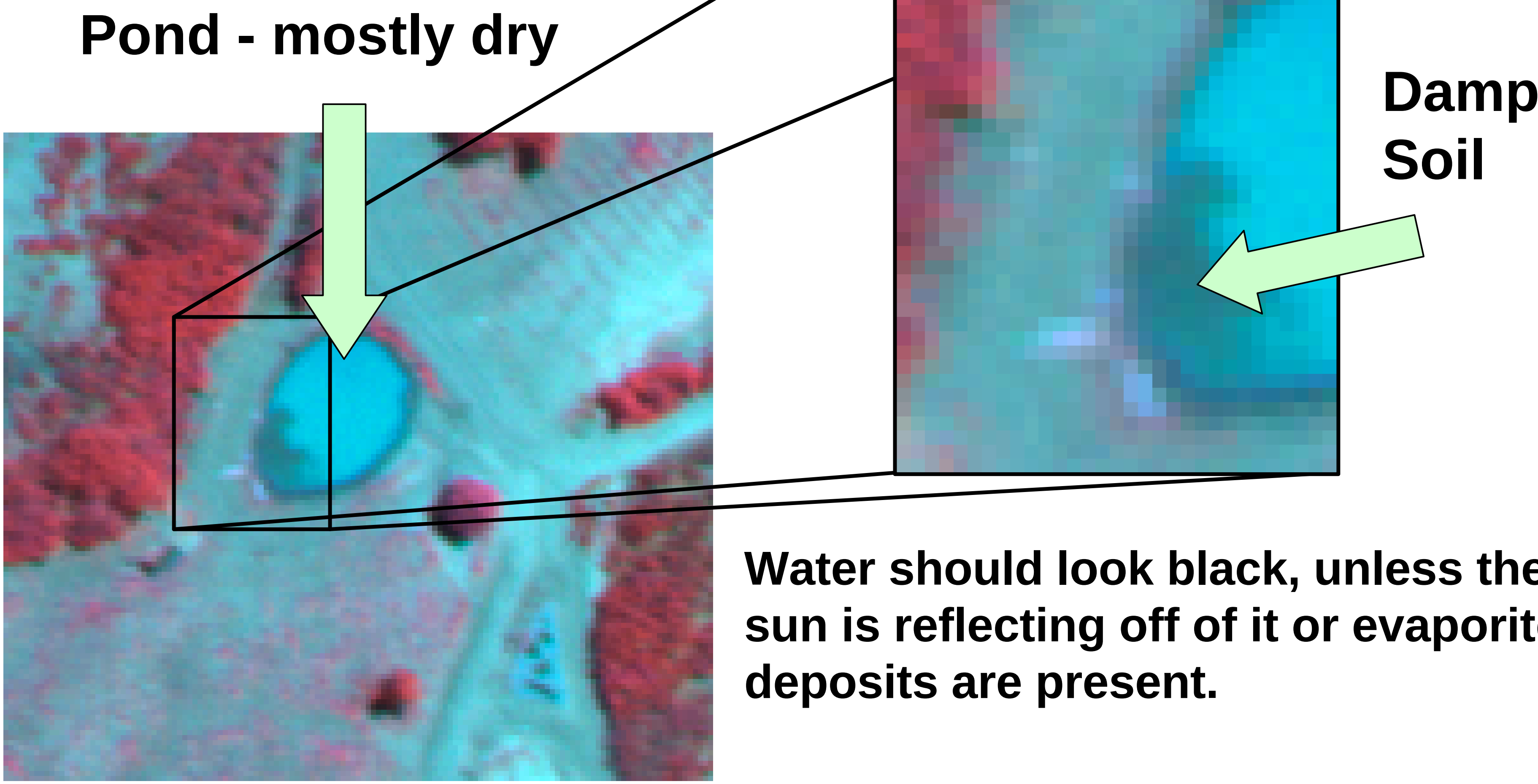


Corrected image is georectified to match a DOQQ

Examples of DCIR features

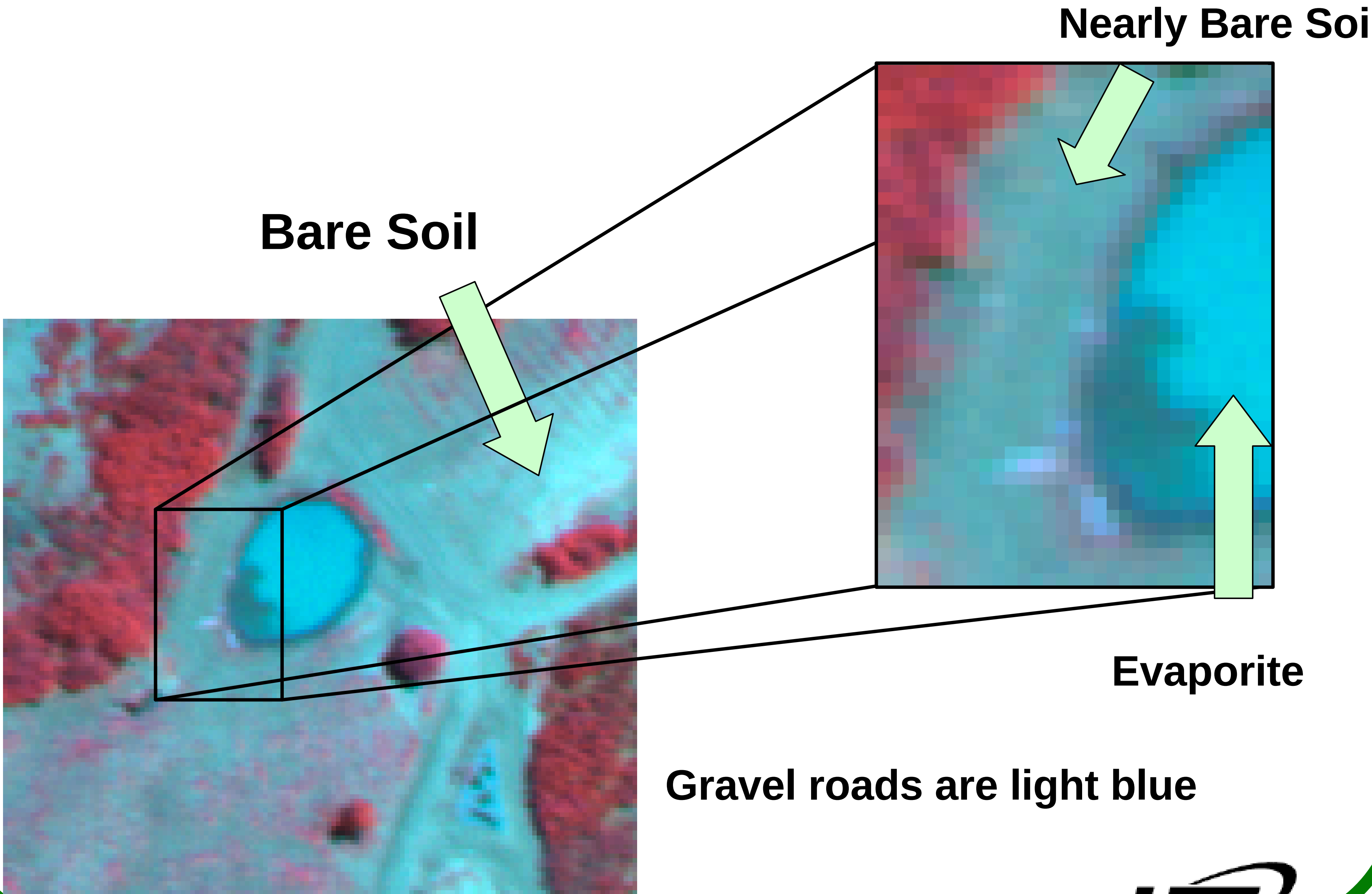


Examples of DCIR features



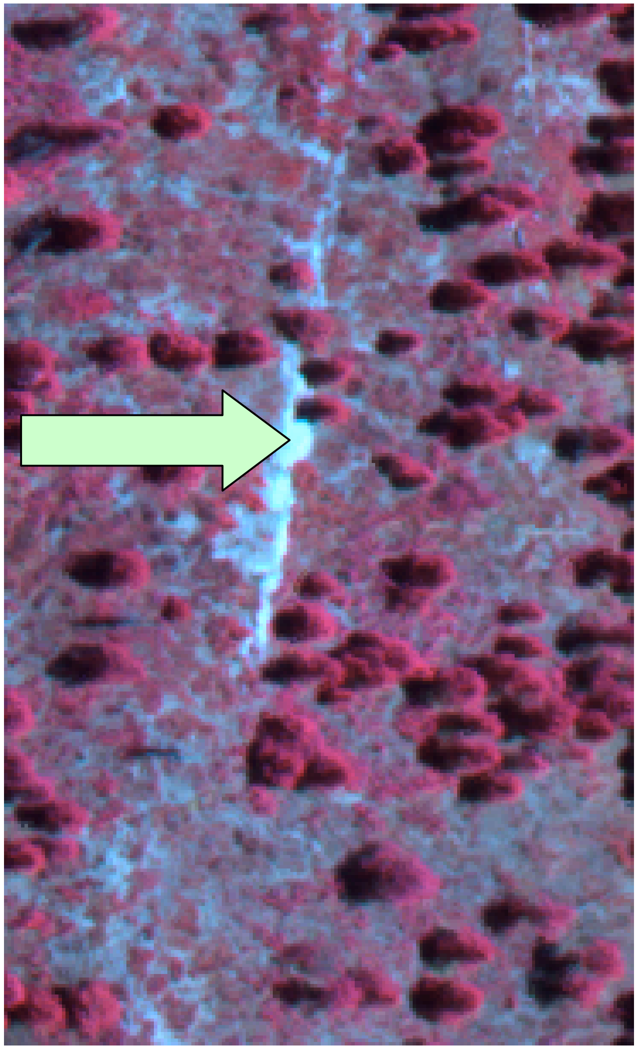
Water should look black, unless the sun is reflecting off of it or evaporite deposits are present.

Examples of DCIR features



Examples of DCIR features

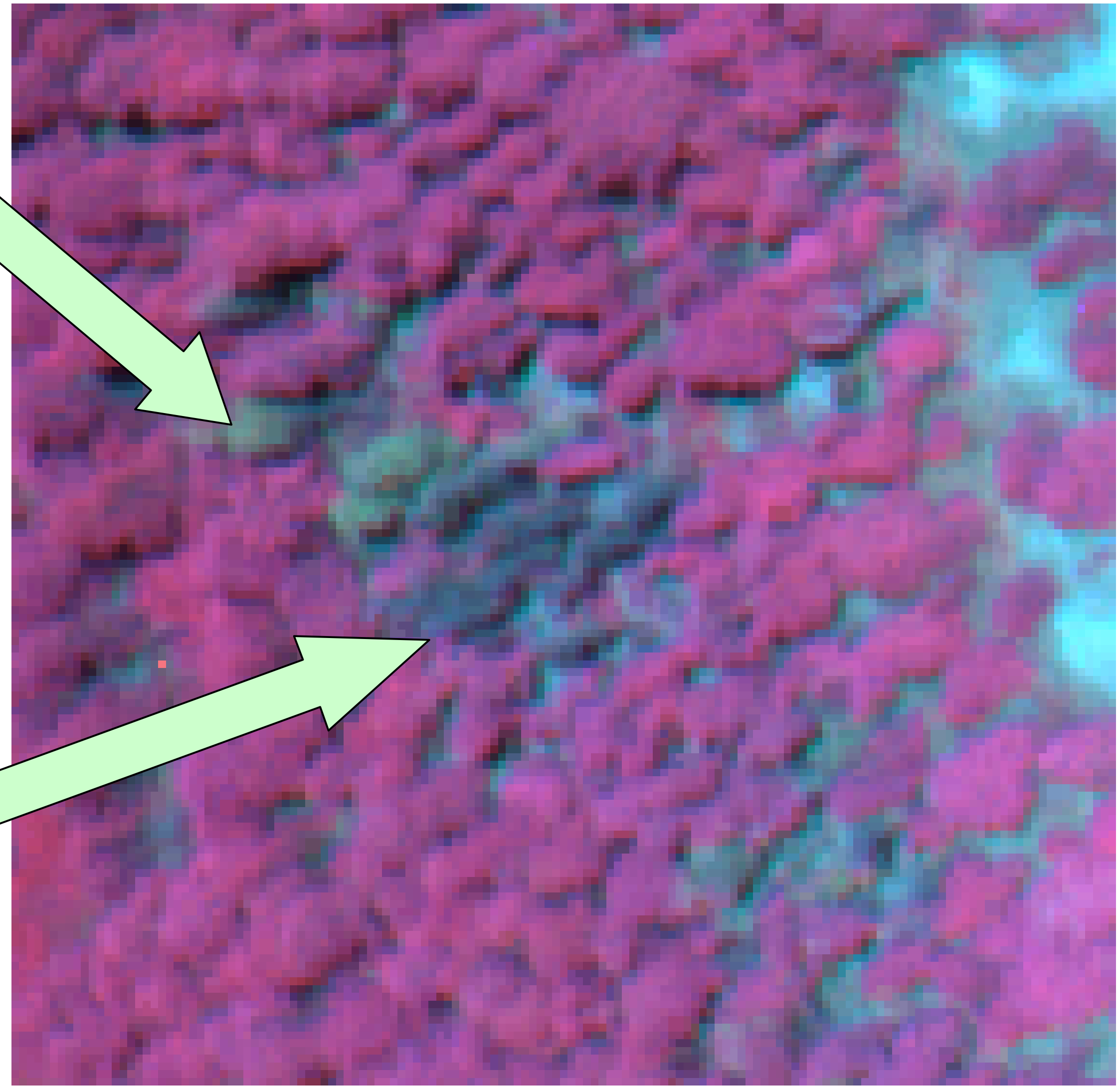
Sandstone



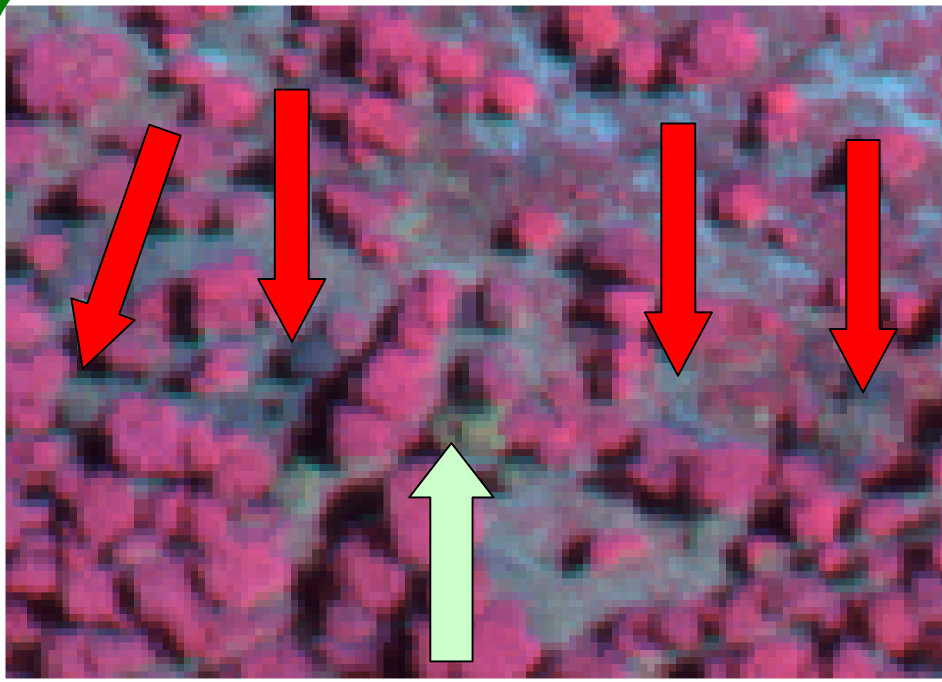
Even partial rock exposure is visible with IR imagery

Examples of DCIR features

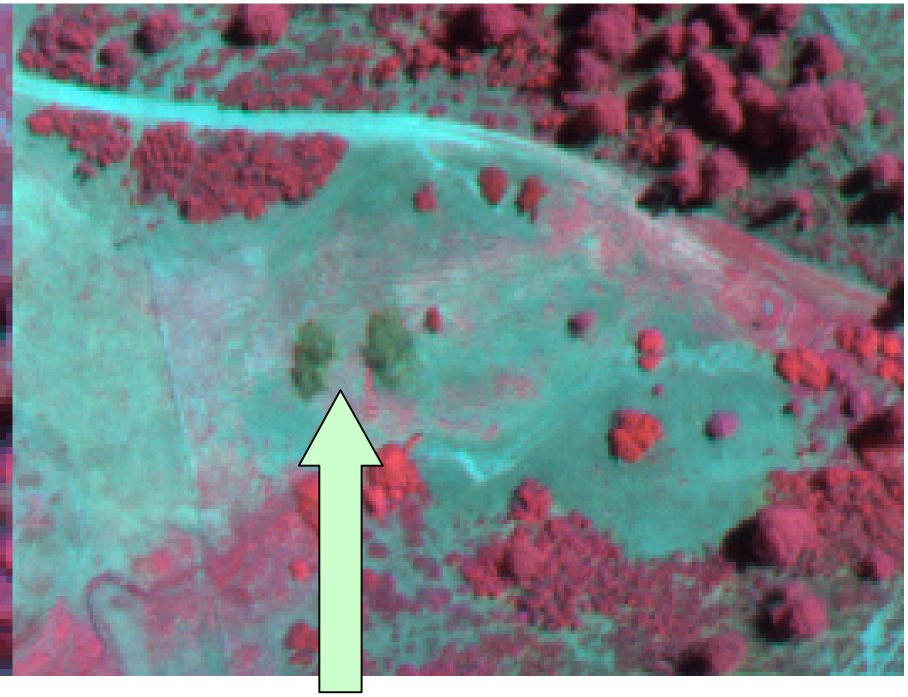
Greenish color is due to red or yellow needles on trees.



As vegetation dries and foliage falls off, the tone becomes gray. Dry wood, with no bark is very light.



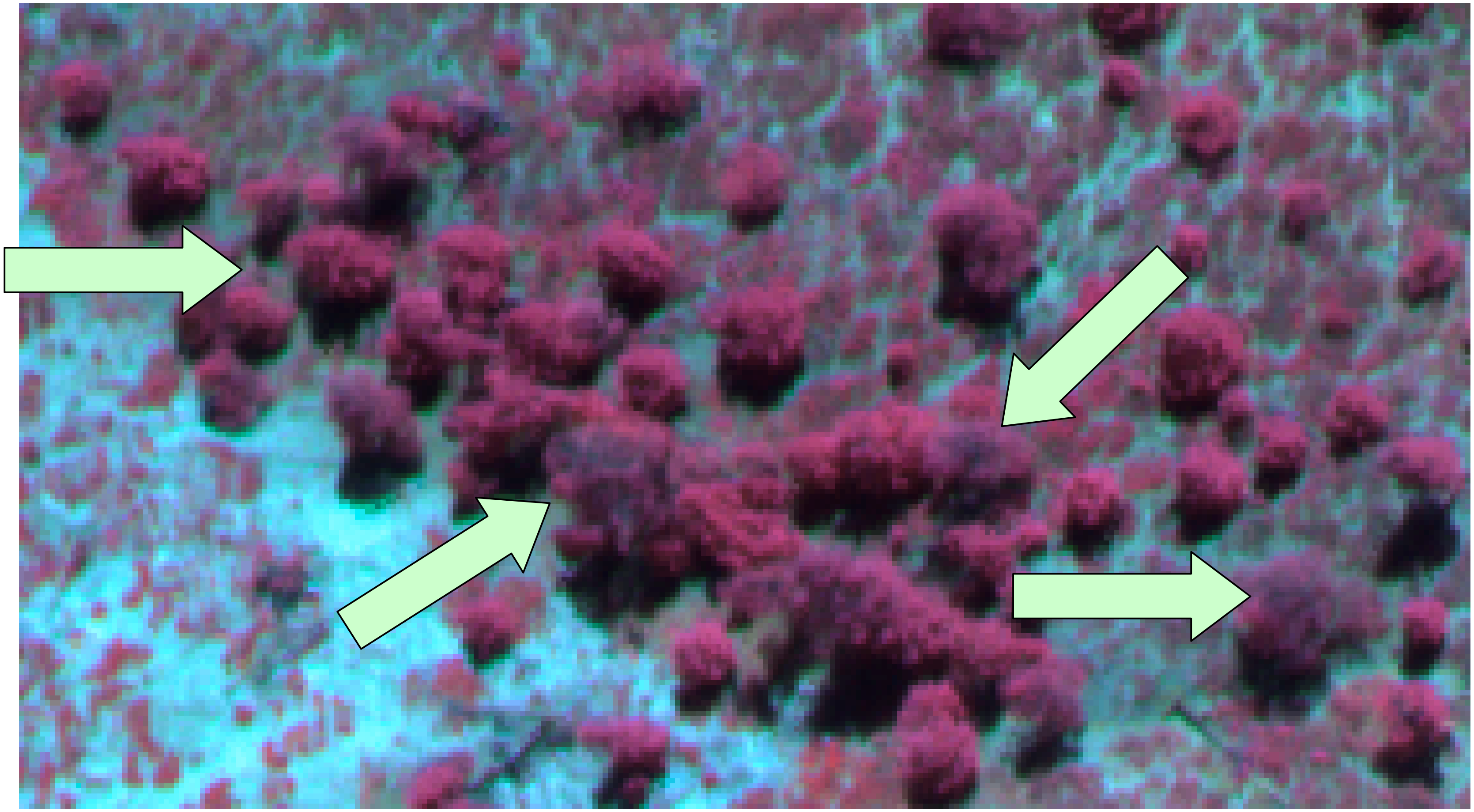
Dead tree with red or yellow needles still clinging to the crown



Large deciduous trees with yellow leaves intact

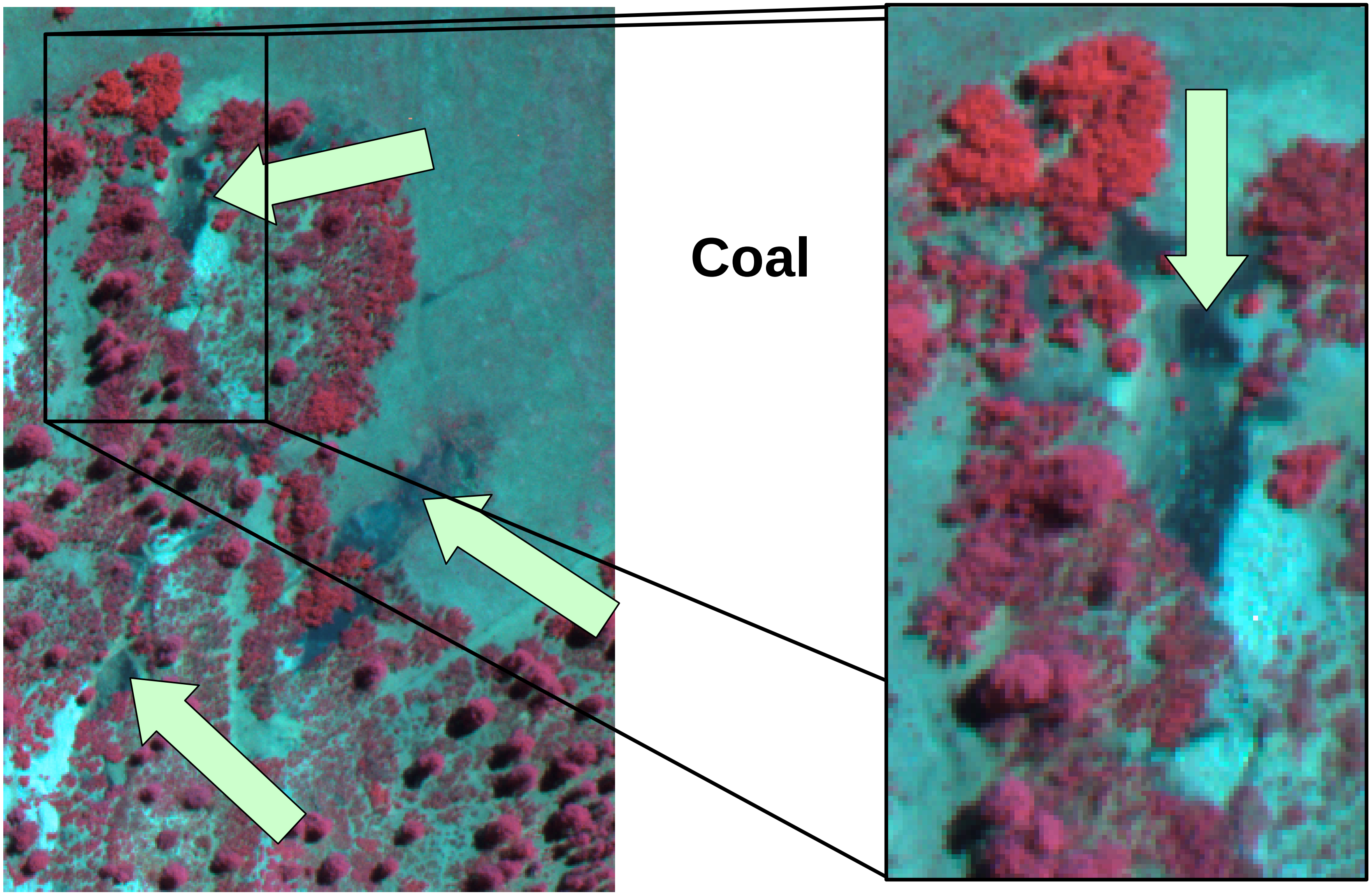
Dead vegetation with no needles or leaves is more difficult to pick out. The grayish colors are similar to shadow and soil.

Examples of DCIR features



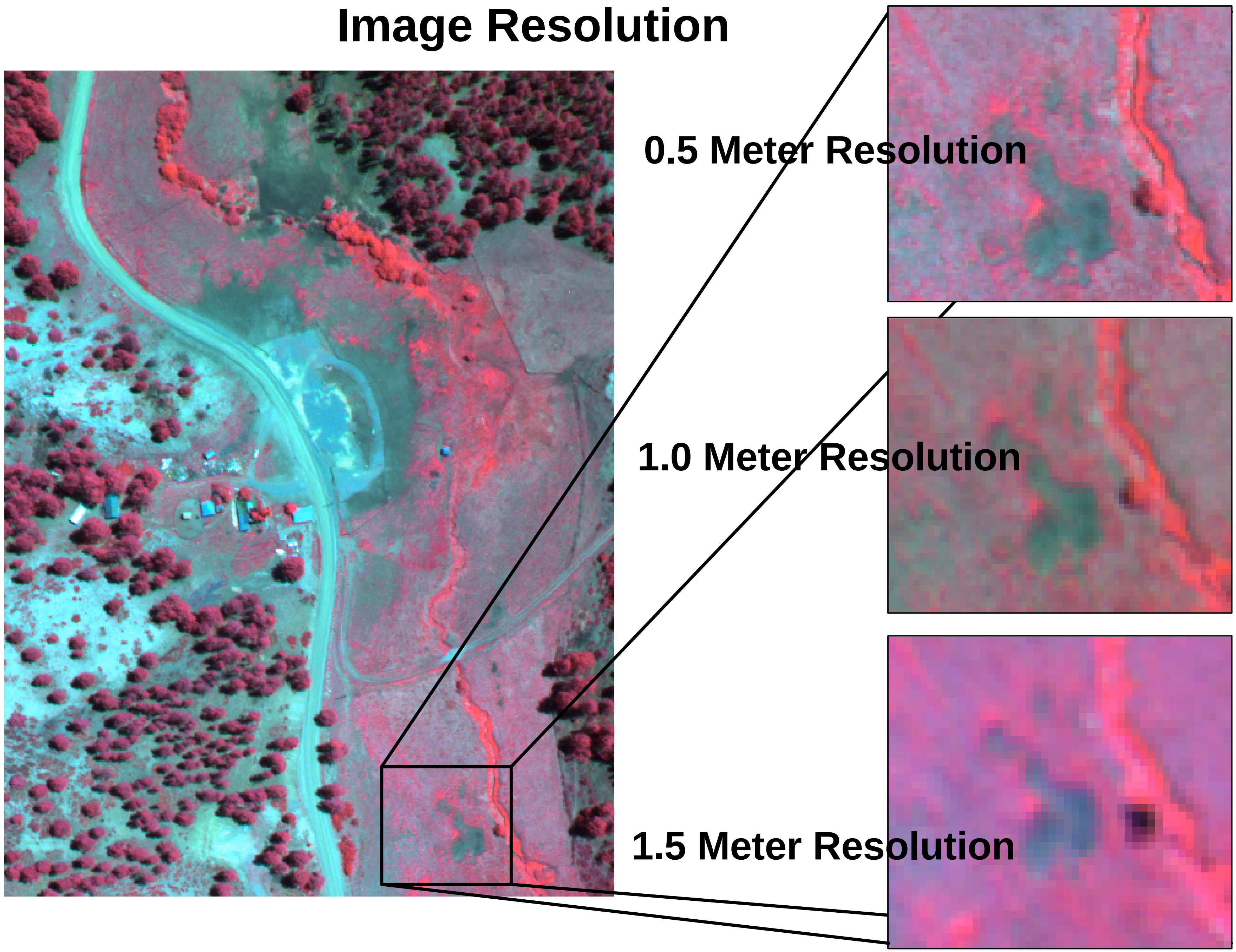
Cottonwood with dead tops and branches

Examples of DCIR features

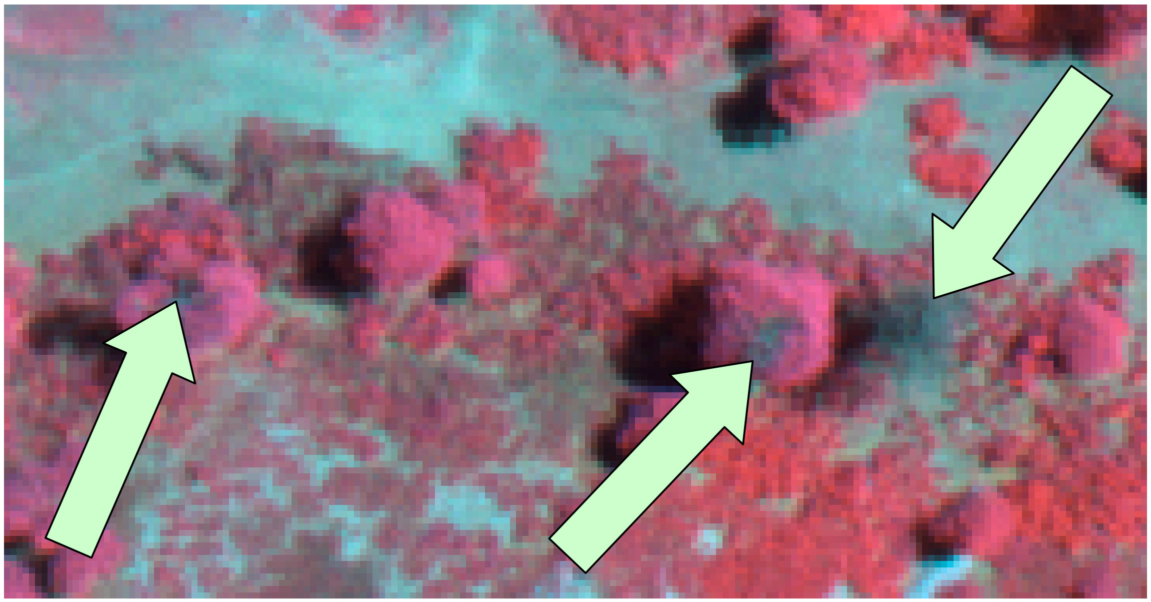


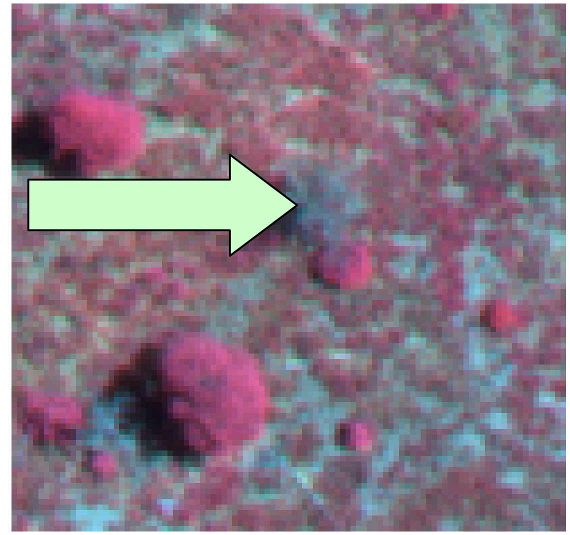
Coal

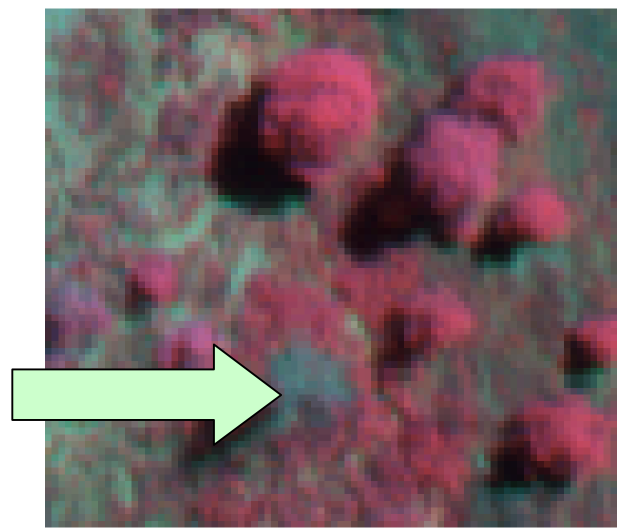
Image Resolution



Examples of DCIR features







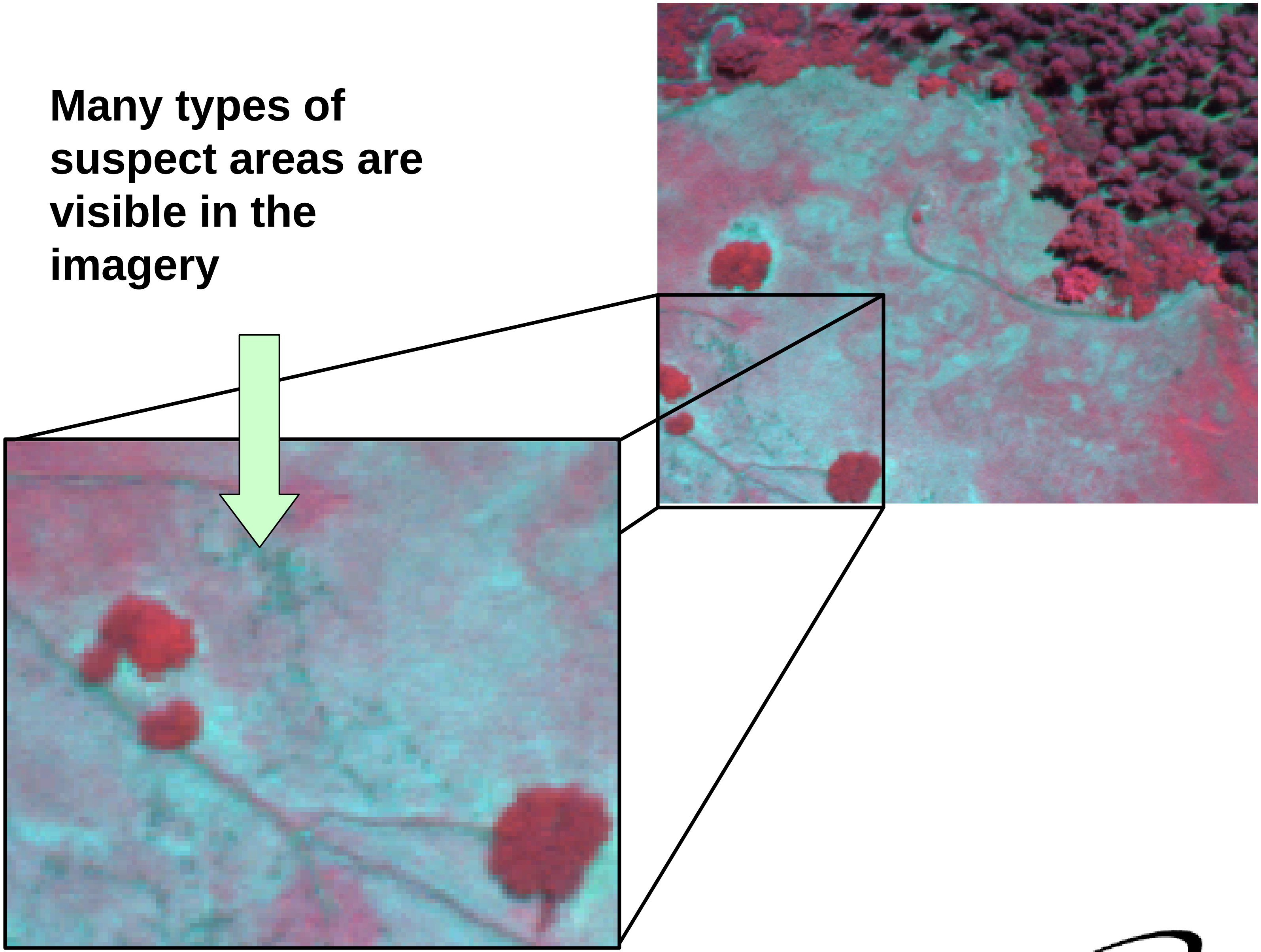
Dead branches are best seen by eye in these 0.5 meter resolution images, but can be detected with spectral analysis techniques at 1.5 meter!

Examples of DCIR features

- Deciduous vegetation, riparian areas, and lush grass are a bright red
- Gamble's oak has an orange tone
- Juniper appears pinkish
- Dry shrubs are purple/brown
- Piñon are usually a rusty red color
- Ponderosa have a feathery crown which may be an intermediate tone between juniper and piñon.
- Dry bare soil is a light blue or cyan color with darker and greenish variations due to organic matter or moist soil.
- Water is black but bluish when turbid.
- Rock is often white.

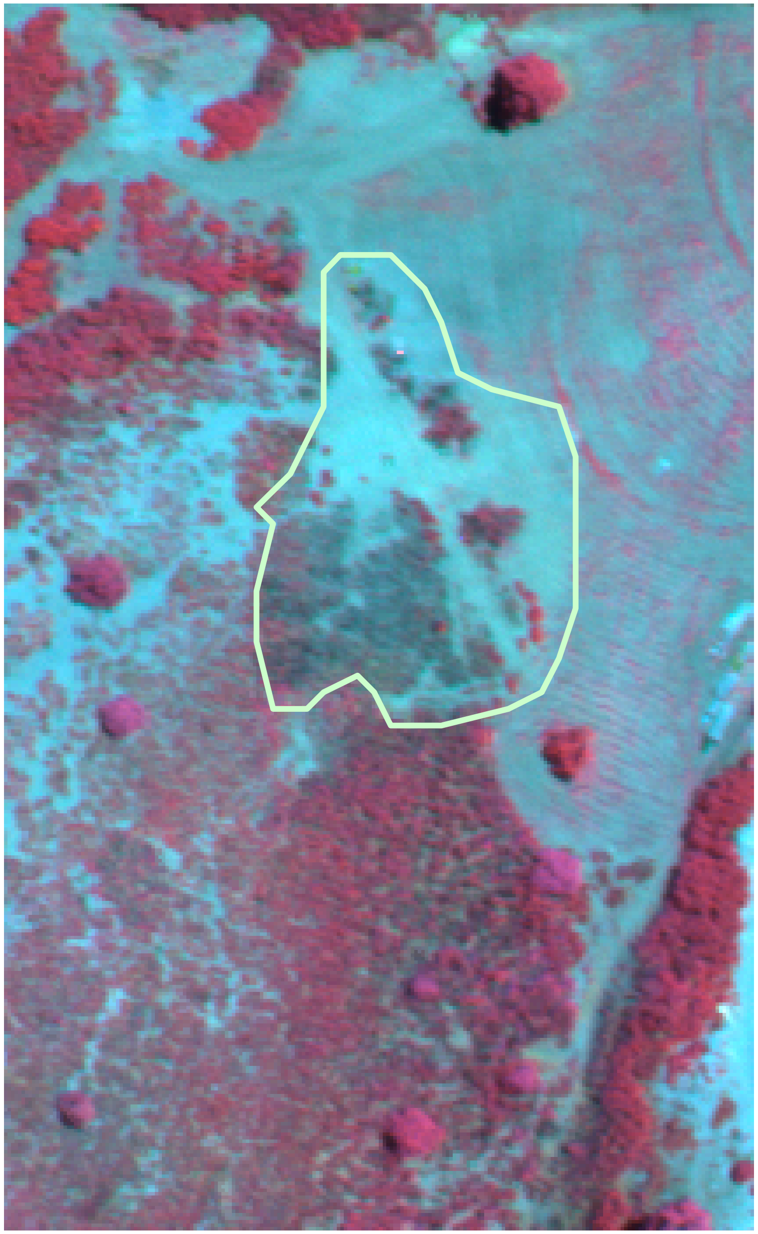
Examples of DCIR features

Many types of suspect areas are visible in the imagery



Examples of DCIR features

Suspect Areas can be faint or distinct



Examples of DCIR features

Features can be captured from the image while the image is displayed on the monitor.

These features can be overlain on the images, or used for stand-alone summary presentation.