Summary of Initial Hydrogeologic Study Results, Evaluation of Impacts from Davis Lane, and Proposed Solutions to Protect Water Sources to Goat, Maple Run, and Blowing Sink Balcones Canyonland Preserve Caves

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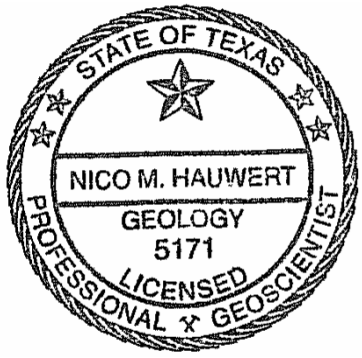
The seal appearing on this document was authorized by Nico M. Hauwert, P.G. 5171, on August 7, 2012



Disclaimer: This report is intended to evaluate the potential impacts of proposed realignment of Davis Lane and the drips in three federal permit caves based on data collected for a hydrogeological study as specified in the U.S. Fish and Wildlife Service permit held by the City of Austin and Travis County for the Balcones Canyonland Conservation Plan (BCCP). Maps and verbal descriptions in this report are intended as project overview and are not intended to serve as engineered plans. Locations and features mapped in this report are derived from project engineer plans, field observations, and other referenced sources and are not precisely located using professional surveying. Furthermore revisions may be made to improve the proposed project. This report does not include a complete assessment of sensitive features or critical environmental features in the studied area and therefore is not intended for submittal as a geological assessment of the project for regulatory approval by Texas Commission on Environmental Quality or City of Austin**.**

Executive Summary

- A realignment project for existing Davis Lane is proposed by City of Austin Public Works Dept. in the vicinity of three caves (Goat, Maple Run, and Blowing Sink Caves) on the City of Austin & Travis County Balcones Canyonland Conservation Plan permit.

- A hydrogeological study is being conducted by CoA Watershed Protection Dept. and Zara Environmental that has provided a better understanding of the water sources to the three caves.

- The Davis Lane realignment project is expected to increase the quality of the cave drips in Goat Cave, Maple Run, and Blowing Sink caves because it proposes to correct drainage problems that pre-existed before the 1996 permit that have likely degraded from increasing traffic loading and poor traffic flow on Davis Lane.

- The Davis Lane realignment project will divert runoff currently entering the West Drainage from Davis Lane that flows over the footprint of both Goat Cave and Maple Run caves and discharge that runoff to a proposed West Davis pond.

- The proposed Davis West pond and storm drain overflow pipe lie on less permeable Del Rio Clay and Georgetown Limestone. The stormwater discharge will be irrigated outside the subsurface catchments areas from the three caves or within roadway medians.

- Curbs will be installed along Davis Lane that will prevent roadway runoff from entering Blowing Sink to the south.

- Inspections will be made by Magellan Pipeline staff and trench-inspecting geologists to insure that accidental pipeline rupture will not occur during construction.

- Further water-quality sampling, tracing, and faunal surveys are recommended and planned to verify water quality improvements to the cave drips and evaluate if further steps are necessary.

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I. Introduction

Davis and Deer Lane are currently offset at Brodie Lane in South Austin. However, west of Coastal Drive, Deer Lane is known as Davis Lane. Because of increasing traffic loads and poor flow of traffic, traffic can typically be seen backing up on Deer Lane from Brodie Lane during afternoon rush hour. A proposed City of Austin project would abandon Deer Lane and realign Davis Lane so that it is connected on both sides of Brodie Lane (Figure 1). The project allows the opportunity to improve water quality controls in order to mitigate impacts to local caves and the Edwards Aquifer. The Davis Lane project involves two water quality ponds, Davis East and Davis West retention ponds that would retain the roadway runoff for irrigation. Stormwater is proposed to be irrigated primarily adjacent to the East Davis pond near Brodie Lane, on the abandoned portion of Deer Lane, and within the vegetated median of proposed Davis Lane. The Davis West pond is proposed to discharge excessive stormwater through a storm drain north into a tributary of the Kincheon branch of Williamson Creek.

The City of Austin and Travis County received a Balcones Canyonland Conservation Plan (BCCP) permit (PRT-788841) in 1996 from US Fish and Wildlife that assures that rare and listed endangered species are adequately protected through 62 cave preserves that are considered part of the Balcones Canyonland Preserve (BCP). The BCCP permit is administered by the BCP Wildlands Conservation Division of Austin Water Utility and the Travis County Natural Resources Department. The permit commits that rare species found in South Austin caves that have not yet been formally listed will be protected as if they are endangered proactively in order to prevent the need for their listing. Adequate protection of the 62 cave preserves reduces the need for separate permit applications to USFW for other sites that may have caves. Consequently the BCCP permit actually facilitates smooth infrastructure growth city wide. Cave ecosystems are also unique features of Austin that encourage local tourism and economy as described in the 1980 Austin Tomorrow Comprehensive Plan (CoA, 1980) and 2012 Imagine Austin Comprehensive Plan (CoA, 2012). Because cave species have surface dependence in their need for water, clean water sources are vital for maintaining healthy cave ecosystems. Two karst preserves, the Goat Cave and Blowing Sink karst preserves, were established in part to protect the rare cave species and three of the BCP permit caves, (Goat, Maple Run, and Blowing Sink caves; Figure 1). Both preserves are administered by the City of Austin Parks and Recreation Dept. and are dual managed by the BCP.

A hydrogeologic study is required for USFW permit PRT-788841:
"*where the surface and subsurface hydrogeologic area around a cave identified for protection is not known, the area delineated by the contour level at the bottom of the cave will be managed for cave protection. In the absence of such site specific information, no Participation Certificates are to be awarded within 0.25 miles of the cave entrance until the hydrogeologic areas are properly delineated.*"

Three of the 62 BCP caves, Goat Cave, Maple Run Cave, and Blowing Sink Cave either lie within 0.25 miles from Davis Lane or currently receive runoff from Davis Lane over their cave entrance and/or cave footprint. Since water sources are derived from higher

elevations, the elevation of the base of a cave can be used to delineate a maximum source area with little effort. Without more detailed study, the surface elevation corresponding to the lowest extent of Blowing Sink Cave (522 ft msl or 254 ft below the entrance) extends a minimum of 3 to 5 miles from the cave locations to the northeast and southeast as well as for many more miles to the west. In this case, the elevation of the bottom of the caves alone is not very helpful in defining the actual area that provides water sources to these caves.

A hydrogeologic study of Goat, Maple Run, and Blowing Sink caves is being completed as a separate report by Watershed Protection Department (WP) with assistance from Zara Environmental in order to better identify sourcewater areas to the three caves. Funding for Zara Environmental and most of the laboratory analysis and supplies is funded by City of Austin Public Works Department (PW) as part of the Davis Lane realignment project. Additional support for the study is provided by the WP under a Spill Tracing Capital Improvement Project for the purposes of simulating an accidental petroleum pipeline spill. Through the gathering of additional data in the hydrogeologic study, the surface areas contributing runoff to cave entrances (surface catchments) can be defined. The study gathers additional data in order to constrain the size of the potential source area contributing infiltration to the cave (subsurface catchment area) in order to more accurately focus on critical areas requiring greatest protection.

The scope of the hydrogeologic study includes mapping of the geologic framework, sampling of surface runoff, cave drips, and cave streams to characterize water quality and their sources, as well as three phases of injected chemical and organic tracers to delineate source areas for cave drips. The study involves identifying all significant drips and cave streams in accessible portions of the caves. The hydrogeologic study is anticipated to be completed during the fall of 2012.

Sufficient information was obtained from Phases I and II to allow an evaluation of potential impacts to the caves from Davis Lane and provide the opportunity for improvements to be made that may result in improved water quality to the caves. This report is intended to bring together geological, tracing, cave dimension, and drainage information together to help evaluate ways in which the proposed Davis Lane project might be designed to maintain or improve water quality in drips of three BCP permit caves compared to 1996 conditions when the federal permit was approved.

This report is intended for limited distribution because it shows the locations of caves in the study area, many of which are unsecured. It was deemed necessary to show the cave locations accurately on maps for the geographic association of the caves to Davis Lane so that the caves and water quality sources can be protected. The public release of cave locations may lead to trespassing and result in injury to untrained and unsupervised citizens as well as lead to damage to the caves and their ecosystem.

II. Existing Conditions

In 1985 a water-quality pond was constructed in Maple Run Section 8 (Maple Run Section 8 WQ pond) adjacent to and northeast of the Goat Cave Karst Preserve. The pond receives residential runoff from the local Maple Run subdivision as well as roadway runoff from Davis Lane along a drainage on the west side of the Goat Cave karst preserve (West Drainage, Figure 1). This West Drainage is about 1,500 feet long and flows directly over the footprint of Goat Cave. The West Drainage does not normally flow into the karst preserve except during flood conditions when flood flows over the drainage banks and flows to the entrances of Goat Cave, Wade Sink, and Hideout Sink. The West Drainage as well as storm runoff from Coastal Drive and residential areas enters the Maple Run Section 8 WQ pond that is directly north of the Goat Cave Karst Preserve.

Davis Lane/Deer Lane currently lie on the drainage divide between the Williamson Creek and Slaughter Creek watersheds. This watershed divide is the northern boundary of the federally designated sole source area for the Barton Springs Edwards Aquifer. Some roadway runoff from Davis Lane historically flows south towards the Blowing Sink tract, since curbs are currently lacking. Drainage from Davis Lane enters a number of internal drainage sinkholes including Brownlee Sink, Flat, Sunspot, and Wyoka Sinks that may be surpassed in flood conditions (Figure 2). Infiltration into these sinks likely enters Blowing Sink Cave subsurface extent through drips or its cave stream at the water table depth of about 240 feet below the surface. Blowing Sink sinkhole is also the terminal catchment for most runoff on the tract that surpasses other sinks closer to Davis Lane. Based on the hydrogeologic study results, it can be assumed that runoff south of existing Davis Lane and Deer Lanes near the project area could potentially enter Blowing Sink Cave either from the surface or subsurface (see Section III below).

Roadway runoff was characterized locally in studies including Barrett et al (1995a, 1995b, 1995c, 1995d) and Irish et al., 1995). These studies found that contaminant loading in roadway runoff was proportional to traffic loading.

During the 1950's, three petroleum pipelines were constructed across the Edwards Aquifer subparallel to Davis Lane on the Blowing Sink tract. Originally the lines were gravity drained from West Texas to the Texas coast. These lines are, from south to north, the Shell Rancho crude oil pipeline, the Phillips EZ liquid natural gas pipeline, and the Exxon crude oil pipeline (Rose, 1986). The Exxon Line was later acquired by the Longhorn Limited Liability Partnership and was converted as the Longhorn pipeline to carry refined petroleum products under pressure from the coast to West Texas. This former Exxon line is now owned by Magellan, which is currently transporting refined petroleum products. Magellan is proposing to convert to transporting crude petroleum products under high pressure later in 2012 or early 2013. The Phillips EZ natural gas line is still operating. The Shell Rancho pipeline is now owned by Kinder Morgan and is currently transporting natural gas. While the ownership, products, destination, and operation have changed over time, the lines have existing trench structures. While utility trenches can potentially influence local hydrogeology by creating conveyances or barriers, no significant physical influences from the trenches has been identified. The three pipelines have all ruptured locally in the past, invariably as a result of third party

construction activities (Rose, 1986). Of the three pipelines, only the former Exxon/Longhorn pipeline crosses Davis Lane. It is of critical importance to all three caves that this line not be compromised during construction of Davis Lane realignment.

III. Preliminary Hydrogeologic Study Results

The hydrogeologic study draws on results from previous groundwater tracing, new tracing conducted in 2012, geologic mapping, water quality analysis, and drip source characterization. While the hydrogeologic study interpretation is incorporated in this impact analysis, the supporting data will be contained within a separate hydrogeologic study report being completed by City of Austin Watershed Protection Dept. and Zara Environmental.

The method of tracing used in the hydrogeologic study utilizes both organic dyes/optical brighteners and chemical tracers to test the natural hydrogeologic connection between a surface point and a subsurface water site, in order to delineate source areas for cave drips, cave streams, and springs. Organic tracers can be monitored for continuously at a relatively low cost using charcoal or unbleached cotton receptors, depending on the tracer used. Note that dyes and particularly optical brighteners are readily sorbed by soils and require the presence of macropores. Because of their limits as soil tracers, the lack of dye detection does not indicate that water does not flow from one site to another. Chemical tracers are advantageous as soil tracers since they can move with water through soil, but are limited by means to continuously detect the tracers at sufficiently low detection limits. Typically chemical tracers are sampled using automatic samplers set at intervals such as 4 to 6 hours, which costs significantly more in lab analysis than the analysis of a few cotton or charcoal receptors for dye. To increase confidence of a result we can inject multiple tracers at the same site simultaneously, or repeat the same tracer at the same injection site after the initial pulse has passed. Tracing results can be very definitive, and the results are relatively simple to interpret. Two of three tracing phases completed have been completed by July 2012, with the final phase being primarily intended as verification of earlier traces.

In May 2010, a dye injected into Wildflower Cave by WP was recovered by BCP staff in Blowing Sink Cave, establishing that the source of recharge to Blowing Sink Cave extended at least a mile to the west (Figure 12). Phase 1 injections and intensive monitoring began on January 23, 2012. Phase II injections occurred in conjunction with rain events on February 3 and 18, 2012. The geological mapping, cross sections, and tracing results are illustrated in Figures 3, 4, and 5.

For Phase I organic tracers were injected in association with a January 25, 2012 storm, essentially over the subsurface footprint of Goat Cave, Maple Run Cave, and Blowing Sink Cave, while background chemical quality was being monitored. Three pounds of an organic optical brightener, tinopal, was poured into the drainage swale over Goat Cave on the evening prior to a Jan. 25, 2012 storm. Tinopal was subsequently detected in the entrance drip of Goat Cave, demonstrating that runoff in the swale does infiltrate through soils into the cave below. On the evening prior to the Jan. 25, 2012 storm, five pounds of

pyranine was also poured into an orifice into the soil at Winter Woods Sink, which approximately lies over the Main Pit in Blowing Sink Cave. Note these two caves have not yet been physically connected to each other by human exploration. Pyranine was detected in three monitored sites in the cave stream of Blowing Sink, arriving sometime within 8 days (the first time after injection that the receptor was recovered). Pyranine was also detected at Main Barton, Eliza, and Old Mill Springs 17 to 18 days after the storm which initially flushed the dye.

Phase II chemical tracers injected in Hideout Cave and Wade Sink in the Goat Cave karst preserve on February 4, 2012 at 2:30 am. Chemical tracers from both injections were recovered in the Balcony Drip of Blowing Sink Cave, a vadose drip roughly a hundred feet above the water table, four days after injection (Figures 5, 10, and 11). Tracer breakthroughs and observations of water flowing down the sides of Main Pit in Blowing Sink Cave suggests that vadose flows are perched on the less permeable 15-feet thick Regional Dense Member and flow 3,000 feet south toward Blowing Sink where the RDM is breached by a pit, allowing the perched water to descend downward at a relatively high gradient to the water table (Figure 5). The RDM is part of the Edwards Group, but contains a significant amount of clay that restricts downward movement, except at breaches of the RDM (Hauwert, 2009). Breaches through the RDM can be observed in a few other caves along Davis Lane, including Maple Run, Sendero Oaks Cave, Wyoka, Sink-in-the-Woods, and Sinky Dinky. On February 18, 2012 at 2:00 am, an optical brightner tracer, Direct Yellow 96, was poured into Sunspot Cave northwest of Blowing Sink near the west edge of the Blowing Sink tract. The tracer injected at Sunspot Cave was detected in the cave stream of Blowing Sink, and apparently breached through the RDM inside this cave down to the water table. While the geology in this cave was not directly examined, a 2003 cave map of Sunspot by Bill Russell and Julie Jenkins shows a 63 feet depth extent, with a pit shaft starting at 27 feet deep that likely represents the top of the RDM. Tracers injected at the same time in Brownlee Cave were not detected, likely because that cave and downstream Flat Sink were plugged with sediment and were recharging poorly. Wyoka Cave lies near the subsurface extent of the upstream portion of the Blowing Sink cave stream, so runoff entering this cave is likely to enter the Blowing Sink cave stream. The observations of RDM outcrop and breaches through the RDM were used to constrain the subsurface catchment area for the Main Drip Pit in Balcony Room Drips in Blowing Sink Cave, all drips in Goat Cave, and drips above the RDM in Maple Run Cave.

Geological mapping of the area, in conjunction with tracing and water-quality analysis, suggests that fault contacts with the Del Rio Clay and Georgetown Limestone just east of the preserve acts as natural subsurface barriers to infiltration and groundwater flow. For vadose drips resulting from perching of vadose flows over the Regional Dense Member, such as Maple Run Waterfall Drip, Maple Run Rainbow Drip, the Maple Run Fissure Drip, the Maple Run Copal Room Drip, and Blowing Sink Main Pit Drip (Figures 8, 9, and 10), the subsurface catchment area should not extend beyond the top of the surface outcrop of the RDM (Figure 12). The surface contour elevation corresponding to the elevation of the Blowing Sink Balcony Drip extends three miles or more to the southeast and northeast of the Davis Lane study site. However, tracing, geological framework, and

the location of caves that drain perched water from the top of the RDM constrains the subsurface catchment for the Main Pit drips to an area north roughly 2,000 ft wide and 6,000 feet long (Figures 5 and 11). The current extent of Goat Cave does not appear to extend beneath the Leached and Collapsed members, so it similarly should receive no contribution from hydrostratigraphic members below the top of the RDM.

Some of the cave drips are found below the RDM in Blowing Sink and Maple Run Cave. Liverpool drip in Blowing Sink Cave is located at the contact of the Kirschberg and Dolomitic members. Maple Run Garden of Earthly Delight drips are developed within the Grainstone Member near the contact with the underlying Kirschberg Member. The high permeability of the Kirschberg and Grainstone Members are such that lateral perching of vadose groundwater over significant distances has not been observed (Hauwert, 2009). Instead vadose waters in the Grainstone and Kirschberg tend to descend at a high gradient. For this reason, drips such as Maple Run Garden of Earthly Delight and the Blowing Sink Balcony Room Drip must have descended from higher members nearby. In contrast, perching of groundwater near the top of the Dolomitic Member and base of the Kirschberg Member is common, observed in local caves such as Flint Ridge. However, because the drip rate of Liverpool Drip is low and non-persistent (dries up), and the perched water is constrained by the same dips as the RDM, the subsurface catchment area for Liverpool Drip should be constrained within the area defined for Balcony Room Drip.

The deepest extent of the three caves is the Eileens River cave stream of Blowing Sink that is about 240 to 254 feet below the surface. Eileens River cave stream of Blowing Sink is developed completely within the Dolomitic Member (Figure 10). Since this cave stream is developed at the water table, all cave passages below it are water saturated. On April 24, 1999, five pounds of Rhodamine WT was injected in Midnight Cave over two miles west of the Davis Lane (Hauwert et al., 2004). Although Blowing Sink cave stream was not monitored for the 1999 injection, the dye likely passed through the cave. On May 24, 2010, 33.5 pounds of sulforhodamine b dye was injected into Wildflower Cave over a mile west of Blowing Sink (Figure 12). The dye was subsequently detected in the Blowing Sink cave stream. As noted above, 2012 tracers injections at Winter Woods Cave, Sunspot Cave, Hideout Cave, and Wade Sink were also detected either in the Blowing Sink cave stream or in upper vadose drips that would naturally reach the cave stream. Injections two miles north of Blowing Sink at Whirlpool Cave (1999; Hauwert et al., 2004a) and Arbor Trails pond collapse sinkhole (2012) did not flow in the direction of Blowing Sink and are known to be outside the groundwater basin for Blowing Sink. An injection on May 5, 2005 in HQ Flat Sink, two miles southwest of Blowing Sink, likely did not pass through Blowing Sink Cave but instead flowed east. One trace in 1999 about one mile southeast of Blowing Sink may have flowed in a reverse direction through Blowing Sink to the north, under unusual flood conditions (Hauwert et al., 2004a; Hauwert et al., 2004b; Hauwert, 2009). The flow reversal in Blowing Sink appears to occur when local flooding overwhelms the groundwater flow paths to the east, causing overflow flooding in Blowing Sink Cave to divert some water north through the normally dry Dark side of the Moon passage (Figure 10). Because diversions under these rare "overflow" conditions are short-lived, and their flow paths are complicated to define and

verify, they are not considered in defining the subsurface catchment areas. Further tracing is needed to define the upstream flow paths to Blowing Sink, some of which is proposed in 2013. Even though the subsurface catchment area for the Blowing Sink cave stream has not been completely delineated, sufficient data has been gathered locally to map the subsurface catchment area in relation to the proposed Davis Lane realignment project.

For the three studied caves, the subsurface catchment areas can further be distinguished into an infiltration area, where surface water can infiltrate through soils and macropores to reach cave drips and a contributing runoff area where runoff is potentially generated in upstream areas that do not directly infiltrate to support the cave drips but flow downstream to infiltration areas. Examples of contributing runoff areas are roadways and low-permeability drainages where flow is diverted to downstream infiltration areas. Also areas underlain by Del Rio Clay are not likely to contribute much infiltration to cave drips, but may provide runoff to downstream infiltration areas. Maple Run and Goat Caves currently have roadway runoff from Davis Lane that has been artificially diverted to infiltration areas directly over the cave footprints. The criteria for defining the subsurface catchments are further discussed in detail in the hydrogeologic study report for Goat, Maple Run, and Blowing Sink caves.

IV. Evaluation of Proposed Davis Lane Realignment

With proper design and implementation, the Davis Lane realignment project and its associated water quality controls can potentially improve the water quality in cave drips in Goat, Maple Run, and Blowing Sink caves over existing conditions. While pre-1996 permit conditions are generally the preferred reference for comparison, current 2012 conditions are used for reference in this analysis since prior background water quality data is not available. Below several options and proposed water-quality controls for Davis Lane are evaluated for their potential effects to the three BCCP permit caves.

IVa. Roadway Construction

The Davis Lane project has a site plan approved by the City of Austin and Water Pollution Abatement Plan (WPAP) approved by the Texas Commission on Environmental Quality (TCEQ) that describes temporary sediment controls that have been installed to reduce downstream sediment deposition. During trenching associated with roadway construction it is possible that voids are encountered, particularly on the west portion of the proposed Davis Lane realignment. The City of Austin Void and Water Flow Mitigation Rule (ECM 1.12.0, COA Item No. 658S of the SSM and 658S-1 through 658S-7 of the Standard Details Manual) require that a Texas licensed geologist or representative be present during all trenching greater than 5 feet depth. Any void greater than one cubic feet in volume is required to be reported (immediately by phone) to the City of Austin environmental inspector and Watershed Protection Dept. geologists. TCEQ also requires that sensitive features encountered during construction be reported within 24 hours.

With the sedimentation and erosion controls proposed in the WPAP, it is not anticipated that significant accumulation of sediment from the Davis Lane roadway realignment project construction will be carried south to the downgradient Blowing Sink tract.

However, the City of Austin Watershed Protection Department has an unrelated Capital Improvement Project to stabilize and restore the recharge of five sinkholes (Brownlee, Wyoka, Winter Woods, Sinky Dinky, and Sink-in-the-Woods) just south and downgradient of Davis Lane on the Blowing Sink tract that contribute to Blowing Sink (Figure 2). This project will begin October 2012 and continue through 2014. Part of the scope of this project includes removing sediment and debris accumulations blocking the sinkholes. In their current state the five sinkholes have unstable entrances and at least one (Brownlee Sink) appears to be essentially plugged with sediment.

IVb. Maple Run Section 8 WQ Pond

Existing drainage of roadway runoff from Davis Lane into the West Drainage (west of the Goat Cave karst preserve) and into the Maple Run Section 8 WQ pond appears to be the primary means for the road to impact Goat Cave and Maple Run caves. A storm drain pipe along Coastal Drive also takes some roadway runoff directly to the Maple Run Section 8 pond where it can potentially infiltrate into Maple Run Cave. Tracing suggests that infiltration around Davis Lane around the Goat Cave karst preserve descends to perch on the Regional Dense Member, a 15 feet thick, clay-rich thin-bedded limestone member of the Edwards Group (Figure 5 and Figure 11). A slight dip and downfaulting to the south appears to direct vadose flow south toward Blowing Sink Cave, rather than north to Goat and Maple Run caves.

The West Drainage is unlined and under some conditions overtops its bank into the adjacent Goat Cave karst preserve and sinkholes such as Goat Cave, Maple Run Cave, Hideout Cave, and Wade Sink. The unlined drainage appears to flow over Goat Cave and infiltrate into it, based on changes in water quality, flashy flow associated with runoff events, and the detection in drips of tracer poured into the West Drainage over Goat Cave (hydrogeologic study report). The footprint of Maple Run Cave extends beneath the Maple Run Section 8 WQ pond (Figure 6). The roughly 20 feet diameter and 20 feet high Copal Room in the rear of Maple Run Cave lies about 20 feet below the base of the Maple Run Section 8 water quality pond, based on cave surveying in April 2012 (Figure 7). Some drips in Maple Run Cave (such as the Maple Run Waterfall Drip and Copal Room) flow only during runoff events when the Maple Run Sec 8 pond and West Drainage held water (Figure 8). The water quality of these drips is similar to water quality measured in the Maple Run Section 8 WQ pond and West Drainage. Based on this data, roadway runoff enters both Goat Cave and Maple Run Caves, and this condition was likely occurring when the BCP permit was established in 1996. It can be expected that with increasing traffic loading over time, concentrations of water-quality contaminants likely have increased in roadway runoff from Davis Lane since 1996 when the BCP permit was established.

Several corrections have been incorporated or are being considered by the City of Austin to mitigate poor-quality flow to Goat and Maple Run caves from the West Drainage. As part of the Davis Lane realignment project by CoA Public Works Dept., flow to the West Drainage from Davis Lane will be completely diverted to the West Davis retention pond that is underlain by less permeable Del Rio Clay and Georgetown Limestone and lined with an artificial clay liner. This single measure would essentially remove potential

impacts from Davis Lane to Goat and Maple Run, as well as greatly reduce impacts to Blowing Sink Cave. Additional work on the West Drainage and Maple Run Section 8 WQ pond is being planned by the CoA Watershed Protection Dept. drainage engineers to improve the water quality of drips in Goat, Maple Run, and Blowing Sink Caves, although these solutions are more complicated. An impervious liner and higher berm could prevent the West Drainage from infiltrating into Goat Cave and entering the entrance of Goat and other caves during floods. Lining the West Drainage may not be critical or necessary once stormwater from Davis Lane is diverted, however. The Maple Run Section 8 WQ pond is being evaluated for installing a liner to prevent stormwater infiltration into Maple Run Cave. However, in order to maintain the existing treatment volume, the pond might require deepening, which could increase the chance of catastrophic sinkhole collapse over the cave or currently unknown cave passages, similar to the collapse occurring in the Arbor Trails pond two miles north in January 2012. Deepening the Maple Run Section 8 WQ pond would require additional investigation, including cave radio survey of Maple Run Cave to more accurately locate the cave under the pond, and a geophysical survey to identify the location and depth of anomalies that could represent yet undiscovered cave rooms beneath the pond. It may be possible to line the pond and accept a lower treatment capacity, considering that some flows that the pond receives now may be diverted to the Davis West pond.

Any loss from diversion of existing flow from Davis Lane, the West Drainage, or Maple Run Section 8 WQ pond is not anticipated to have an adverse effect of the ecosystem in Goat, Maple Run, or Blowing Sink caves. All three caves have persistent drips originating from other sources that are of higher quality. Drips fed solely by discrete runoff are flashy and short lived, whereas other more persistent drips in the cave are derived from more distant and higher quality sources.

IVc. Davis Lane Curbs

A curb proposed along Davis Lane will prevent roadway runoff from crossing the Blowing Sink tract and infiltrating into Blowing Sink Cave to the south. The roadway runoff will be diverted through storm drain pipes to the Davis East and West retention ponds. This improvement will enhance the quality of runoff to the surface and subsurface catchments of Blowing Sink, including the Eileens River cave stream.

IVd. Davis West Retention Pond

The west retention (Davis West) pond proposed for Davis Lane is located over the Del Rio Clay outcrop (Figure 3). Borings suggest the underlying Georgetown Formation will likely be encountered in some portions of the pond (Figure 4). The retention pond is proposed to be lined with an 18-inch clay liner over a compacted earthen embankment. Prior to proposed pond construction from 2010 to 2012, this site was observed to pond water considerably after several rain events. No significant natural soil piping features were observed at the proposed Davis West pond site that indicated the presence of natural conduit beneath the Del Rio Clay through the Georgetown Formation. One depression noted at the west pond site appears to be an incompletely plugged geotechnical boring that will be removed during the pond excavation. An existing stock pond several hundred feet north of the west pond site is similarly constructed through a veneer of Del Rio Clay

into the top of the Georgetown Formation and is observed to hold water for months after rain.

The west pond excavation will be examined and documented by a WP geologist prior to lining. However, this proposed Davis West pond site is not likely to directly infiltrate significant subsurface flow to the drips of the three caves because less permeable rock types and lack of natural recharge structures. Because of the lack of infiltration on the surface, direct tracing from the west pond site was deemed unnecessary (and not possible) in order to examine potential hydraulic subsurface connection to the three permit caves.

Roadway runoff directed to this pond is proposed to be irrigated on the surface further east of the pond site, outside the surface and subsurface catchments for the three caves, except for the Blowing Sink Eileen's River cave stream (Figure 1). The stormwater irrigation is proposed over areas of Del Rio Clay and Georgetown Limestone, as well as roadway median, where infiltration is generally retarded and well-developed conduit connection is uncommon. Note that important recharge structures have been observed in the Georgetown Limestone (such as Antioch Cave and Horseshoe Cave in the Onion Creek watershed) and less likely within the Del Rio Clay (Elm Waterhole in Slaughter Creek), but such recharge structures are not distributed throughout the outcrop. Within the study area, a soil-piping sinkhole (Goat Field) was observed within the Del Rio Clay of a former drainage about 900 feet northeast of the West Davis Pond site in the late 1990's, but is no longer exposed. Furthermore the amount of irrigated runoff from the Davis Lane project is relatively small compared to the flow of the cave stream known thus far and is not anticipated having a measureable impact on its water quality. Overflow drainage from the pond will be discharged through an existing 42-inch storm drain pipe to a tributary of the Kincheon branch of Williamson Creek that flows downstream of the Maple Run Section 8 WQ pond (Figure 2). The discharge from this storm drain flows east about 400 feet, to the discharge of Maple Run Sect 8 pond and north about 500 feet to the extent of the subsurface catchment area for the three caves, defined by the surface exposure of the top of the RDM. Along this 900 feet downstream of the storm drain pipe discharge, the drainage overlays faulted exposures of the Edwards Group and Georgetown Formation and where infiltration can potentially occur within the subsurface catchments of the three caves. However no outstanding recharge structures were observed within the 900 linear feet of drainage. If significant infiltration is observed or later tracing shows strong hydraulic connection from the drainage downstream of the West Davis pond overflow storm drain pipe, it may be possible for WP to line this portion of the drainage. Overall, diverting roadway runoff away from the West Drainage (where runoff passes directly over Goat and Maple Run Caves) to the Davis West retention pond is expected to increase the existing water quality to all three studied caves.

The Davis West Pond is proposed to cover an area of 0.75 acres or 32,000 ft^2, much of which now flows through the Goat Cave karst preserve and into Wade and Hideout Sinks (Figure 2). Since these sinks have been traced to Blowing Sink Cave, consequently their catchment areas are part of the current subsurface catchment area for Blowing Sink. Construction of the pond will result in the diversion of contributing runoff to the Blowing

Sink subsurface infiltration area. The overall benefit of the pond for treating water that would otherwise go to Blowing Sink outweighs the small loss of contributing area to Blowing Sink.

Note the West Pond as digitized on Figure 3 approaches close to the fault contact with the Edwards Group. It is recommended that sufficient lateral thickness (such as 50 feet) of natural Del Rio Clay lie between the pond and the fault to the west, at the east edge of the Goat Cave karst preserve, to allow the natural ability of the clay to prevent infiltration to Blowing Sink.

IVe. Davis East Retention Pond

The east retention pond was excavated into the Del Rio Clay adjacent to Brodie Lane and the proposed Davis Lane realignment (Figure 3). It is outside of the surface or subsurface catchment area for the three caves and is not expected to have any influence on the three caves (Figures 2, 11, 12, and 13). No tracing was necessary for verification because of no recharge structures could be found and water can be observed ponding in nearby stock ponds.

IVf. Magellan Petroleum Pipeline

CoA Public Works created a Reimbursement and Encroachment easement in September 2010 with Magellan that provides inspection of the Davis Lane roadway construction and evaluation of the roadway design to insure that the pipeline is not impacted. As part of the agreement, Magellan staff will inspect the construction plans and observe the construction to insure that the pipeline is not damaged. Furthermore as noted in IVa, a licensed geologist or representative is required to be present during any trenching over 5 feet deep. This inspection oversight is expected to prevent accidental damage to the pipelines that occurred locally during utility construction on four cases in the 1970's to 1980's to each of the three local pipelines.

V. Monitoring and Adaptive Management

Based on existing data it appears that water quality controls associated with Davis Lane have the potential to improve the existing water quality in the drips and cave stream of Goat, Maple Run, and Blowing Sink caves. Continued monitoring and evaluating if additional mitigation is required in order to insure that the water quality system is working as intended. Demonstration for improvement of existing conditions can help the city and USFW evaluate how well the preserve is functioning and if additional actions are needed, particularly when the BCP permit expires in 2026. The following monitoring is recommended:

1) Permitted biologists (holding a US Fish and Wildlife endangered species permit) conduct faunal surveys in Goat, Maple Run, and Blowing Sink Cave. Cave cricket exit surveys are recommended four to six times a year to help establish the general health of the cave ecosystem.
2) Future sampling of the cave drips to quantify improvements in drip quality that is anticipated and detect unanticipated problems. For comparison, the existing water

quality of the drips and surface runoff is currently being monitored in the hydrogeologic study. To characterize a cave drip, monitoring at least seven storms, with daily composite samples over five days (or until the drip ceases flowing) is recommended. Only one water-quality characterization after the operation of realigned Davis Lane is necessary to evaluate improvements or problems. The cave drips Blowing Sink Balcony Room, Maple Run Waterfall/Rainbow Room/Fissure, and Goat Cave Entrance/Main/Alcove drips are recommended.

3) Additional tracing can serve to further constrain the subsurface catchment areas and verify the results of the Davis Lane tracing under varying conditions. The phreatic (water table level) cave stream in Blowing Sink is too large and persistent to be derived locally and will require considerable more tracing to delineate its total source area accurately. Groundwater tracing is planned in the area as part of a WP spill tracing CIP project in 2013.

VI. References

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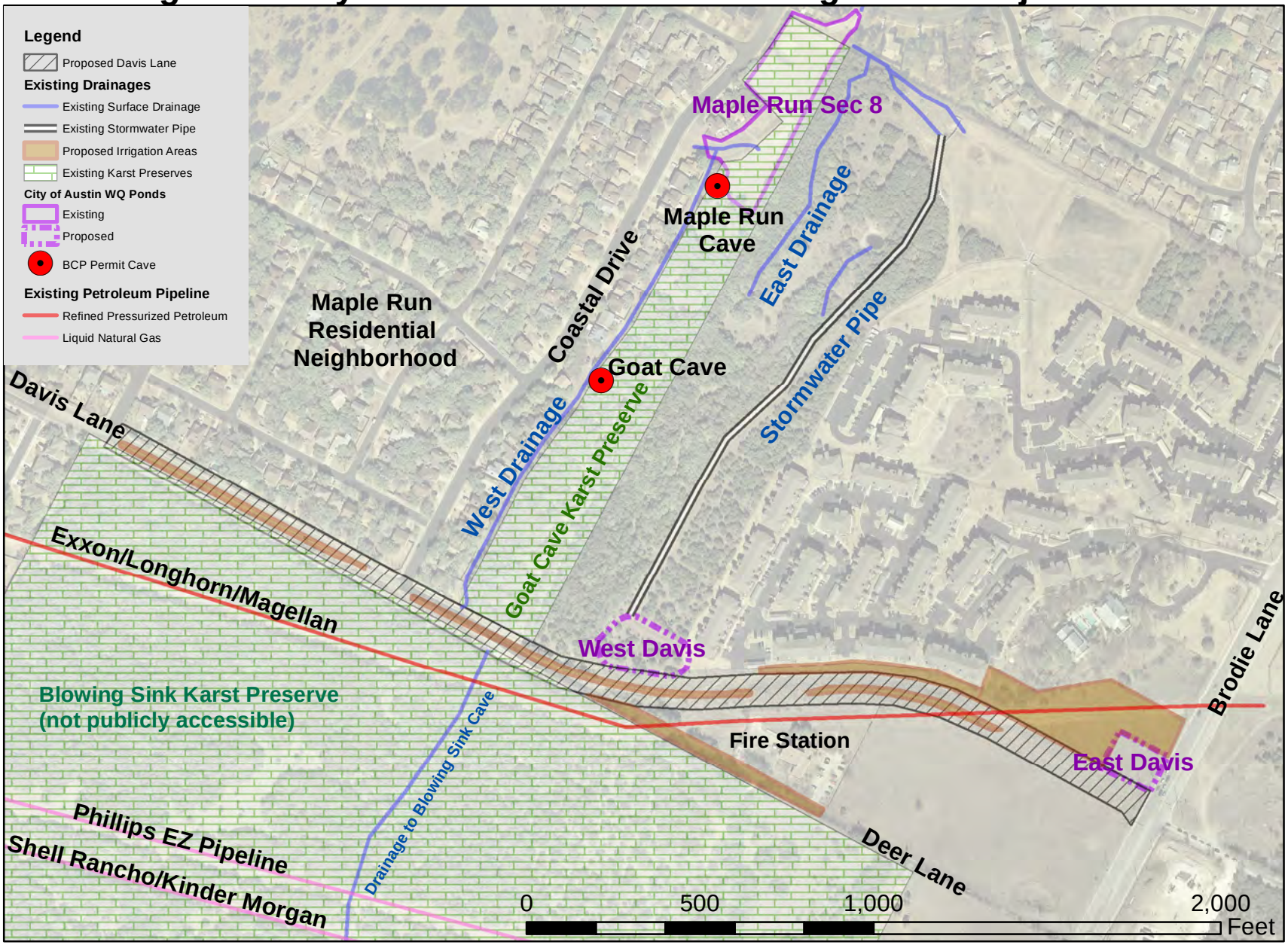
Small, T.A., Hanson, J.A., and Hauwert, N.M., 1996, Geologic Framework and Hydrogeologic Characteristics of the Edwards Aquifer Outcrop (Barton Springs Segment), Northeastern Hays and Southwestern Travis Counties, Texas: U.S. Geological Survey Water Resources Investigations 96-4306, 15 p. Prepared in cooperation with the BSEACD and TWDB. http://pubs.usgs.gov/wri/wri96-4306/

Figures

Figure 1. City of Austin Davis Lane Realignment Project



Map prepared by Nico Hauwert, Ph.D, PG, City of Austin Watershed Dept. August 2012. Road project, irrigation, and pond details digitized from "Davis Lane from Brodie Lane to Coran Ferry Project Overview and Survey Control" by City of Austin Public Works Dept. dated 6/20/10. Features shown in this map are not located using professional surveying and are not intended as engineering plans.

Figure 2. Davis Lane Surface Hydrology

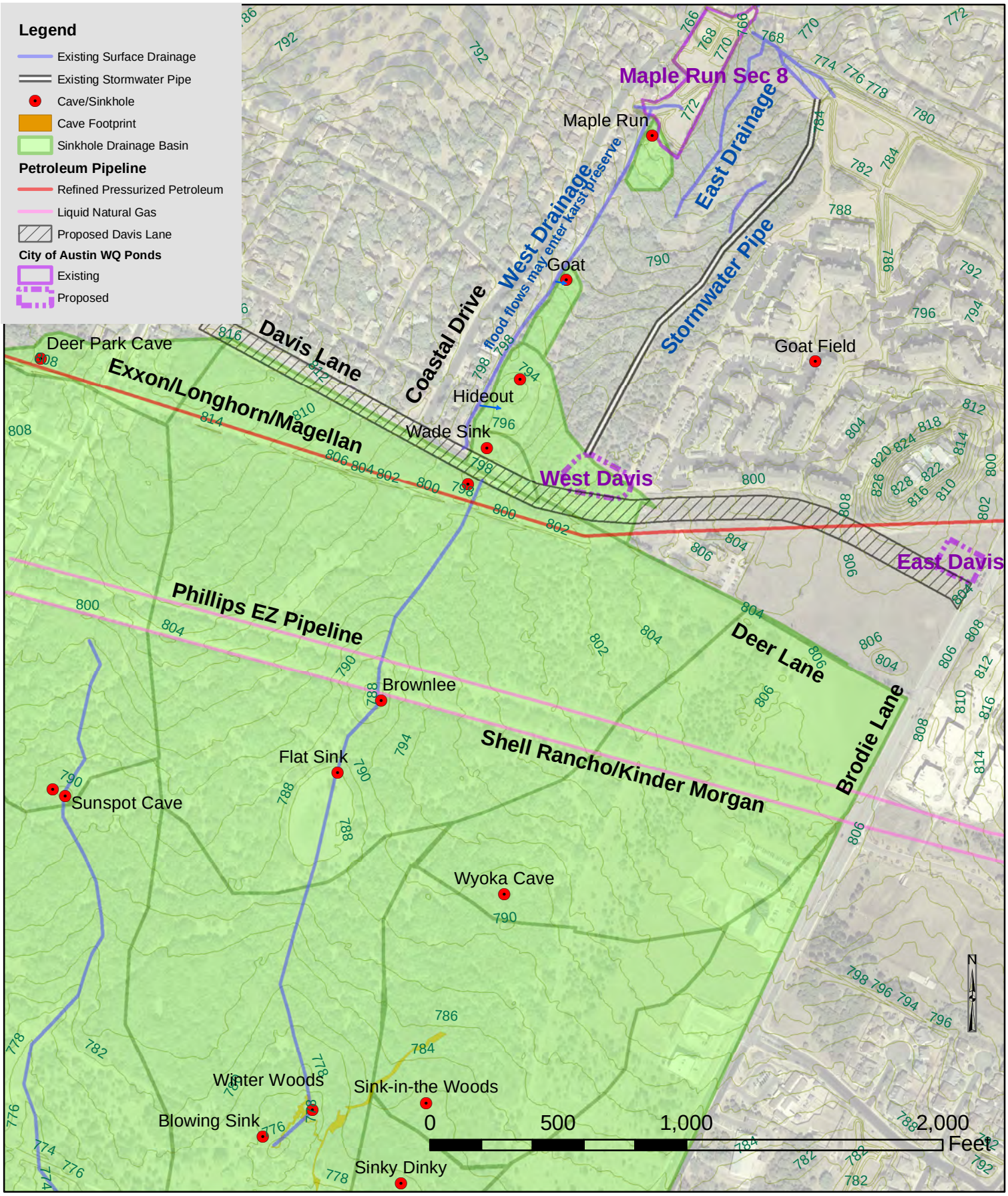
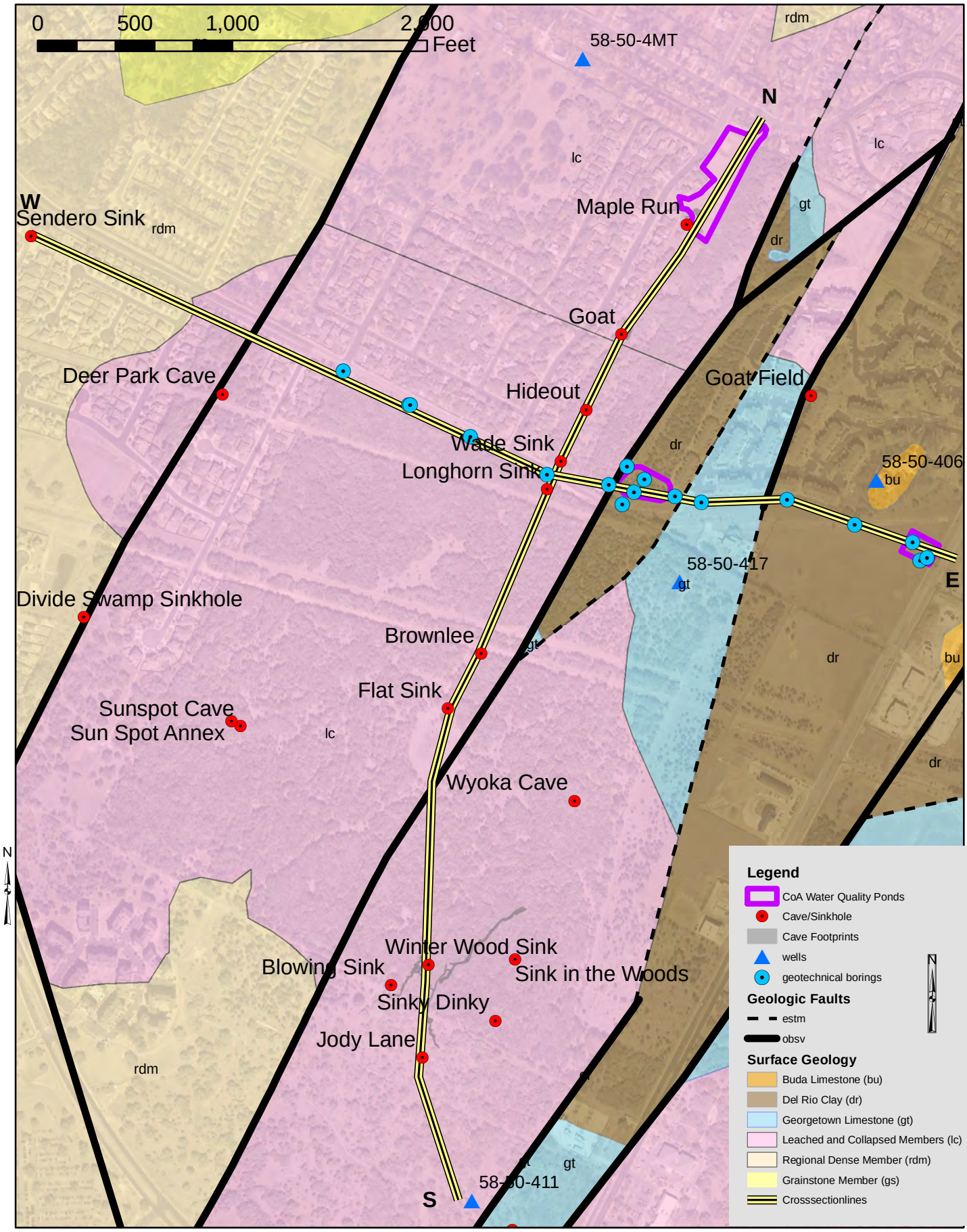


Figure 3. Surface Geology Along Davis Lane Area



Interpretation by Nico Hauwert, PhD, PG, CoA Watershed Protection
Modified from original coverage presented in Small, Hanson, & Hauwert, 1996

Figure 4

Geological Cross Section Along Proposed Davis Lane Realignment

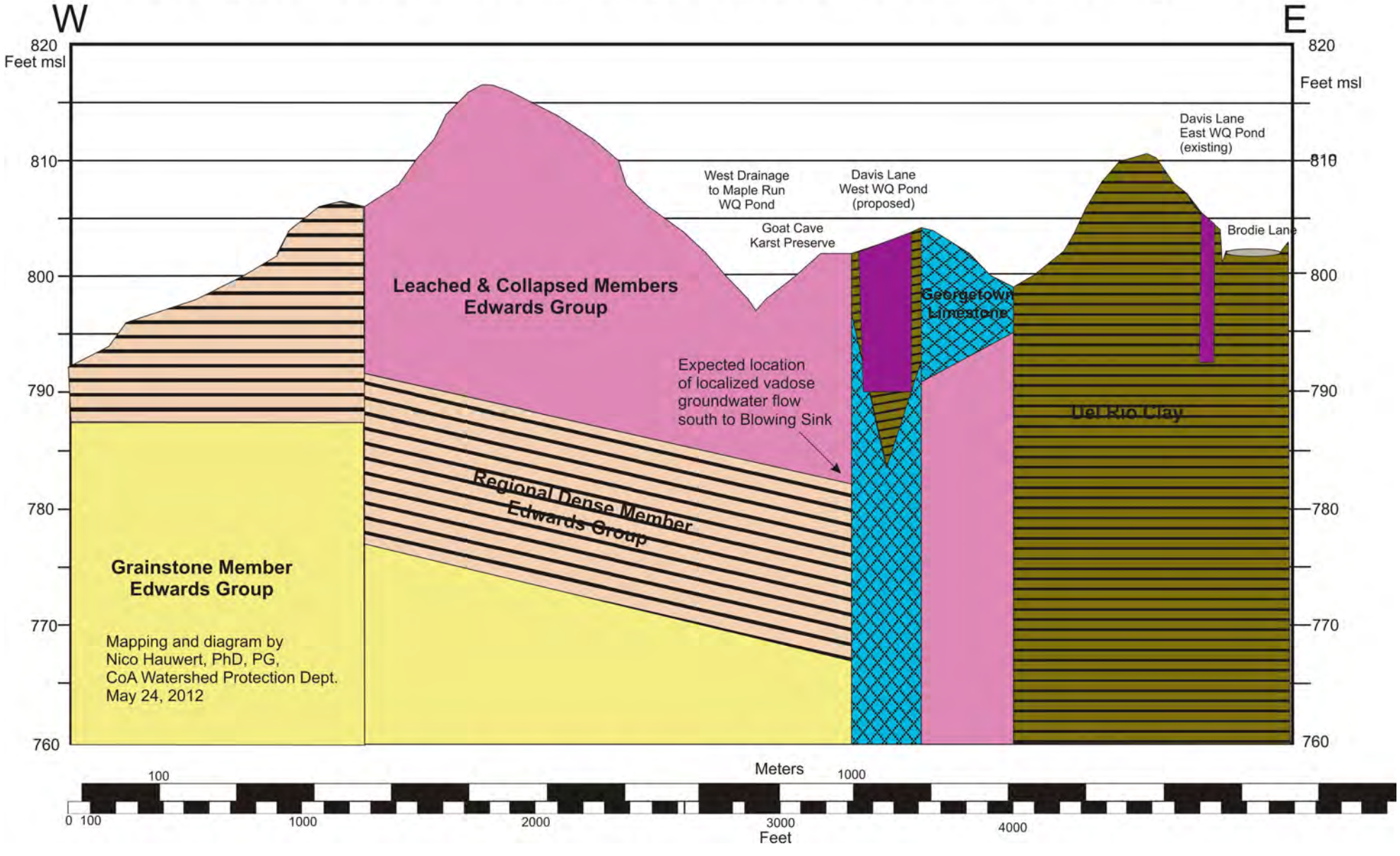
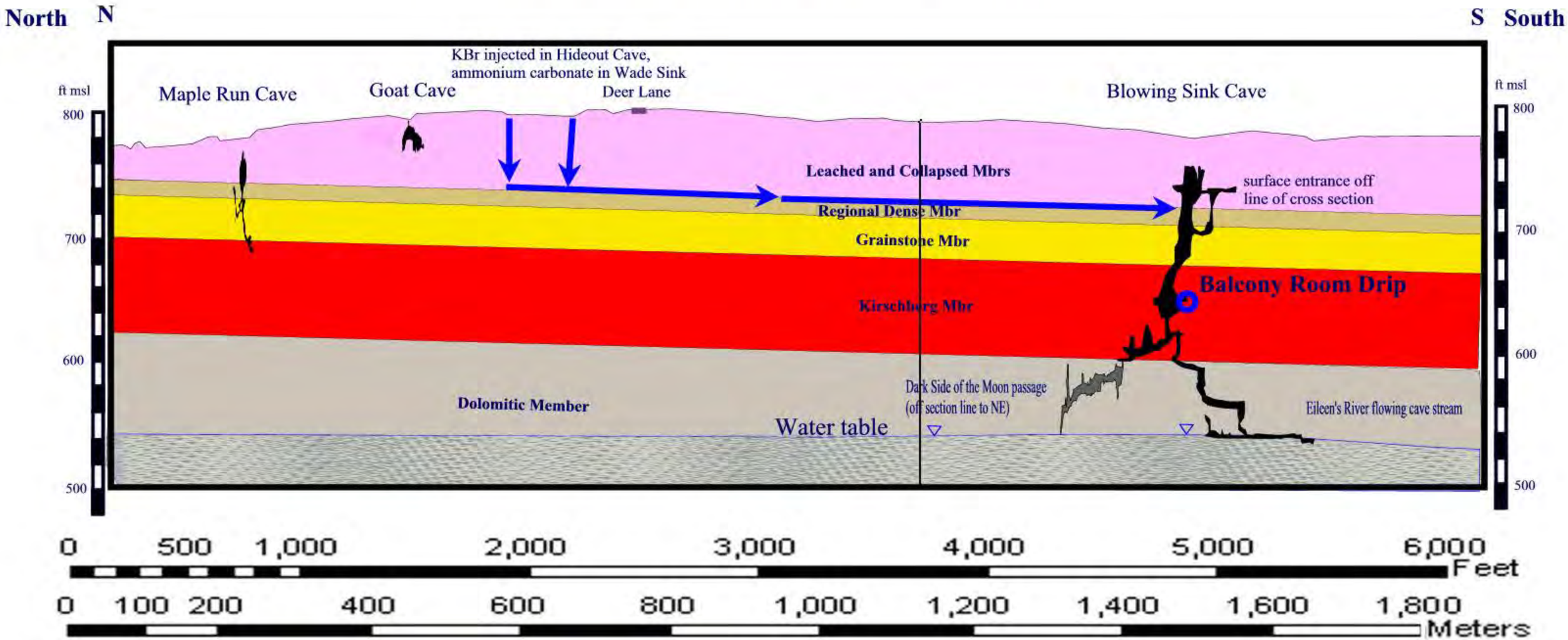


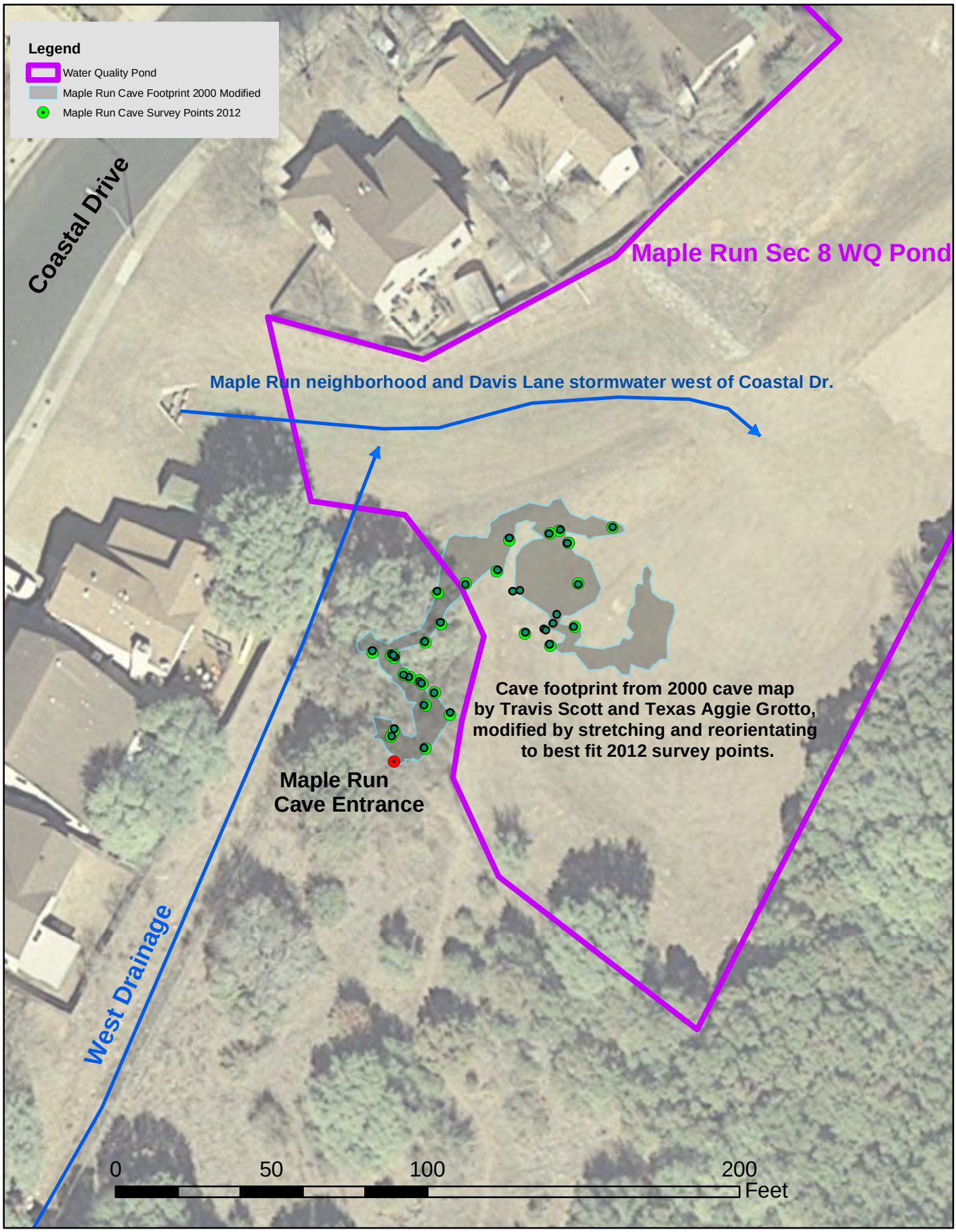
Figure 5.

North to South Cross Section



Drafted by Nico Hauwert, Ph.D, PG, May 2012
Hydrostratigraphic units in Blowing Sink Cave from "Blowing Sink Measured Section" by Nico Hauwert (1995).
Cave Cross section modified from "Blowing Sink Cave" map by TCMA (1995)
Cross Section expanded and modified from Hauwert (2009)

Figure 6. Maple Run Cave Under Maple Run Section 8 WQ Pond



2012 Cave Survey by by Nico Hauwert, PhD, PG, CoA Watershed Protection Dept. and David Papke, Ranger, CoA Parks and Rec. Dept.

Figure 7

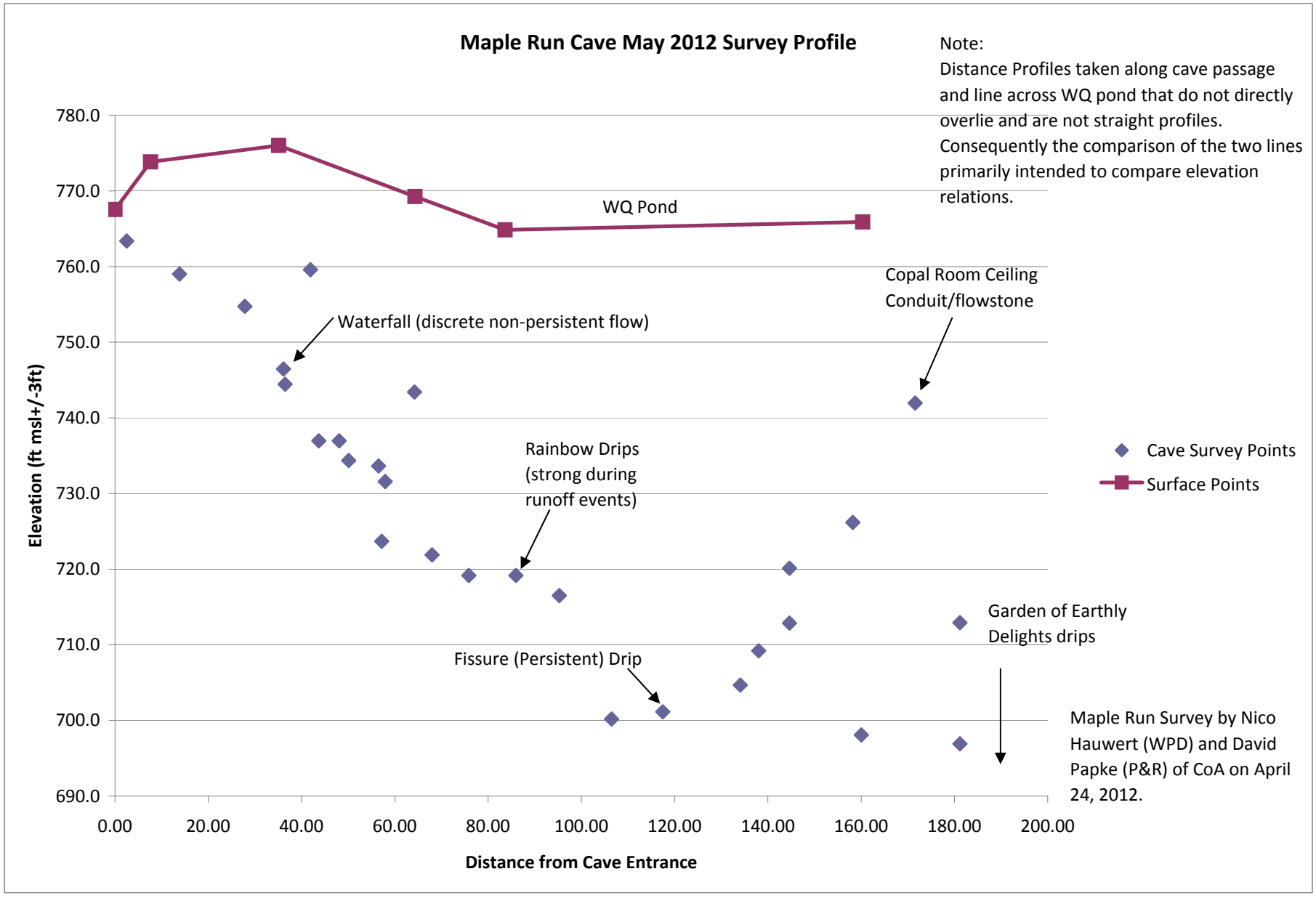

Maple Run Cave May 2012 Survey Profile
Note:
Distance Profiles taken along cave passage and line across WQ pond that do not directly overlie and are not straight profiles. Consequently the comparison of the two lines primarily intended to compare elevation relations.
WQ Pond
Copal Room Ceiling Conduit/flowstone
Waterfall (discrete non-persistent flow)
Rainbow Drips (strong during runoff events)
Fissure (Persistent) Drip
Garden of Earthly Delights drips
Cave Survey Points
Surface Points
Maple Run Survey by Nico Hauwert (WPD) and David Papke (P&R) of CoA on April 24, 2012.
Elevation (ft msl+/-3ft)
780.0
770.0
760.0
750.0
740.0
730.0
720.0
710.0
700.0
690.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Distance from Cave Entrance

Figure 8

Maple Run Drip Sample and Faunal Survey Sites
Davis Lane Hydrogeological Study

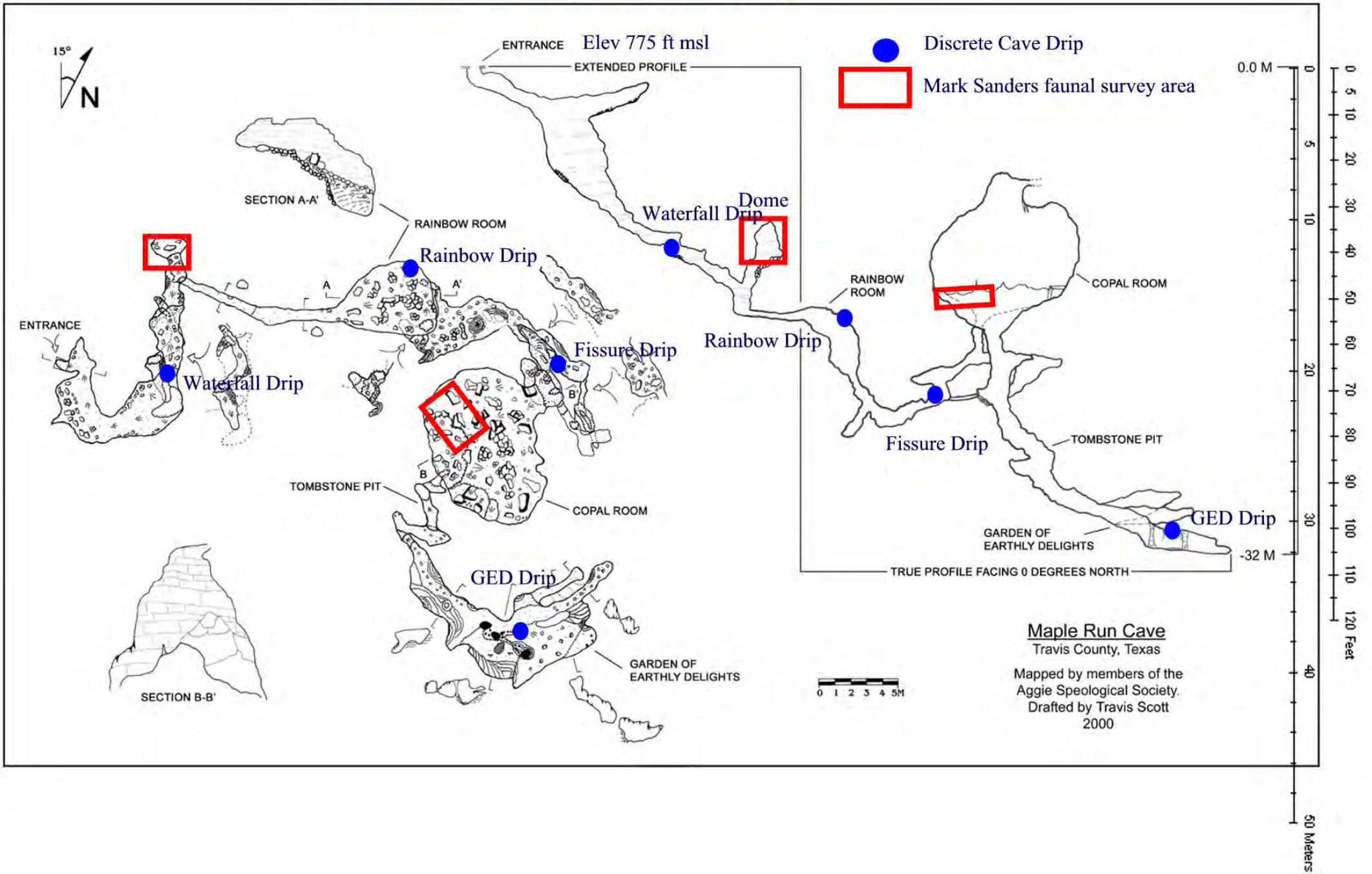


Figure 9

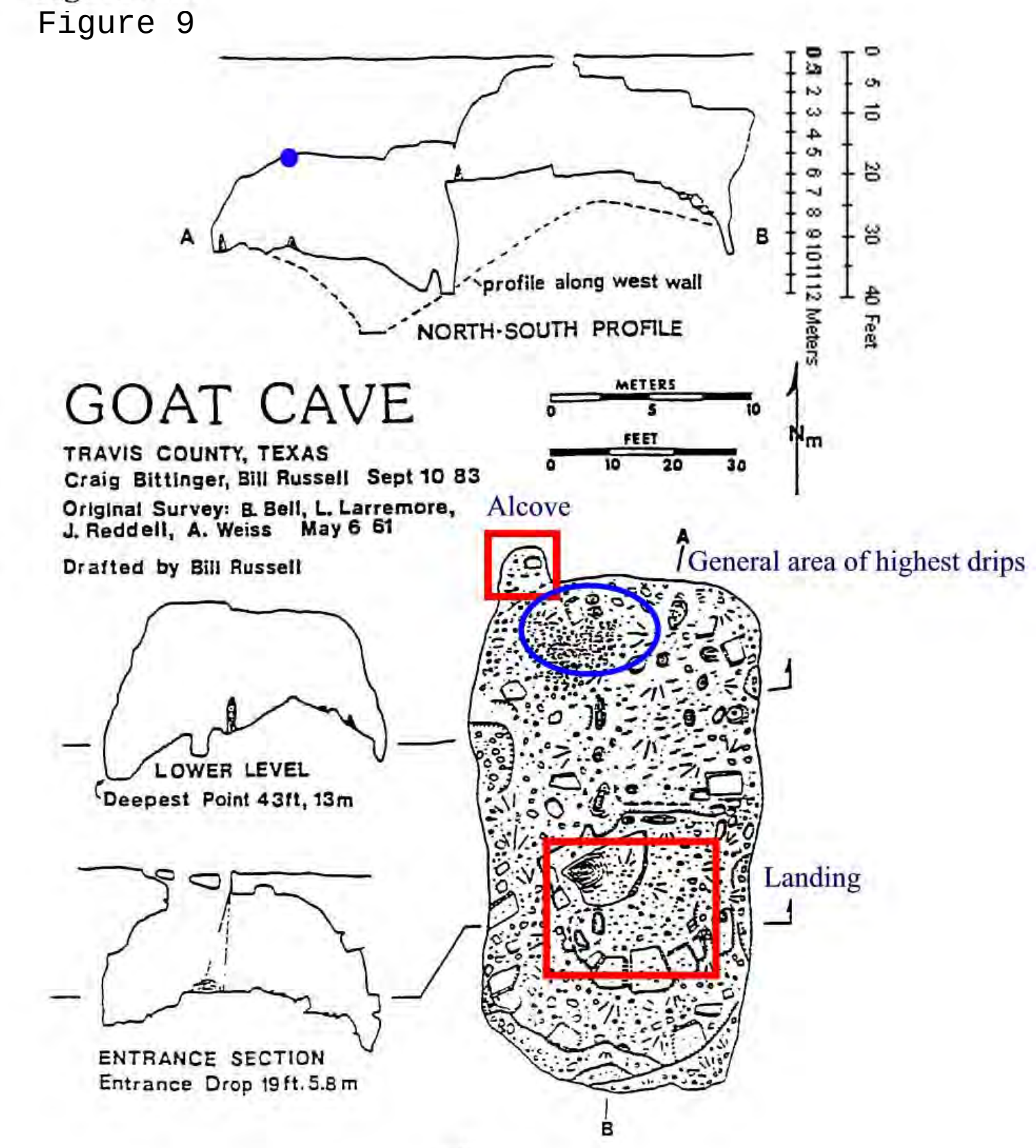

A
B
profile along west wall
NORTH-SOUTH PROFILE
0 5 10 20 30 40 Feet
0 1 2 3 4 5 6 7 8 9 10 11 12 Meters
GOAT CAVE
TRAVIS COUNTY, TEXAS
Craig Bittinger, Bill Russell Sept 10 83
Original Survey: B. Bell, L. Larremore, J. Reddell, A. Weiss May 6 61
Drafted by Bill Russell
METERS
0 5 10
FEET
0 10 20 30
Alcove
A
General area of highest drips
Landing
B
LOWER LEVEL
Deepest Point 43ft, 13m
ENTRANCE SECTION
Entrance Drop 19ft. 5.8m

Figure 10

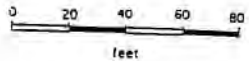
BLOWING SINK CAVE

Oak Hill Quadrangle, Travis County, Texas

Texas Cave Management Association
Fall, 1995

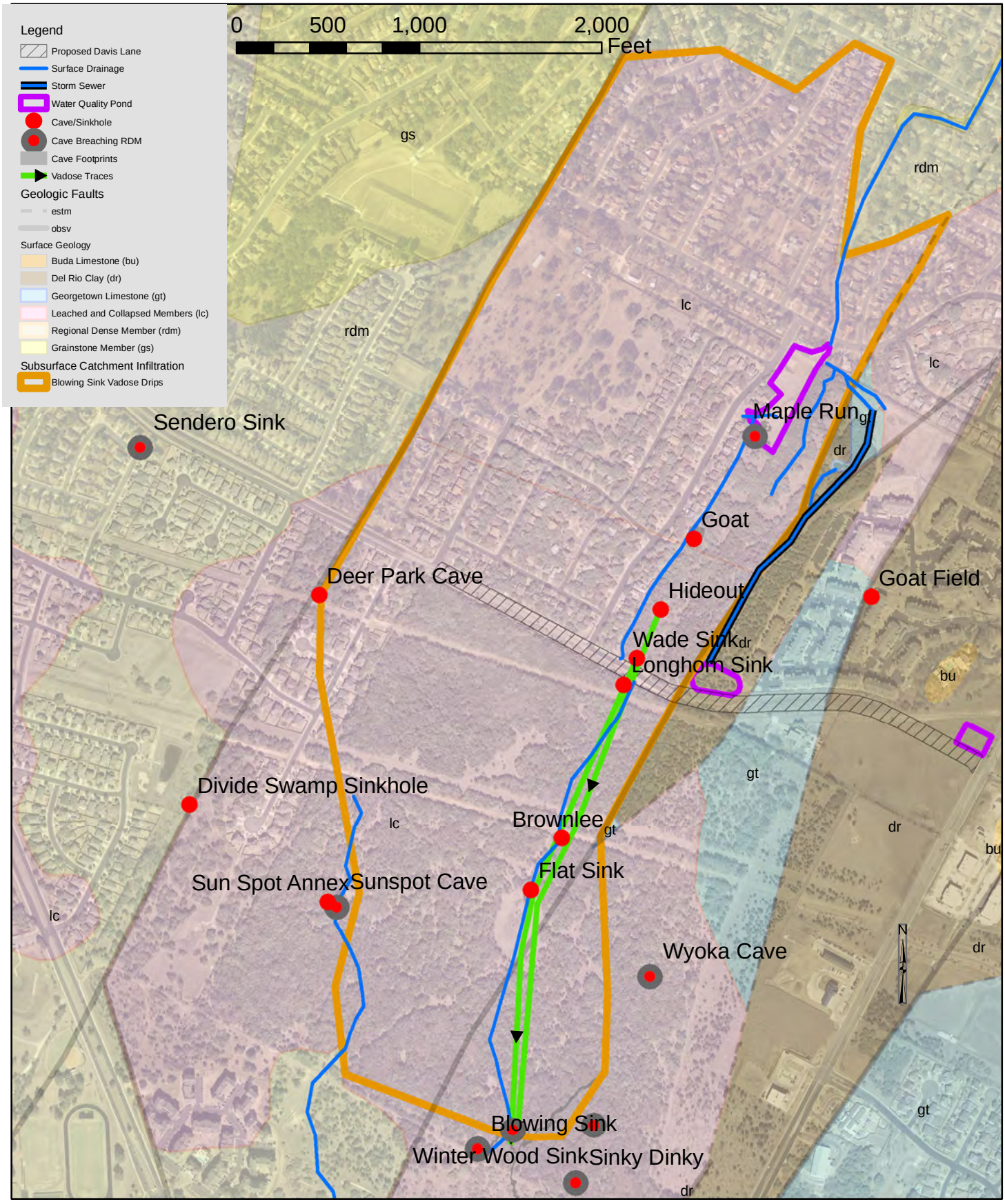
Extended Profile
Passage length, inclination and elevation are correct

Total Passage Length 1655 feet
Maximum Depth Below Entrance 254 feet



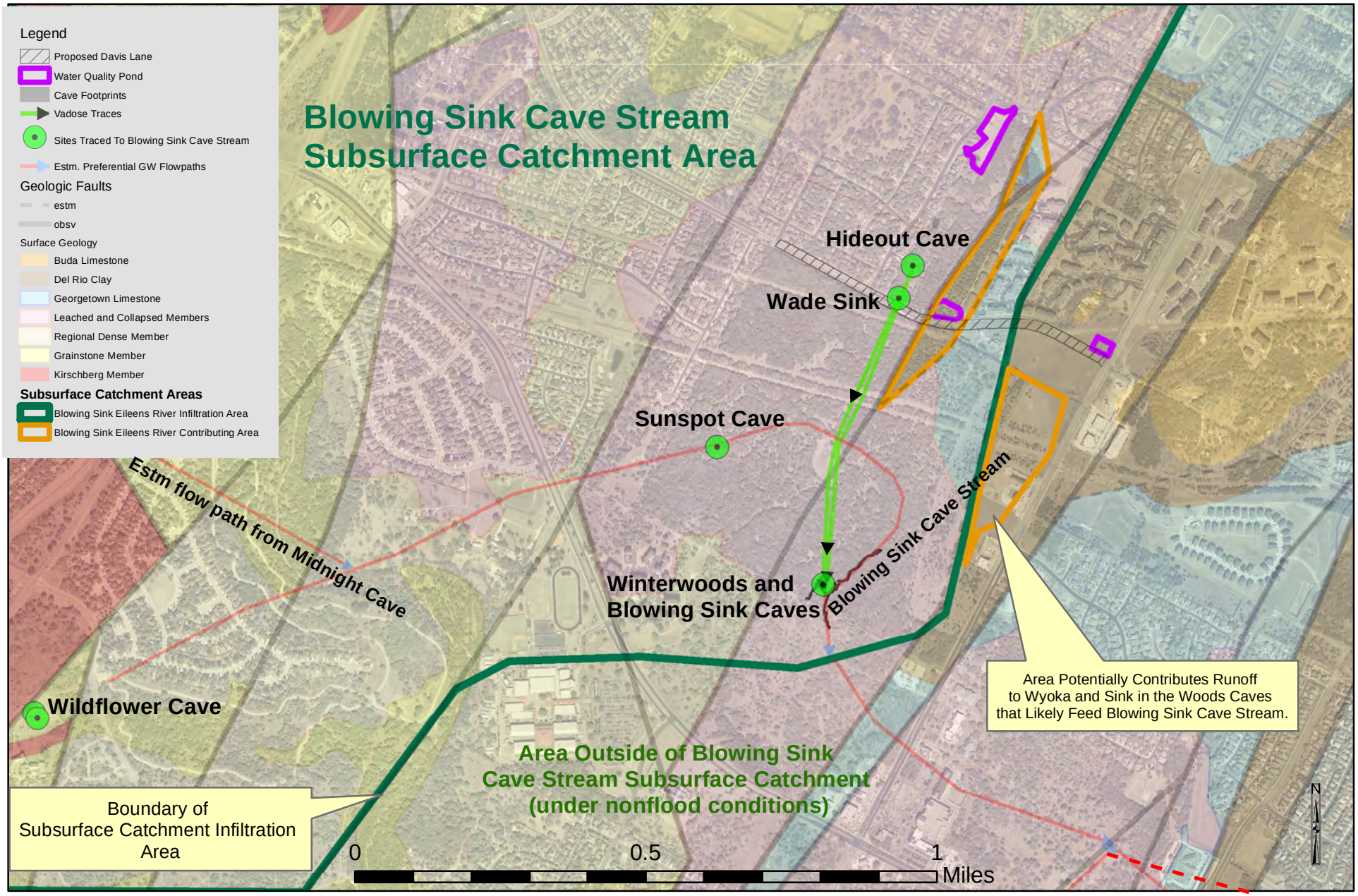
Vertical and Horizontal Scale

Figure 11. Subsurface Catchment Area for Blowing Sink Vadose Drips (Main Pit, Balcony, Liverpool Drips)



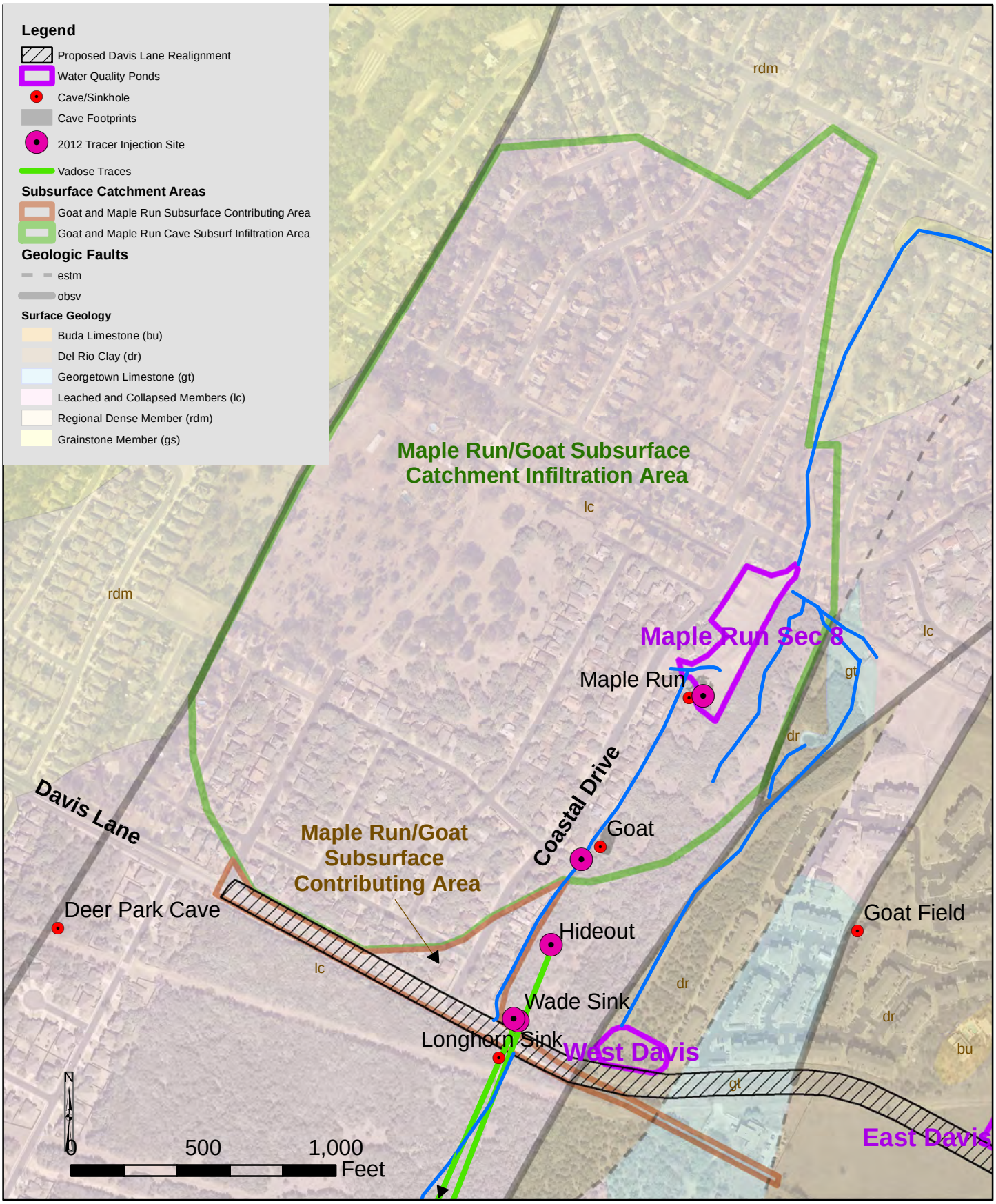
Geology and Subsurface Catchment Area Interpretation by Nico Hauwert, PhD, PG, CoA Watershed Protection. Subsurface catchment areas based on mapped geological framework, vadose traces, location of caves breaching RDM, and drip characteristics/location. Map prepared by Nico Hauwert, Aug. 20102

Figure 12. Areas Traced to Blowing Sink Phreatic Cave Stream (Portion of Eileens River Subsurface Catchment Area)



Geology and Subsurface Catchment Area Interpretation by Nico Hauwert, PhD, PG, CoA Watershed Protection.
Subsurface catchment areas based on mapped geological framework and groundwater traces, Map prepared by Nico Hauwert, August 20102

Figure 13. Subsurface Catchment Area for Maple Run and Goat Cave Drips



Geology and Subsurface Catchment Area Interpretation by Nico Hauwert, PhD, PG, CoA Watershed Protection Dept.
Map prepared by Nico Hauwert, August 2012