

Groundwater Recharge Feasibility Study

Prepared For: Raisin City Water District

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The Kings Basin is in critical overdraft and a groundwater cone of depression has been developed in the central and western parts of the Basin and is centered near the southwestern boundaries of the Raisin City Water District (RCWD). Overdraft increases the competition for available groundwater supply between geographic areas within the region. Declining groundwater levels and groundwater migration across jurisdictional boundaries are also potential sources of increased concern. In addition, site-specific issues associated with groundwater quality, groundwater recharge, and the need for water and wastewater management facilities to address the overdraft have been identified as high priority issues.

RCWD is actively participating in the Kings River Conservation District (KRCD) Coordinated Groundwater Management Plan (GWMP) and the Upper Kings Basin Integrated Regional Water Management Plan (IRWMP) to help address the groundwater overdraft. The groundwater recharge elements of the regional plans support the development of recharge basins to store surface water and replenish the groundwater supply, which will help secure the reliability of the primary source of water supply in the region.

RCWD has conducted a groundwater recharge feasibility study, funded through the Local Groundwater Assistance Grant (AB303 Program) from California Department of Water Resources, to identify required land, water, and conveyance structures and determine efficient, cost effective methods to replenish the groundwater supply through recharge projects. The groundwater recharge feasibility study contributes to the attainment of groundwater stability. The study covers areas within RCWD and at its boundaries with Fresno Irrigation District (FID) and Consolidated Irrigation District (CID). A map of the project area is presented in Figure 1.1.

The purpose of this report is to present the details of the data collected, work completed, and results of the recharge feasibility study. The results of field exploration work are presented in Section 5 and appendices.

1.1 GOALS AND OBJECTIVES OF THE STUDY

The goals of the feasibility study are to enhance the knowledge of groundwater basin recharge capacity, establish a groundwater recharge project to aid in the planning process, and evaluate the benefits that could be realized through the recharge of the groundwater basin. The project supports the goals and objective of the GWMP. The key goal is to stabilize and reverse overdraft and create a balance between groundwater demand and supply, ensuring that the resource will be available in the future. The groundwater recharge feasibility study is an integral part of achieving this goal. Producing a reliable, consistent source of groundwater information will provide new knowledge and a better understanding of the current conditions of the basin.

1.2 PURPOSE OF THE PROJECT

The purpose of this project is to collect and assess the data required to support the regional efforts by the GWMP stakeholders and participants to protect the groundwater basin as a source of water for agriculture and municipal use. A summary of data used in this analysis is listed in Table 1.1.

The groundwater recharge feasibility study supports the primary Basin Management Objective (BMO) of the GWMP to:

“Identify and build near-term groundwater recharge projects within each Water Management Area (WMA) to capture flood flows; begin to stabilize the basin; and demonstrate project feasibility, benefits, and cost effectiveness.”

This project also supports the goals and objectives of the IRWMP. The goals and objective of the IRWMP, as related to this project and the GWMP, are:

- Halt, and ultimately reverse, the current overdraft and provide for sustainable management of surface and groundwater;
- Increase the water supply reliability, enhance operational flexibility, and reduce system constraints;
- Define local and regional opportunities for groundwater recharge, water reuse/reclamation, and drinking water treatment;
- Develop large scale regional conjunctive use projects and artificial recharge facilities to:
 - Improve the ability to store available sources of surface water in the groundwater basin;
 - Capture storm water and flood water currently lost in the region;
 - Provide multipurpose groundwater recharge facilities that provide flood control, recreation, and ecosystem benefits; and
 - Promote ‘in-lieu’ groundwater recharge to reduce reliance on groundwater.

1.3 SCOPE OF PROJECT

The major project components consist of background investigation of existing conditions related to water supply and conveyance system, characterization of land use for potential project sites, and assessment of project impacts and benefits. A summary of the project tasks are as follows:

- Task 1 – Recharge Site Feasibility Investigation
- Task 2 – Water Availability Study
- Task 3 – Conveyance Alternative Analysis
- Task 4 – Drilling and Site Characterization
- Task 5 – Projects Impacts and Benefits Assessment Study

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- Task 6 – Final Report
 - Task 7 – Public Outreach
 - Task 8 – Project Management

This report presents the work performed for and the results of Tasks 1, 2, 3, 4, 5 and 6.

1.4 ORGANIZATION OF THE REPORT

This report is organized as follows:

- **Section 1 – Introduction:** This section.
- **Section 2 – Recharge Site Feasibility Investigation:** presents the evaluation of recharge capacity of potential recharge sites within the boundaries of and in the vicinity of RCWD. These activities were performed as part of activities of Task 1.
- **Section 3 – Conveyance Alternative Analysis:** presents the existing canal inventory and proposed improvements to the existing conveyance facilities and infrastructure. These analyses were performed as part of activities of Task 3.
- **Section 4 – Water Availability:** identifies the source of water and availability for recharge as a part of Task 2 activities.
- **Section 5 – Site Characterization:** presents the exploratory program for potential recharge facilities. This program was designed and applied as a part of activities of Tasks 1 and 4.
- **Section 6 – Overview of Kings IGSM:** presents an overview of the Kings Basin Integrated Groundwater and Surface Water Model (Kings IGSM) and Kings IGSM Existing Conditions Baseline scenario. This overview was provided as a part of activities of Task 5.
- **Section 7 – Recharge Rates and Schedules:** summarizes the volume and timing of surface water availability for the activities of Task 5.
- **Section 8 – Project Impacts and Benefits:** lists the updates to Kings IGSM model to develop recharge scenarios as a part of the activities of Task 5. It also summarizes impacts and benefits of the recharge operations at the potential recharge sites as part of the activities of Task 5.
- **Section 9 – Project Prioritization and Preferred Project:** summarizes the results of the analysis completed in Task 1 to 5 and presents the project prioritization and preferred project.
- **Section 10 – Summary:** provides a summary of the work performed and results of the project.

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- **Section 11 – References:** lists the documents cited in this report.
 - **Tables:** lists the tables used in Sections 1 to 10.
 - **Figures:** lists the figures used in Sections 1 to 10.
 - **Appendix A – Textural Summary of Boring Logs:** presents the textural summary of the USGS boring logs in the immediate vicinity of the project area.
 - **Appendix B – CPT Results:** presents the additional data for the CPT logs.

The performance of conjunctive use projects is enhanced through direct recharge, spreading, and groundwater banking of available allocated and unallocated flood waters. The recharge capacity of recharge ponds is dependent on site conditions and significantly influenced by soil conditions, depth to groundwater, and permeability of aquifer material. This section presents the evaluation of recharge capacity of potential recharge sites within the boundaries and in the vicinity of RCWD.

2.1 LAND SUITABILITY ANALYSIS

Site conditions have a significant impact on the success of recharge operations through recharge ponds or surface spreading. Properties of near surface soils directly affect the ability of water to infiltrate the ground, and subsurface aquifer conditions directly affect the quantity of water that can be stored in the subsurface. A good understanding of the properties of soils in the region provides valuable information for land acquisition opportunity, when a property comes into market.

This section describes the processes used to evaluate the suitability of lands in and around RCWD for recharge at a regional scale, based on the physical properties of the soil conditions and the economic feasibility of the land.

2.1.1 DATA SETS

Five different digital maps and data sets were collected and used to identify suitable lands in the region. These maps and data sets, all available as GIS shapefiles, include:

1. Land use
2. Hydrologic soils
3. A- and E-clay
4. Specific yield
5. Depth to groundwater water

The land use data were used to identify economically feasible lands in the region. Data items 2 and 3 were used to assess the infiltration ability and permeability of the regional lands. Data items 4 and 5 were used to evaluate the aquifer storage capacity. An index ranking system was developed, on a scale from 1 to 5, for different features of each of the data sets. A lower index value was assigned to less suitable land. An index value of zero was given for situations that would preclude a successful project. The ranking factors and quantification methods are shown in Table 2.1.

Land Use

Land use maps were used to screen out areas (e.g., urbanized areas) that are not economically feasible for spreading basins or are inappropriate for developing large scale recharge facilities. Areas in the urban spheres of influence may be excluded from conjunctive use sites; however, spheres of influence were not used as a criterion in this analysis. Idle and vacant lands are given higher rankings than cropped lands, and annually cropped lands are given higher rankings than the more permanently cropped lands. The ranking index for land use is shown in Figure 2.1 and Table 2.1.

Surface and Subsurface Conditions

Soils maps from the United States Department of Agriculture, Natural Resources Conservation Service present classifications of the Hydrologic Soil Groups were used to assess groundwater recharge feasibility. The soils map and the map of A-clay and/or E-clay formations were used to define areas that would allow for high rates of recharge and be favorable for downward flow of water to the aquifer. Areas identified as having the smallest runoff potential (Type A) are ranked highest, and areas identified as having the greatest runoff potential (Type D) are ranked lowest. Runoff potential is inversely proportional to infiltration rates (i.e., low runoff potential means high infiltration rates). Maps of the ranking index for Hydrologic Soil Groups and the presence of A-clay and/or E-clay are shown in Figures 2.2 and 2.3, respectively.

Available Storage

Available groundwater storage is a function of (1) the distance between the water table and the root zone of nearby crops, and (2) the ability of the geologic materials to transmit and store water, or the specific yield of the formation. Ranking criteria are based on both of these factors. Areas with a larger unsaturated zone and with higher specific yield are ranked higher. To be conservative, a Spring 2003 water levels map was used to calculate the depth to ground water. This was a year that followed a number of wet years and had relatively higher water table elevations. Maps of the ranking index for depth to water and specific yield are shown in Figures 2.4 and 2.5, respectively.

Weighting of Ranking Indices

To keep the analysis simple and straightforward, the resulting rankings were calculated with all factors evenly weighted. All of the five data coverages were overlaid in the GIS and the ranking indexes were applied to develop a composite score. A maximum possible value of 25 would represent land most suitable for recharge, and a minimum possible value of 3.92 would represent land least suitable for recharge. The distribution of the composite index is shown in Figure 2.6.

The composite index was then reclassified to produce a more general recharge potential map. Figure 2.7 simplifies the recharge potential into four categories, identifying areas as having very high, high, medium, or low potential for implementation of a successful direct recharge project.

2.2 PRELIMINARY SITE SELECTION

In addition to the data sets described in the previous sub-section, land availability, landowner cooperation, maximizing use of existing infrastructure, utilizing existing right-of-way to expand or extend conveyance facilities, and ensuring consistency with long-term land uses and water rights agreements were also considered and used as screening criteria during the selection process for the sites.

After compiling all the necessary information to identify suitable lands in the project area and consultation with RCWD, four site locations were selected, as shown in Figure 2.8 and Figures 2.9.a – 2.9.d. Two sites are within CID service area, one is within FID service area, and one is within RCWD service area. Table 2.2 summarizes some of the main characteristics of the proposed recharge sites.

Figure 2.10 shows the recharge potential of the proposed recharge sites. Similarly, site conditions relative to land use, soil permeability, E-clay, depth to groundwater, and relative specific capacity are shown in Table 2.3, with ranking indexes for each site and category. Table 2.3 shows that CID Marks Pond and CID Goldie Pond have higher recharge potential than FID Lower Dry Creek Pond and RCWD Vacant Land.

2.3 ENVIRONMENTAL IMPACTS ASSESSMENT

2.3.1 MINIMIZING THE ENVIRONMENTAL IMPACTS

The California Natural Diversity Database (CNDDDB) holds data on the status and locations of rare and endangered plant, animal, and vegetation types – information maintained by the Habitat Conservation Division of the California Department of Fish and Game (CDFG). The CNDDDB 2011 GIS layers were overlaid on top of the project sites, as shown in Figure 2.11.a and 2.11.b, to examine if the project sites are within any of the areas specified by the CNDDDB federal and California lists for rare and endangered plant, animal, and vegetation types. Figure 2.11.a and 2.11.b show that the projects sites are out of the areas specified by the CNDDDB federal and California lists.

2.3.2 AREAS OF GROUNDWATER CONTAMINATION

A detailed description of the groundwater quality around the project area is presented in WRIME (2002a,b). Primary groundwater quality concerns in the area are pesticides and nitrates. In general, groundwater in the area is suitable for intended agricultural use. The quality of water available for recharge (from Friant Kern Canal as Section 215 water or flood water from Kings River) at the project site will likely be higher than that of the underlying groundwater.

GeoTracker GAMA is an online groundwater information system from the California Department of Water Resources (DWR) that gives access to water quality data from 200,000

discrete well locations throughout the state. The database integrates groundwater quality data from multiple sources, which are searchable by chemical or location. The locations of the project sites were compared with wells with any chemical comparison concentration within the area. There are a few wells with high nitrate levels within RCWD, but they are not near any of the proposed project sites.

Water quality has not been an issue at nearby recharge basins and is not expected to be an issue for this project, based on the findings from reports created by WRIME (2002a,b) and GeoTracker GAMA database.

2.3.3 LIMITING THE LAND SUBSIDENCE POTENTIAL

Land subsidence results from extensive groundwater pumping beneath laterally extensive confining layers. The removal of groundwater causes increased pressure on fine grained deposits below the confining layer, which results in compaction of the fine grained layers at depth and is evident at the ground surface as land subsidence. While there has been subsidence in the areas of Western San Joaquin Valley (such as in the Westland Water District and the Pleasant Valley Water District), there is no regionally extensive land subsidence within RCWD (Ireland et al. 1980). Faunt ed. 2009 estimates around one foot of land subsidence around RCWD from the distribution of land subsidence estimated from 1961 to 1977 extensometer data. The same report estimates a few feet of total simulated subsidence from water years 1962 through 2003 around RCWD.

2.4 SITE VISITS

The purpose of the site visit was to identify any fatal flaws, review the location for access, and evaluate conditions for selection of the final exploration and monitoring well locations. Four sites were selected based on land availability, preliminary groundwater recharge potential, maximizing use of existing infrastructure, and land owner cooperation. Two sites are currently used as groundwater recharge ponds near the western boundary of CID Goldie Pond and Marks Pond. The third site is vacant land owned by RCWD. The fourth site is near the boundary of RCWD and FID. FID holds a flood easement and has two canals in place to deliver water for recharge.

2.4.1 FID FLOOD EASEMENT SITE

The Fresno Irrigation District recharge pond is located between McMullin Grade and Lincoln Avenue and between Highway 145 and Jameson Avenue (Figure 2.9.a). The pond is approximately 60 acres and has flood easement rights (shown in Figure 2.8) to the surrounding 1,600 acres. The site has access from McMullin Grade along a canal connecting the pond and James Irrigation District's McMullin Grade canal. The source of water comes from FID's Lower

Dry Creek Canal, with a capacity of approximately 100 cfs. The surrounding land is currently being farmed and is available for the spreading of flood water under FID's flood easement. The existing pond would be under consideration for future expansion to 80 acres for surface water retention and groundwater recharge and banking.

2.4.2 RCWD VACANT LAND

The project site (Figure 2.9.b) within RCWD is located on the northeast corner of Chateau Fresno Avenue and Manning Avenue, in Fresno County. RCWD purchased this land as a potential groundwater recharge basin because it was available and anecdotal information from neighboring landowners indicated that the site would make a good site for groundwater recharge. There are two constraints to overcome for this project site. First, there are no existing canals that can deliver water to the site and any infrastructure to convey water would have to be through a buried pipeline. Neighboring landowners are in-favor of the project but do not want to have canals running through their farmland. Second, the site is outside of the Kings River Water Association (KRWAA) service area and may have to rely on short-term contracts for Kings River water or other sources of water.

2.4.3 CID GOLDIE POND

Goldie Pond (Figure 2.9.c) is owned and operated by CID and is located on Marks Avenue, north of Manning Avenue, in Fresno County. The pond is currently used for groundwater recharge and is approximately 40 acres. Wristen Ditch is an existing CID canal and has a capacity at the headgate of 100 cfs. The canal size has a 45 cfs capacity, which feeds Goldie Pond through a pipeline with a capacity of 25 cfs. Canal and pipeline improvements are needed to increase capacity to 50 cfs into the recharge pond. Goldie Pond has the potential to recharge surface water from the Kings River and other sources. The site has street access along Marks Avenue for site drilling and soil testing.

2.4.4 CID MARKS POND

Marks Pond (Figure 2.9.d) is owned and operated by CID and is located south of Flora Avenue and west of Marks Avenue, in Fresno County. The pond is currently used for groundwater recharge and is approximately 40 acres. Marks Pond receives surface water from the Kings River during flood events and is delivered by two canals, Wristen Ditch with a capacity of 45 cfs from the north, and a second canal with approximately 40 – 50 cfs from the south. The pond does not have direct street access, and drilling rigs approaching from Flora Avenue may find access difficult. Access from Mark Avenue may be possible, but the canal bank is steeper on the east.

This section presents the existing canal inventory to determine whether existing conveyance facilities are adequate for transferring water from the selected sources to the selected recharge locations. It also presents the proposed improvements to the existing conveyance facilities and infrastructure needed to convey the selected quantities of recharge water to the selected recharge sites.

3.1 ESTIMATED RECHARGE VOLUMES

The capacities of the conveyance systems and recharge basins are generally the limiting factors for the volume of water that can be recharged. The existing canals were examined to determine if they have enough capacity to convey the total amount of water needed for recharge operations. Table 3.1 shows how much water can be recharged for an estimated minimum and maximum recharge rate for each site and the corresponding design flows. The numbers from Table 3.1 can help assess if any improvements to the existing conveyance facilities, any additional new conveyance facilities, or any new infrastructure are necessary.

3.2 EXISTING CANAL INVENTORY

Existing canal locations and capacity data were obtained from FID, CID, KRCD, and personal communications with local authorities. Based on the available data, canal capacities for the major FID and CID canals are shown in Figures 3.1 and 3.2, respectively. Also, canal capacity data for the major FID and CID canals and Friant-Kern Canal is summarized in Table 3.2.

Frequency analysis of the daily diversion potentials and canal capacity was conducted to determine the availability of excess canal capacity above other demands, at the time when recharge water is available. The frequency analysis was also used to determine the timing of canal capacity availability. Headgate diversion records of the CID's Consolidated Canal and FID's Fresno Canal and Gould Canal were obtained from KRWA. Friant-Kern Canal flow data was obtained from U.S. Geological Survey (USGS). Available canal capacities were determined by evaluating the daily differences between canal capacity and headgate diversions from 1964 to 2011. Table 3.3 shows what percent of the time the available canal capacities were more than 75 cfs, 100 cfs, 150 cfs, 200cfs, and 250 cfs on daily basis. Available canal capacities greater than 200 cfs for Friant-Kern Canal, Consolidated Canal and Fresno-Gould Canals are 100%, 100% and 95% of the days from 1964 to 2011, respectively. The combined design flow for all of the proposed recharge ponds is 160 cfs (Table 3.1) for the estimated maximum recharge rates. The availability of all three canal capacities becomes 100% when the same analysis is done just for the flood dates. As a result, canal capacity for the three major canals should not be a limiting factor to divert water to proposed recharge ponds.

Figure 3.3 shows the CID and FID tail-end canals close to the proposed recharge sites. Table 3.4 also summarizes the canal capacity for Wristen Ditch and Dan Smith Ditch, which are the tail-end canals for CID recharge sites, and the Central Wasteway, McMullin Grade, and Lower Dry Creek Canals, which are the tail-end canals for the FID recharge site. Since flood water from Kings River and Friant-Kern Canal will be only available during the flood seasons when there is almost no irrigation, we can assume that canal capacity for the tail-end canals would be available at almost 100%.

Design flow for the CID Goldie Pond is 40 cfs at the maximum estimated recharge rate. Wristen Ditch has enough capacity to provide this flow during the flood releases. The remaining capacity of Wristen Ditch combined with Harlan Stevens Ditch would have enough capacity to provide 40 cfs of design flow to CID Marks Pond at the maximum estimated recharge rate. Both Central Wasteway and McMullin Grade have capacities bigger than 40 cfs, which is the design flow for the RCWD recharge site at maximum estimated recharge rates. Additional conveyance facilities should be added to convey water from the Central Wasteway or McMullin Grade to the RCWD recharge site. The capacity of the Lower Dry Creek is large enough to convey 40 cfs of water, which is the design flow for the Lower Dry Creek Pond at maximum estimated recharge rate.

3.2 IMPROVEMENTS / NEW CONVEYANCE FEASIBILITY

FID and CID operate extensive canal systems that carry water from Friant-Kern Canal and Kings River to their respective service areas. The existing canal systems can transfer water all the way to the boundary of RCWD. The existing canals can be used to convey water for the proposed recharge sites within the CID and FID service areas with minimum improvements. However, more improvements and new facilities would be necessary to carry the water to the RCWD recharge site.

The intent is to utilize existing canals, available land, and recharge facilities to maximize the opportunity to recharge groundwater. The selected recharge ponds are underutilized because of initial design constraints of the canal system. The canals were designed to deliver surface water from the river at the headgate to the farm land, thus requiring large capacities near the river and less at the end of the canal. The headgate capacity of the main canal in CID is 2,100 cfs, while the canals at the end of the system may only require 15 cfs.

This section outlines improvements to existing facilities and the development of a new conveyance system to optimize movement of surface water for direct groundwater recharge.

3.2.1 EXISTING FACILITIES IMPROVEMENTS

The CID Goldie Pond's primary source of water is delivered through Wristen Ditch. Wristen Ditch has a headgate capacity of 100 cfs and tapers down to approximately 45 cfs. The water is

diverted into the pond through a buried, 24-inch pipeline, approximately 200 yards in length. The recommended improvements are to increase the canal capacity and diversion pipeline (Figure 3.4). The soil in the general area is sandy. Enlarging the canal to 100 cfs may require reinforcement of the levies to protect neighboring landowners from flooding. The canal should be enlarged from CID Goldie Pond to Highway 41, approximately 5.25 miles. The underpass at Highway 41 constrains the water flow to an unknown capacity. The rebuilding of the underpass may allow 100 cfs flow of water through Wristen Ditch.

Enhancement to Wristen Ditch to deliver additional water to the CID Marks Pond requires increasing capacity of two segments of pipeline and two segments of canals, as shown in Figure 16. Downstream of the Goldie Pond, Wristen Ditch flows through a buried pipeline, 1.75 miles in length, resurfaces to a canal of approximately 45 cfs for 0.5 mile, and flows into another buried pipeline for another 0.5 mile. The pipeline discharges into a canal for 0.5 mile leading to the CID Marks Pond. The sizes of the buried pipes and canal are unknown, but are estimated to allow up to 45 cfs flow of gravity fed water. Increasing the capacity of the segments of pipe and canal will allow additional intake of water to the CID Marks Pond and future pond development between the CID Goldie and Marks Ponds.

The Lower Dry Creek Pond and surrounding flood easement land is capable of receiving water through the Lower Dry Creek Canal, which has a 100 cfs capacity. The pond site is currently only 60 acres and receives water during flood seasons. Increasing the capacity of the pond to 80 acres when land becomes available is recommended. The pond can be used for groundwater recharge or as a holding/regulation basin to optimize conveyance operations. The pond is located along the McMullin Grade and it can allow for possible future water banking or exchange projects with James Irrigation District. Exchanging surface water to reduce or eliminate pumping along McMullin Grade would help restore the groundwater basin.

3.2.2 NEW CONVEYANCE FACILITIES

The vacant land owned by RCWD, located near Manning Avenue, is 80 acres. Delivering water to the RCWD pond will require development of new canals or pipelines. There are a few canals within the district for on-farm use. Landowners are supportive of having recharge basins developed within the district, but do not want canals interrupting access to their farmland, impeding operations, or causing a loss of available farmland. The alternative is to use a buried pipeline to convey water. A series of pipeline options that connect CID and FID conveyance systems to the proposed RCWD pond are described below.

There are two options to connect the CID conveyance system to the proposed RCWD pond. These options are labeled as CID Intertie Options 1 and 2 in Figure 3.5. CID Intertie Option 1 diverts water from Wristen Ditch downstream of CID Goldie Pond through a 3.9-mile pipeline along Manning Avenue. CID Intertie Option 2 diverts water from Wristen Ditch near CID Marks Pond through a pipeline, 5.25 miles along Henderson Road, with a turnout at Manning

Avenue to the RCWD pond. Figure 17 shows the option labeled as FID Intertie to connect the FID conveyance system to the proposed RCWD pond. FID Intertie diverts water from Central Wasteway through a pipeline, 4.6 miles along S. Grantland Avenue, with a turnout at Manning Avenue to the RCWD pond. 48 inch diameter pipes would be used for the proposed buried pipelines that would allow 50 cfs gravity flow.

The availability of surface water for infiltration at the potential recharge sites needs to be assessed for source, volume, and timing of excess surface water availability standpoint. This section discusses the recharge water availability.

4.1 SOURCES OF WATER SUPPLY

The sources of surface water potentially available in this region include the Kings River (flood flows, entitlement flows, and conserved releases), Section 215 flood water releases from Millerton Lake to Friant-Kern Canal, and excess storm flow and treated wastewater from the City of Fresno.

4.1.1 FLOOD FLOWS FROM THE KINGS RIVER

Kings River is a fully appropriated stream. This means that water rights have been granted for the entire year round flow of the Kings River. Even with the full appropriation of surface water supplies, there are times when Pine Flat Reservoir and existing facilities cannot store or manage all of the available water in the Kings River. Flood flows not stored behind the Pine Flat Dam or currently being diverted into irrigation districts' canals run down the Kings River to the Lower Basin, where they may be directed to either the North Fork of the Kings River and the James Bypass flood channel, or to the South Fork of the Kings River and Tulare Lake Basin. The flood flows could be captured and used as a water supply for the groundwater recharge project.

The Kings River flood water has been a reliable source for groundwater recharge. However, there are institutional constraints for the use of Kings River water. The Kings River is managed by the 28-member KRWA. Water from the Kings River can only be used within the KRWA service area that includes the individual district members' boundaries. The RCWD proposed sites are outside the KRWA service area and not eligible to receive water from the Kings River. The KRWA has made exceptions for recharging groundwater if there will be benefits to the KRWA service area through a short-term, annual-renewable contract for use of the Kings River flood water. Use of Kings River water may be available, but since long-term agreements cannot be made, it is assumed that water from sources other than the Kings River will be used for recharge at the RCWD project site.

4.1.2 SECTION 215 WATER

Pursuant to Section 215 of the Reclamation Reform Act of 1982 (RRA) (Public Law 97-293), the Secretary of the Interior is authorized to contract for temporary supplies of water, resulting from an unusually large water supply not otherwise storable for project purposes, or from infrequent and otherwise unmanaged flood flows of short duration, provided such temporary

water supplies do not adversely affect other authorized project purposes. These temporary water supplies are commonly referred to as Section 215 water or surplus water.

The U.S. Bureau of Reclamation (Reclamation) has determined that unusually large water supplies may result from winter hydrology in some years such that future restricted storage capacity in Millerton Lake may create a non-storable supply of water, pursuant to Section 215 of the RRA (Section 215 water). This water supply may be offered to non-Central Valley Project (CVP) contractors via temporary water service contracts. Friant Division and Cross Valley CVP long-term contractors have first priority in the offering and conveyance of the Section 215 water. Non-CVP contractors have a lower priority in the offering and conveyance of Section 215 water.

4.1.3 RECLAIMED WATER FROM FRESNO-CLOVIS REGIONAL TREATMENT PLANT

Municipal wastewater from the Cities of Fresno and Clovis and industrial wastewater from some of the food processing plants in the Fresno Metropolitan Area at a rate of about 80,000 AF/year are treated at the Fresno-Clovis Regional Wastewater Treatment Facility. The treated wastewater from this plant is directed mostly to percolation ponds where it percolates down into the aquifer. There are several reclamation wells at this facility that pump out groundwater to control the mound underneath the ponds. The reclaimed water is pumped into FID canals. These canals transfer the reclaimed water downstream for agricultural use. About 5% to 10% of treated wastewater is directly used for agricultural land at and in the vicinity of the facility. It will be assumed that any potential water from the Fresno-Clovis Regional Wastewater Treatment Plant will not be a reliable source of recharge water for the purposes of this project, because FID is developing a strategic plan to optimize its existing recharge facilities to utilize the extra water from this plant.

4.1.4 STORMWATER FROM CITY OF FRESNO

Management of stormwater collection and ponding is performed by cooperation between the Fresno Metropolitan Flood Control District (FMFCD), the Cities of Fresno and Clovis, and FID. A cooperative groundwater recharge program was developed among these partnering agencies to capture approximately 90% of urban runoff in stormwater basins for groundwater recharge. The stormwater basins are used by FID and the cities during the dry seasons as groundwater recharge basins. FMFCD and FID are currently developing a strategic plan to optimize the capture and recharge (in-lieu or direct) of stormwater. It will be assumed that any potential water from urban runoff will not be a reliable source of recharge water for the purposes of this project.

4.2. FREQUENCY ANALYSIS OF WATER SUPPLY SOURCES

4.2.1 FLOOD FLOWS FROM THE KINGS RIVER

Kings River flood flows are highly variable from year to year, as shown in Figure 4.1, which presents the daily flows at the James Bypass gaging station for the period of record. Table 4.1 shows the frequency, duration, and episodic nature of the flow events from 1964 to 2009. Also shown are the daily minimum, maximum, averages, and annual sum of the quantities of water within the combined Upper Districts' entitlements, which have been lost to the Upper Basin during these flood events. It is these quantities of water that may be the sources of water for RCWD's recharge projects.

Daily analysis of flow and frequency of occurrence help to quantify diversion and recharge opportunities. Figure 4.2 shows a frequency analysis including the flows at the James Bypass. It shows that measured flows at the James Bypass occurred less than 15% of the time from 1964 to 2009. As shown in Figure 4.1, these flows typically occur at high rates over relatively short periods of time. Table 4.2 shows the frequency of measured flows at the James Bypass during flood events exceeds 50 cfs, 75cfs, 100, cfs, 150 cfs, 250 cfs, and 300 cfs, respectively. Either 150 cfs or greater amounts of water were lost through the James Bypass 92% of the time. This could provide more than enough water for all the proposed recharge ponds, except the RCWD site, when they are all recharging water at their estimated maximum rate. Either 300 cfs or greater amounts of water were lost through the James Bypass 89% of the time. This could provide for all the proposed recharge ponds plus 300 acres of additional ponds that can recharge one foot of water per day.

4.2.2 SECTION 215 WATER

Section 215 water is non-storable Millerton Lake water due to flood space requirements. It can be used by non-Friant contractors. It is usually declared as it flows into Millerton Lake during winter rain floods or spring snowmelt floods, and is often declared to quickly evacuate water stored in the flood control storage pool. Figure 4.3 shows the monthly deliveries of Section 215 water to various districts, cities and agencies from 1982 to 2006. Additional Section 215 water declaration and availability data could not be obtained.

Table 4.3 shows the comparison of the duration and timing of the flood events at the James Bypass and Section 215 water releases from water year 1983 to water year 2006. Although the long term average duration of the events is almost the same, occasionally the timing and duration of the events differs. As a result, Section 215 water can be used as a supplement to the flood flows from Kings River for recharge operations for CID and FID recharge ponds, and it can be the source of water for the RCWD recharge pond, which does not have any water rights from the Kings River. Also, Section 215 water can extend the duration of the water availability

for CID and FID recharge ponds, when it starts earlier or ends later than the Kings River flood flows.

Table 4.4 shows the frequency, duration, and amount of delivered water events from water year 1983 to water year 2006. There is no data available on how much more water was available on top of the amount of water delivered. The RCWD recharge pond would require around 2400 acre-feet of water per month if a maximum recharge rate of one foot per day is assumed. The average amount of water delivered as Section 215 water was around 27,000 acre-feet per month when it was available. This is almost 11 times more water than what is needed for the RCWD recharge pond. The average amount of water delivered as Section 215 water (27,000 acre-feet per month) is almost 1/12th of the average Kings River flood water measured at the James Bypass during the flood events. It would be safe to assume that there was more Section 215 water available during flood releases than what was delivered. As a result, it can be assumed that there should be at least enough Section 215 water available for use for the RCWD recharge pond.

4.3. PURCHASE AND DELIVERY COSTS

4.3.1 FLOOD FLOWS FROM THE KINGS RIVER

Kings River water is managed by the KRWA using a scheduled of water rights based on river water storage and flows. During flood events, river water is available to all of the KRWA member agencies. According to KRWA, every drop of water from the Kings River has a name associated with it, meaning all of the water is purchased and owned by the members of KRWA. The Kings River supplies the member agencies with low cost water. Landowners served by FID with Kings River water, on average, pay approximately \$9 per acre-foot. During flood events, water has already been paid for by the member agencies' standard rates and they will not be charged for additional flood water delivered. In essence, this makes flood water very inexpensive, or free, if a member agency has the capacity to take additional water.

4.3.2 SECTION 215 WATER

Historically, Section 215 water was nearly free and generally used for early season irrigation or groundwater recharge. However, Reclamation started charging for Section 215 water in 1986, when legislation led to new operation and maintenance costs assessed to irrigators. This resulted in a fourfold increase in prices in 1989 (Moss 1998). However, the greatest impact on Friant water costs has been the passing of the Central Valley Project Improvement Act (CVPIA) in 1992. The CVPIA mandated a Friant Surcharge and a Restoration Fund Charge added to regular water assessments, which resulted in a \$14 increase per acre-foot delivered for Class 1 (the first 800,000 acre-feet available water at Millerton Lake, which is considered the firm yield of the Friant project), Class 2 (the next 1,400,000 acre-feet, which is only declared when inflow

forecasts indicate that all Class 1 demands can be met), and Section 215 water. Section 215 flood water prices are currently on the order of Class 2 prices (Leu, 2001). But, Section 215 water prices can decrease to encourage the evacuation of flood water from Millerton Lake.

Table 4.5 summarizes the breakdown of the water rates for irrigation and M&I Section 215 water from 2004 to 2011, published by United States Bureau of Reclamation (USBR).

The subsurface investigation focused on the upper portions of the aquifer, to identify potential low conductivity layers that could slow recharge or contribute to seepage problems on nearby properties. By focusing on performing Cone Penetrometer Tests (CPT) in the upper portions of the aquifer to approximately 100 feet, detailed data was obtained for the shallow subsurface while relying on data on deeper materials from boring logs available from DWR logs.

As per the recommendations of Technical Memorandum No. 1, the subsurface investigation was revised to make better use of existing boring log data and focus the site characterization efforts to the upper portions of the aquifer to identify potential low conductivity layers that could slow recharge or contribute to seepage problems on nearby properties. An analysis of boring logs from DWR and USGS showed that numerous boring logs are available in the area of the proposed basins to a depth of approximately 200 to 500 feet below ground surface. Boring logs such as these are typically more accurate at depth ranges near the anticipated or final screened interval and areas near the surface are often logged with less precision. By focusing CPT to maximum depth of 100 feet, more data were obtained for the shallow subsurface while extensive data on deeper materials were obtained from the well logs.

5.1 REGIONAL SETTING

Surficial geology in the area indicates the prevalence of quaternary age sand dunes for the three sites where field work was performed. The fourth site, FID Lower Dry Creek Pond, is in an area of quaternary older alluvium. Major features at depth in the region are the A-, C-, and E- Clays. The sites are located slightly to the northeast of the extent of the A-Clay and the C-Clay, regionally extensive clays at depths of approximately 100 ft below ground surface (bgs) and 200 ft bgs, respectively. The E-Clay (or Corcoran Clay) is present in the area. The E-Clay is typically at a depth of approximately 600 ft bgs. The depths of wells included in this study ranged from 185 to 555 feet deep, with an average depth of 315 feet. These depths suggest that the ability to recover recharged water would not be significantly impacted by the E-Clay.

5.2 CPT METHODS

Prior to the field work program, permits were obtained from Fresno County and utilities were cleared by a private utility surveyor and by Underground Services Alert.

CPT Testing was performed by Gregg Drilling under contract to WRIME. The CPTs were performed using an integrated electronic cone system (See Figure 5.1). The soundings were conducted using a 20 ton capacity cone with a tip area of 15 cm² and a friction sleeve area of 225 cm². The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.80.

The cone takes measurements of cone bearing (q_c), sleeve friction (f_s) and penetration pore water pressure (u_2) at 5- cm intervals during penetration to provide a nearly continuous log. CPT data reduction and interpretation is performed in real time facilitating on-site decision making. The above mentioned parameters are stored electronically for further analysis and reference. All CPT soundings were performed in accordance with revised (2007) ASTM standards (D 5778-07).

The cone also contains a porous filter element located directly behind the cone tip (u_2). It consists of porous plastic and is 5.0mm thick. The filter element is used to obtain penetration pore pressure as the cone is advanced as well as Pore Pressure Dissipation Tests (PPDT's) during appropriate pauses in penetration. Prior to penetration, the element is fully saturated with oil under vacuum pressure to ensure accurate and fast dissipation. The cone has the following accuracy: 1 tsf for q_c , 0.02 tsf for f_s and 0.5 psi for u_2 .

When the soundings are complete, the test holes were grouted to the surface, per Fresno County regulations. The grouting procedures consisted of pushing a hollow tremie pipe with a "knock out" plug to the termination depth of the CPT hole. Grout is then pumped under pressure as the tremie pipe is pulled from the hole. Disruption or further contamination to the site is therefore minimized.

CPT operations generated no cuttings or liquid waste.

5.3 CPT AND BORING LOG LOCATIONS

The CPT field program and analysis of available boring logs occurred at three of the four proposed sites: RCWD Vacant Land, CID Marks Pond, and CID Goldie Pond. The FID Lower Dry Creek Pond was partially flooded at the time of field work and was removed from the field program. Additional CPT borings were performed at the remaining three locations. The locations of the CPT borings and available boring logs from DWR are shown in Figure 5.2, with additional detail provided in Figures 5.3, 5.4, and 5.5.

5.4 ANALYSIS OF BORING LOGS

Between four to six boring logs in the immediate area of each proposed location were obtained and reviewed to identify subsurface materials, focusing on the prevalence of coarse (sands) and fine (clays) grained materials and on the thickness and lateral extent of fine grained materials. Data was obtained from a USGS database which classified textural categories for specified depth intervals from available driller's logs. It should be noted that the locations of the borings are approximate given the limitation of the original data sources and to maintain confidentiality of the data source. Appendix A contains the complete details from the USGS database, but the actual boring logs are not provided due to confidentiality. The boring logs may be obtained from DWR by agencies if needed for specific and appropriate usage.

Figures 5.3, 5.4, and 5.5 were developed to show the location of the CPT and boring logs as well as to summarize the information collected.

5.5 ANALYSIS OF CPT LOGS

CPT logs are included in the figure with the Soil Behavior Type (SBT) and penetration pore pressure, measured behind the cone (u_2). Additional data not displayed due to space limitations on the figure are included in Appendix B.

The SBT is based on the work of Lunne et al. (1997) and utilizes data collected by the CPT to categorize subsurface materials into the types listed in Table 5.1.

Pore pressure can be used to assist in identification of soil type, adding to other data collected through the CPT (e.g., tip resistance and sleeve friction). In soft clay and silt the penetration pore pressures can be very large, whereas, in stiff heavily over-consolidated clays or dense silts and silty sands the penetration pore pressures can be small and sometimes negative relative to the equilibrium pore pressures. (Gregg Drilling, 2010)

A summary of the results from the three sites is provided in the following subsections.

RCWD VACANT LAND SITE

Data for the RCWD Vacant Land Site includes six new CPT locations and six existing boring logs. These data are summarized in Figure 5.3. The CPT results show details of the shallow subsurface (upper 100 feet). The shallow subsurface is characterized by primarily “sand & silty sand” (yellow) and “silty sand and sandy silt” (green). Few clays (blue) are present, but there are several intervals of over-consolidated or cemented materials (finer grained: light grey, coarser grained, dark gray). These over-consolidated materials could slow the downward migration of recharge water and could result in a perched aquifer and lateral movement of water. These materials are generally located in two depth ranges, the shallower range between 20 and 40 feet bgs and the deeper range between 85 and 100 feet bgs. There is variability across the site, with 2CPT4 (southwest corner) showing significantly less over-consolidated or cemented materials and 2CPT6 (southeast corner) showing significantly more. No correlation between the CPT logs and the boring logs could be discerned, although the logs show more fine grained materials than coarse grained materials.

CID GOLDIE POND SITE

Data for the CID Goldie Pond Site includes four new CPT locations and four existing boring logs. These data are summarized in Figure 5.4. The CPT results show details of the shallow subsurface (upper 100 feet). The shallow subsurface is characterized by primarily “sand & silty sand” (yellow) and “sand” (orange). Few clays (blue) are present, with one notable exception of clays at approximately 30 to 40 feet bgs. There are also several intervals of over-consolidated or

cemented materials (finer grained: light grey, coarser grained, dark gray). Along with the clays, these over-consolidated materials could slow the downward migration of recharge water and could result in a perched aquifer and lateral movement of water. These materials are generally located at depths below 30 feet bgs. There is variability across the site, with 3CPT4 (southwest corner) showing significantly more clays below 50 feet and the other locations showing more over-consolidated or cemented materials. No correlation between the CPT logs and the boring logs could be discerned, although the logs show similar amounts of coarse grained and fine grained materials.

CID MARKS POND SITE

Data for the CID Marks Pond Site includes five new CPT locations and four existing boring logs. These data are summarized in Figure 5.5. The CPT results show details of the shallow subsurface (upper 100 feet). The shallow subsurface is characterized by primarily “sand & silty sand” (yellow) and “sand” (orange). Few clays (blue) are present, but there are a few intervals of over-consolidated or cemented materials (finer grained: light grey, coarser grained, dark gray). These over-consolidated materials could slow the downward migration of recharge water and could result in a perched aquifer and lateral movement of water. These materials are generally located in one depth ranges: between 60 and 90 feet bgs. There is variability across the site, with 4CPT5 (southwest corner) showing significantly less over-consolidated or cemented materials and 2CPT1 (southeast corner) showing significantly more. No correlation between the CPT logs and the boring logs could be discerned, although the logs show more coarse grained materials than fine grained materials.

5.6 RECOMMENDATIONS BASED ON CPT RESULTS

Of the three ponds where CPT was performed, the CID Marks Pond Site appears best suited for recharge activities. Both the CPT results and the existing boring logs show coarser materials than present, on average, at the other sites. The RCWD Vacant Land Site contains generally finer grained materials and the Goldie Pond Site contains more extensive over-consolidated or cemented materials. It is recommended that efforts proceed with developing a recharge program for the CID Marks Pond Site, with additional work at the RCWD Vacant Land and Goldie Pond Site on hold until details on pilot testing or full scale recharge activities is available from the CID Marks Pond Site. If Marks Pond is successful, additional work may be warranted at the less suitable sites.

The Kings Basin Integrated Groundwater and Surface water Model (Kings IGSM) was used to evaluate the impacts and prioritize project alternatives of the RCWD recharge project. The Kings IGSM is a regional integrated water resources model that covers the entire Kings Basin and incorporates forty one years of hydrogeologic conditions, land use, crop pattern, diversions of Kings River and major canals in the Kings Region to simulate the surface water and groundwater systems of Kings Basin.

6.1 MODEL AREA

The Kings IGSM, as shown in Figure 6.1, covers the Kings Groundwater Basin area plus the Mendota Pool area, Tranquility Irrigation District, and urban and agricultural areas in the foothills. The model area extends about 50 miles from west to east and about 35 miles from north to south. The model area includes the Fresno-Clovis metropolitan and other urban areas, two major rivers (Kings River and San Joaquin River), major canals, and several small creeks.

6.2 MODEL GRID AND SUBREGIONS

Water and land use management in the model area is represented in the Kings IGSM by subdividing the model area into 32 management areas called subregions (Figures 6.1 and 6.2). The subregions are used for independent analysis of water budgets and hydrologic conditions for each management area. Subregions represent urban areas sphere of influence, individual water districts, irrigation districts, or other organized and/or unorganized areas within the model. Figure 6.2 shows the Subregion 21 that represents the Raisin City Water District service area.

6.3 CALIBRATION PERIOD

The IGSM is a dynamic simulation model that simulates groundwater flow and stream flow for a continuous period of time. The time period of 1964-2004 was selected for calibration of Kings IGSM. This period contains an array of representative wet and dry periods and includes the operations of Pine Flat Reservoir under the final agreements. It also follows importation of Friant-Kern water to Kings Basin. Figure 6.3 shows the annual rainfall total at Hanford, California for the 1927-2004 hydrologic period. This figure indicates that the 77-year average annual rainfall (1927-2004) is 8.1 inches in the valley floor. The calibration period of 1964-2004 has an average annual rainfall of 8.4 inches.

6.4 EXISTING CONDITIONS BASELINE

The Kings IGSM model was used to evaluate the scenarios for the recharge project based on the 2005-Existing Conditions land and water use conditions. The model input files for the Existing Conditions (EC) Baseline were developed using the assumptions listed in Table 6.1. The results of the recharge scenarios were compared with those of EC Baseline Scenario.

The Kings IGSM model uses the hydrology and surface water deliveries that occurred during the calibration period, from 1964 to 2004, to represent future hydrological conditions. It is assumed that the hydrologic conditions observed over the past 40 years for Kings River and San Joaquin streamflows and diversions would occur over the next forty years. The 1964 to 2004 period contained both wet and dry periods and appropriate hydrologic variability to represent a range of conditions.

Simulated groundwater levels for EC Baseline Scenario under wet and average hydrologic conditions of 1983 and 2004 are shown in Figures 6.4 and 6.5, respectively. The contour maps show that the groundwater decline in RCWD area continues into the future. Long-term annual average water budget for RCWD subregion is shown in Figure 6.6. The annual average outflow from the RCWD subregion is by 201,400 acre-feet/year of groundwater pumping. The annual average inflow to the RCWD subregion is compensated by 143,300 acre-feet/year of subsurface inflow from the surrounding subregions and 44,600 acre-feet/year of deep percolation from rain and irrigation. Groundwater pumping is greater than inflow to subregion and groundwater storage is depleted by 13,500 acre-feet/year. Simulation of recharge scenarios, presented in the following sections, show how the groundwater levels and water budget components of RCWD subregion changes as a result of the recharge operations.

The availability of surface water for recharge at the potential recharge sites was assessed in Sections 3 and 4 for source, volume, and timing of surface water availability. The sources of surface water available for recharge at the proposed recharge ponds include the Kings River streamflows, Section 215 flood water releases from Millerton Lake to Friant-Kern Canal. The estimated daily recharge rates shown in Table 3.1 were used to estimate the monthly low and high recharge rates for each recharge site (Table 7.1). It is assumed that capacity of the existing and proposed conveyance facilities would be sufficient to convey water for the proposed monthly recharge rates.

Flood flows of Kings River will be recharged at the proposed recharge ponds within the Kings River Water Association (KRWA) service area located in FID and CID. The proposed site outside of the KRWA service area, RCWD, will receive flood flows under Reclamation's Section 215 water. The availability of these waters varies based on hydrologic conditions of San Joaquin and Kings rivers and their durations change from year to year as shown in Tables 4.1, 4.3, and 4.4. These tables were used to develop annual recharge quantities and schedules for recharge scenarios. Monthly recharge rates remain as those in Table 7.1; however, the number of months with active recharge ponds were estimated based on historical data shown in Tables 4.1, 4.3, and 4.4.

The annual recharge rates and schedules in Figures 7.1 and 7.2 were used to develop the recharge rates and schedules of the recharge scenarios. The simulated recharge rates at RCWD Pond are based on availability of Section 215 water from Friant-Kern Canal and the annual recharge rates for the forty one year simulation period are shown in Figure 7.1. This figure shows the annual low and high recharge rates for the years with Section 215 water.

The simulated recharge rates at Dry Creek Pond, Goldie Pond, and Marks Pond are based on availability of Kings River flood waters and the annual recharge rates for the forty one year simulation period are shown in Figure 7.2. This figure shows the annual low and high recharge rates for the years with Kings River flood water.

8.1 RECHARGE SCENARIOS

Suitability of four sites in and around RCWD was evaluated in Section 2 for recharge at a regional scale. Based on the proposed recharge sites and the recharge schedule of Section 7, five scenarios were developed as follows:

- Scenario 1 – Recharge at RCWD Pond
- Scenario 2 – Recharge at FID Pond
- Scenario 3 – Recharge at Goldie Pond
- Scenario 4 – Recharge at Marks Pond
- Scenario 5 – Recharge at All Ponds

For each one of the above scenarios two sub-scenarios were developed for low and high recharge rates as follows:

- Scenario a - Low Recharge Rate
- Scenario b - High Recharge Rate

Thus, a total of 10 scenarios were developed to evaluate the impact of recharge operations at the four potential recharge sites. The first column of Table 8.1 lists all ten simulated recharge scenarios. Columns 2 to 6 of Table 8.1 present the average annual recharge rates for all scenarios. Average recharge rates for Dry Creek, Goldie, and Marks ponds are based on 17 years of Kings River flood years; while the average recharge rates of Scenarios 1a and 1b for RCWD pond are based on 12 years of Section 215 water years. Average recharge rates for Scenarios 5a and 5b is for a combination of Kings River flood years and Section 215 water years. As some of the Kings River flood years and Section 215 water years occur in the same year, there are a total of 22 years of flood years for Scenarios 5a and 5b. The impact of the simulated recharge scenarios are presented in Section 9.

The impacts of 10 recharge scenarios, 1a to 5b, were evaluated using the Kings IGSM Model and compared to the results of the EC Baseline Scenario. The following criteria were used to compare the impacts of the EC Baseline conditions to the project scenarios:

- Hydrographs of groundwater levels at the recharge sites,
- Contour maps of changes in groundwater levels at RCWD and the surrounding areas, and
- Change in groundwater storage in RCWD subregion.

Hydrographs and contour maps are presented in this section to show the project impacts and benefits. Changes in groundwater storage will be used in Section 9 to prioritize the scenarios and select the preferred recharge project.

8.2 RECHARGE AT RCWD POND

Impacts of recharging Section 215 water at low and high recharge rates (Scenarios 1a and 1b) at RCWD Recharge Pond are shown by groundwater hydrographs in Figure 8.1 and groundwater level change contour maps for year 21 in Figures 8.2 and 8.3.

The EC Baseline groundwater hydrographs, Figure 8.1, shows the comparison of groundwater levels at the RCWD recharge pond for Scenarios 1a and 1b, and Scenarios 5a and 5b. The lowest water levels are for EC Baseline, the two highest water levels are for Scenarios 1b and 5b (i.e. high recharge rates at the RCWD pond and all ponds, respectively), and the two middle water levels are for Scenarios 1a and 5a (i.e. low recharge rates at the RCWD pond and all ponds, respectively). Groundwater levels rise by approximately 25 feet in year 21 of Scenarios 1a and 5a when the highest recharge rates occur (see Figure 7.1). Groundwater levels rise by approximately 50 feet in year 21 of Scenarios 1b and 5b.

Maximum increases of groundwater levels in RCWD occur in year 21 of Scenarios 1a and 1b and are shown by contour maps in Figures 8.2 and 8.3, respectively. As shown in these figures, the impacted areas are mostly within RCWD service area and areas with 5 feet or more increase in groundwater levels are approximately 8,000 acres and 18,000 acres for Scenarios 1a and 1b, respectively.

Average annual groundwater recharge of Scenario 1a is 4,370 acre-feet/year, which results in approximately 3,300 acre-feet/year increase in groundwater storage in RCWD and approximately 1,100 acre-feet/year less groundwater subsurface flow from neighboring areas (Table 8.1). Similarly, recharge of approximately 9,300 acre-feet/year in Scenario 1b results in approximately 6,500 acre-feet/year of increase in groundwater storage in RCWD and approximately 2,800 acre-feet/year less groundwater subsurface flow from neighboring areas.

8.3 RECHARGE AT DRY CREEK POND

Impacts of recharging Kings River flood water at low and high recharge rates (Scenarios 2a and 2b) at Dry Creek recharge pond are shown by groundwater hydrographs in Figure 8.4 and groundwater level change contour maps for year 21 in Figures 8.5 and 8.6.

Hydrographs in Figure 8.4 show groundwater levels under the Dry Creek recharge pond under EC Baseline, Scenarios 2a and 2b, and Scenarios 5a and 5b. The lowest water levels are for EC Baseline, the two highest water levels are for Scenarios 2b and 5b (i.e. high recharge rates at Dry Creek pond and all ponds, respectively), and the two middle water levels are for Scenarios 2a and 5a (i.e. low recharge rates at the Dry Creek Pond and all ponds, respectively).

Groundwater levels rise by approximately 20 feet in year 21 of Scenarios 2a and 5a when the highest recharge rates occur (see Figure 7.2). Groundwater levels rise by approximately 40 feet in year 21 of Scenarios 2b and 5b.

Maximum increases of groundwater levels at Dry Creek pond occur in year 21 of Scenarios 2a and 2b and are shown by contour maps of Figures 8.5 and 8.6, respectively. As shown in these figures, the impacted areas extend to RCWD and result in increased groundwater subsurface flow to RCWD.

Average annual groundwater recharge at Dry Creek pond in Scenario 2a is approximately 5,100 acre-feet/year, which results in approximately 1,300 acre-feet/year increase in groundwater storage in RCWD and approximately 1,300 acre-feet/year more groundwater subsurface flow from neighboring areas (Table 8.1). Similarly, recharge of approximately 10,200 acre-feet/year at Dry Creek pond in Scenario 2b results in approximately 2,600 acre-feet/year increase in groundwater storage in RCWD and approximately 2,600 acre-feet/year more groundwater subsurface flow from neighboring areas to RCWD.

8.4 RECHARGE AT GOLDIE POND

Impacts of recharging Kings River flood water at low and high recharge rates (Scenarios 3a and 3b) at Goldie recharge pond are shown by groundwater hydrographs in Figure 8.7 and groundwater level change contour maps for year 21 in Figures 8.8 and 8.9.

Hydrographs of Figure 8.7 show groundwater levels under the Goldie recharge pond under EC Baseline, Scenarios 3a and 3b, and Scenarios 5a and 5b. The lowest water levels are for EC Baseline, the two highest water levels are for Scenarios 3b and 5b (i.e. high recharge rates at Goldie pond and all ponds, respectively), and the two middle water levels are for Scenarios 3a and 5a (i.e. low recharge rates at the Goldie pond and all ponds, respectively). Groundwater levels rise by approximately 15 feet in year 21 of Scenarios 3a and 5a when the highest recharge rates occur (see Figure 7.2). Groundwater levels rise by approximately 30 feet in year 21 of Scenarios 3b and 5b.

Maximum increases of groundwater levels at Goldie pond occur in year 21 of Scenarios 3a and 3b and are shown by contour maps of Figures 8.8 and 8.9, respectively. As shown in these figures, the impacted areas extend to RCWD and result in increased groundwater subsurface flow to RCWD.

Average annual groundwater recharge at Goldie pond in Scenario 3a is approximately 5,100 acre-feet/year, which results in approximately 1,100 acre-feet/year increase in groundwater storage in RCWD and approximately 1,100 acre-feet/year more groundwater subsurface flow from neighboring areas (Table 8.1). Similarly, recharge of approximately 10,200 acre-feet/year at Goldie pond in Scenario 3b results in approximately 2,300 acre-feet/year increase in groundwater storage in RCWD and approximately 2,300 acre-feet/year more groundwater subsurface flow from neighboring areas to RCWD.

8.5 RECHARGE AT MARKS POND

Impacts of recharging Kings River flood water at low and high recharge rates (Scenarios 4a and 4b) at Marks recharge pond are shown by groundwater hydrographs of Figure 8.10 and groundwater level change contour maps for year 21 of Figures 8.11 and 8.12.

Hydrographs of Figure 8.10 show groundwater levels under the Marks recharge pond under EC Baseline, Scenarios 4a and 4b, and Scenarios 5a and 5b. The lowest water levels are for EC Baseline, the two highest water levels are for Scenarios 4b and 5b (i.e. high recharge rates at Marks pond and all ponds, respectively), and the two middle water levels are for Scenarios 4a and 5a (i.e. low recharge rates at the Marks pond and all ponds, respectively). Groundwater levels rise by approximately 20 feet in year 21 of Scenarios 4a and 5a when the highest recharge rates occur (see Figure 7.2). Groundwater levels rise by approximately 40 feet in year 21 of Scenarios 4b and 5b.

Maximum increases of groundwater levels at Marks pond occur in year 21 of Scenarios 4a and 4b and are shown by contour maps of Figures 8.11 and 8.12, respectively. As shown in these figures, the impacted areas extend to RCWD and result in increased groundwater subsurface flow to RCWD.

Average annual groundwater recharge at Marks pond in Scenario 4a is approximately 5,100 acre-feet/year, which results in approximately 1,200 acre-feet/year increase in groundwater storage in RCWD and approximately 1,200 acre-feet/year more groundwater subsurface flow from neighboring areas (Table 8.1). Similarly, recharge of approximately 10,200 acre-feet/year at Marks pond in Scenario 4b results in approximately 2,400 acre-feet/year increase in groundwater storage in RCWD and approximately 2,400 acre-feet/year more groundwater subsurface flow from neighboring areas to RCWD.

8.6 RECHARGE AT ALL PONDS

Impacts of recharging Section 215 water at RCWD recharge pond and Kings River flood water at all other recharge ponds at low and high recharge rates (Scenarios 5a and 5b) are shown by groundwater hydrographs of Figure 8.1, 8.4, 8.7, and 8.10 and groundwater level change contour maps for year 21 of Figures 8.13 and 8.14.

Maximum increases of groundwater levels at recharge ponds occur in year 21 of Scenarios 5a and 5b and are shown by contour maps of Figures 8.13 and 8.14, respectively. As shown in these figures, the impacted areas extend to most of RCWD service area and result in increased groundwater subsurface flow to RCWD.

Average annual groundwater recharge at all ponds in Scenario 5a is approximately 14,300 acre-feet/year, which results in approximately 3,900 acre-feet/year increase in groundwater storage in RCWD and approximately 1,300 acre-feet/year more groundwater subsurface flow from

neighboring areas (Table 8.1). Similarly, recharge of approximately 28,600 acre-feet/year Scenario 5b results in approximately 7,900 acre-feet/year increase in groundwater storage in RCWD and approximately 2,500 acre-feet/year more groundwater subsurface flow from neighboring areas to RCWD.

SECTION 9 PROJECT PRIORITIZATION AND PREFERRED PROJECT

The selection of the preferred project was determined by ranking the projects impact in reduction of the groundwater overdraft in RCWD. There were two primary factors in determining project impacts to the groundwater; the volume of surface water available to recharge at each site, and the resulting change in groundwater storage in RCWD. The projects were ranked in order of highest degree of impact under each project scenario. The second consideration in the prioritization process was to consider other factors such as water availability, soil investigation, construction costs, EIR and permitting requirements, right-of-ways and landowner participation. The budget constraints under this project did not allow for a comprehensive analysis of other factors, however, landowner participation, land accessibility and viability, and water costs were qualitatively discussed with prospective project participants and agencies.

A total of 10 recharge scenarios were developed to simulate recharge operations at four recharge ponds in RCWD, FID, and CID. Impacts of recharge operations under these scenarios were quantified in the previous sections. Table 8.1 presents a summary of the recharge scenarios and impact on groundwater storage in RCWD (column 8). The last column of Table 8.1 presents the percentage of recharged water that result in groundwater storage increase for RCWD. In Scenario 1a, recharge of 4,370 acre-feet/year of Section 215 water at RCWD recharge ponds results in 3,272 acre-feet/year of groundwater storage increase. In other words, 75% of every acre-foot of Section 215 water recharged at RCWD pond will results in groundwater storage increase. The remaining 25% of recharge water will result in reduced groundwater subsurface flow from adjacent areas. In contrast, recharge of 5,075 acre-feet/year of Kings River flood water at Dry Creek pond in Scenario 2a results in only 1,305 acre-feet/year of groundwater storage increase at RCWD. Only 25% of every acre-foot of Kings River flood water recharged at Dry Creek pond will result in groundwater storage increase at RCWD. The ranking in order of project impact to the groundwater storage in RCWD from greatest is: RCWD Pond (3,272 af), Dry Creek Pond (1,305 af), Marks Pond (1,167 af) and Goldie Pond (1,135 af).

Based on the results of field investigation (Section 5) CID ponds have higher coarse aquifer material and recharge capacity. However, based on the recharge scenarios (Section 8) and analysis of benefits to the aquifer at RCWD, recharging at RCWD pond has higher benefits to groundwater at RCWD and will result in increased groundwater elevations at RCWD. Recharging at RCWD pond would require new conveyance system and agreements between RCWD and CID or RCWD and FID for transfer of Section 215 water through CID or FID canals. Additionally, other recharge projects based on Scenarios 2, 3, and 4 could be developed by cooperation of RCWD and the participating agencies. Cumulatively, the potential benefit to cooperatively working to implement three projects with the participating agencies would be

greater than the one project at RCWD and a reduced cost and eliminating other factors previously described.

RCWD conducted this groundwater recharge feasibility study, which was funded by California Department of Water Resources through the Local Groundwater Assistance Grant (AB303) Program. The goal of the study was to identify the available land, water, and conveyance structures, determine methods to replenish the groundwater supply through recharge projects, and evaluate the impacts and benefits of the recharge operations on groundwater supply.

The study consisted of eight tasks ranging from data collection and analysis, field investigation, simulation of potential recharge projects, and project management. This report presented the details of technical work and field investigation conducted for the study.

Available recharge sites, flood water and conveyance systems for delivering water to the recharge sites are presented in Sections 2 to 4 of the report. Four sites (one at RCWD, one at FID and at the boundary with RCWD, two at CID at the boundary with RCWD) were identified for recharge operations. Kings River flood water and Section 215 flood water releases from Friant-Kern Canal are potentially available for recharge at the identified sites. Enhancements to some of CID canal are needed to deliver recharge water to CID ponds. Delivery of recharge water to the RCWD pond will require development of new canals and pipelines.

Site characterization was conducted by CPT tests for top 100 feet at RCWD and CID sites and analysis of well logs from DWR and USGS for lower parts of the aquifer at all sites. RCWD site generally contains finer grain materials while CID sites have coarser materials.

The Kings Basin Integrated Groundwater and Surface water Model (Kings IGSM) was used to evaluate the impacts of the recharge activities at the four proposed sites. A total of 10 scenarios were developed and simulated for evaluation of project impacts. This modeling effort showed that recharging at RCWD pond has higher benefits to groundwater at RCWD and will result in increased groundwater elevations at RCWD. However, the potential benefit to cooperatively working to implement three projects with participating agencies would be greater than the one project at RCWD.

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TABLES

Table 1.1 - Summary of Data Used in the Analysis

Purpose of Analysis	Database Description	Source	Spatial and/or Temporal Coverage
Land Suitability	Land Use	DWR	Kings County (2003) Fresno County (2000)
	Hydrologic Soils	NRCS	Fresno Central, Fresno West, and Kings,
	A Clay and E Clay	KRCD	2004
	Specific Yield	KRCD	2004
	Depth to Water	DWR	Spring 2003
Conveyance Capacity	FID facilities	FID	2005,2011
	CID facilities	CID	2003,2011
	FID Carrying Capacities of Ditches	FID	2005,2011
	CID Canal Capacities	KRCD and CID	2005, 2011
	Head Gate Diversions to CID and FID	KRWA	1964 - 2001
Water Availability	Kings River Flow	KRWA	1964 - 2011
	Stream flow rates at James Weir	KRWA, USGS	1964 - 2009
	San Joaquin River Flow at Millerton and Mendota	USGS	1907-2011 1939-2011
	Friant-Kern Canal Deliveries	KRWA, USGS	1964 - 2011
	Section 215 Deliveries	Friant Water Authority	1982 - 2006
	Section 215 Water Rate	US Bureau of Reclamation	2004-2011
	Wastewater effluent flow	Fresno Regional WWTP	1970-2011
Environmental Impacts Assessment	Environmental Impacts	California Natural Diversity Database	2011
	Groundwater Contamination	DWR	2011
	Land Subsidence	USGS, 2011	1961-2003

Table 2.1 - Ranking Factors and Quantification Methods

Factor	Quantification Method	Attribute	Ranking Index
Appropriate land uses	Land use is quantified by land use maps, preferring idle or annual crops to urban or habitat areas.	Land Use Idle / Existing Ponds Vacant Field Crop, Pasture Other Crops Urban, Semi Ag Riparian, Water, Native	5 4 3 2 1 0
Surface and Subsurface Conditions	Soil permeability is quantified using soils data from USDA-NRCS soil surveys in combination with the presence of the a-clay and e-clay.	Hydrologic Soil Groups Type A Type B Type C Type D A and E Clay Neither Clay E Clay Both Clays	5 * * 1.25 5 3.33 1.67
Available storage	Available storage is quantified by depth to water and specific yield maps	Specific Yield 17% - 19% 14% - 16 % 13% 10% - 12% 8% - 10 % Depth to Water (ft) >100 76 - 100 51-75 26-50 11 - 25 0 - 10	5 4 3 2 1 5 4 3 2 1 0

* Hydrologic Soil Groups are ranked in a continuous range from 1.25 to 5 based on the relative percentage of A, B, C, and D soils in each mapped area.

Table 2.2 - Proposed Recharge Sites

Site	Owner	Location (Figure #)	Area (Acres)	Estimated/ Proposed Wetted Area (Acres)	Land Elevation (ft above MSL)
FID Lower Dry Creek Pond	FID	36°37'39.05"N , 120°01'32.44"W (Figure 10-a)	60	80	205
RSWD District Vacant Land	RSWD	36°36'22.70"N , 119°55'52.25"W (Figure 10-b)	64	80	230
CID Goldie Pond	CID	36°36'39.97" N , 119°51'4.26" W (Figure 10-c)	24	40	240
CID Marks Pond	CID	36°34'13.86"N , 119°51'7.26"W (Figure 10-d)	32	40	240

Table 2.3 - Site Conditions Related to Land Use, Soil Permeability, E-Clay, Depth to GW, and Relative Specific Capacity with Ranking Index in Parenthesis

Site	Land Use	Soil Permeability	E-Clay	Most Recent Measured Depth to GW (ft)	Relative Specific Capacity
FID Lower Dry Creek Pond	Idle & Existing Ponds (5)	Moderate to poor (2) *	Present (3.33)	135 (5)	Moderate to poor (2)
RSWD District Vacant Land	Other Crops (2)	High to Moderate (4)	Present (3.33)	181 (5)	Moderate (3)
CID Goldie Pond	Idle & Existing Ponds (5)	Poor (1.25) *	None (5)	87.6 (4)	Moderately high (4)
CID Marks Pond	Idle & Existing Ponds (5)	Poor (1.25) *	None (5)	129.9 (5)	Moderately high (4)

* Even though FID Lower Dry Creek Pond, CID Goldie Pond, and CID Marks Pond are existing ponds, their soil permeability shows low. Besides, they are surrounded by high permeability soil. The soil permeability of these sites should have been assigned wrong.

Table 3.1 - Estimated Recharge Volumes and Design Flows for Proposed Recharge Sites

Site	Proposed Poned Area (Acres)	Estimated Min Recharge Rate *			Estimated Max Recharge Rate **		
		Recharge Rate (ft/day)	Recharge Volume (AF/day)	Design Flow (cfs)	Recharge Rate (ft/day)	Recharge Volume (AF/day)	Design Flow (cfs)
FID Lower Dry Creek Pond	80	0.5	40	20	1.0	80	40
RSWD District Vacant Land	80	0.5	40	20	1.0	80	40
CID Goldie Pond	40	1.0	40	20	2.0	80	40
CID Marks Pond	40	1.0	40	20	2.0	80	40
Total	240	N/A	160	80	N/A	320	160

* These recharge rates are relatively conservative given the soil conditions and personal communications with local authorities who have operational experience around the project area.

** These recharge rates are relatively high given the soil conditions and personal communications with local authorities who have operational experience around the project area.

Table 3.2 - Canal Capacity for Major FID and CID Canals and Friant-Kern Canal

Canal Name	Capacity (cfs)
Friant-Kern Canal	5,000
Consolidated Canal	2,100
Fresno Canal	1,500
Gould Canal	500

Table 3.3 - Frequency Analysis of Available Canal Capacity for Major FID and CID Canals and Friant-Kern Canal from 1964 to 2011

Canal Name	Capacity (cfs)	% of Days When Available Canal Capacity was Greater Than				
		75 cfs	100 cfs	150 cfs	200 cfs	250 cfs
Friant-Kern Canal	5,000	100%	100%	100%	100%	99%
Fresno Canal + Gould Canal	2,000	98%	98%	97%	95%	94%
Consolidated Canal	2,100	100%	100%	100%	100%	99%

Table 3.4 - Canal Capacity for Tail-End Canals

Canal Name	District	Capacity (cfs)
Central Wasteway	FID	50
McMullin Grade	FID	50
Lower Dry Creek	FID	100
Wristen Ditch	CID	45-50
Dan Smith Ditch	CID	45-50

Table 4.1 - Annual Estimates of Available Water in Kings River Flood Events at James Bypass

Water Year	Flood Dates	Duration (days)	Min Daily Flow (cfs)	Max Daily Flow (cfs)	Ave Daily Flow (cfs)	Total Water Lost out of the Service Area (AF)
1964	-	-	-	-	-	-
1965	-	-	-	-	-	-
1966	-	-	-	-	-	-
1967	4/17 - 7/21	99	0	3,260	2,440	479,023
1968	12/7 - 12/18, 12/20 - 12/26	19	-	-	-	-
1969	1/27 - 8/4	190	732	5,570	4,067	1,532,353
1970	12/2 - 12/12, 12/19 - 1/5, 1/12-2/4	53	0	1,851	559	58,725
1971	-	-	-	-	-	-
1972	-	-	-	-	-	-
1973	6/9 - 6/12	4	-	-	-	-
1974	4/13 - 5/10, 5/16 - 6/18	62	0	2,181	670	82,431
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	-	-	-	-	-	-
1978	3/7 - 6/30	116	50	4,407	2,359	542,557
1979	4/10 - 4/23, 5/18 - 6/2	30	0	984	169	10,034
1980	1/15 - 2/7, 2/18 - 7/7	165	0	4,830	1,744	570,543
1981	-	-	-	-	-	-
1982	4/6 - 6/21, 6/30-7/13	91	7	4874	2494	449965
1983	11/4 - 7/20, 8/10 -9/30	311	20	5,355	3,732	2,301,563
1984	10/1 - 2/2	125	4	4,296	2,287	566,793
1985	-	-	-	-	-	-
1986	2/21 - 6/12	112	88	4,975	2,948	654,739
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	-	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	-	-	-	-
1992	-	-	-	-	-	-
1993	-	-	-	-	-	-
1994	-	-	-	-	-	-
1995	3/23 - 7/20	120	53	3,994	2,405	572,294
1996	3/14 - 3/28, 5/9 - 5/30	37	0	3,783	996	73,052
1997	1/6 - 3/17	71	249	4,849	3,013	424,231
1998	2/24 - 7/20	147	140	4,969	3,351	976,709
1999	11/23 - 12/16	24	73	620	370	17,605
2000	-	-	-	-	-	-

2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	-	-	-	-	-	-
2004	-	-	-	-	-	-
2005	5/19 - 6/13	25	50	2,550	1,262	60,637
2006	4/6 - 6/28	84	1,370	4,500	3,674	611,993
2007	-	-	-	-	-	-
2008	-	-	-	-	-	-
2009	-	-	-	-	-	-
Total		1,885	N/A	N/A	N/A	9,985,247
Average (Flood Years)		94	N/A	N/A	N/A	554,736
Average (1964 to 2009)		41	N/A	N/A	N/A	217,070
Min		4	N/A	N/A	N/A	10,034
Max		311	N/A	N/A	N/A	2,301,563

Table 4.2 - Frequency Analysis of Measured Flows at James Bypass during Flood Events from 1964 to 2009

	% of Days When Flow was Greater Than						
Flow	50 cfs	75 cfs	100 cfs	150 cfs	200 cfs	250 cfs	300 cfs
%	95%	93%	93%	92%	90%	89%	89%

Table 4.3 - Comparison of the Duration and Timing of the Flood Events at the James Bypass and Section 215 Water Releases from Water Year 1983 to Water Year 2006

Water Year	King River Flows at James River		Section 215 Water	
	Flood Dates	Duration (Days)	Delivery Dates	Duration (Months)
1983	11/4 - 7/20, 8/10 -9/30	311	11/1 - 10/30	11
1984	10/1 - 2/2	125	10/1 - 11/30	2
1985	-	-	-	-
1986	2/21 - 6/12	112	-	-
1987	-	-	-	-
1988	-	-	-	-
1989	-	-	-	-
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	3/23 - 7/20	120	-	-
1996	3/14 - 3/28, 5/9 - 5/30	37	-	-
1997	1/6 - 3/17	71	-	-
1998	2/24 - 7/20	147	2/1 - 3/31, 5/1 - 6/30	4
1999	11/23 - 12/16	24	11/1- 2/28	4
2000	-	-	3/1 -4/30	2
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	6/1 - 6/30	1
2004	-	-	-	-
2005	5/19 - 6/13	25	3/1 - 7/31	5
2006	4/6 - 6/28	84	1/1 - 1/31, 3/1 - 7/31	6
Total	N/A	1056	N/A	35
Average (Flood Years)	N/A	106	N/A	4.4
Average (1983-2006)	N/A	44	N/A	1.5

Table 4.4 - Annual Section 215 Deliveries

Water Year	Delivery Dates	Duration (Months)	Min Monthly Delivery (AF)	Max Monthly Delivery (AF)	Ave Monthly Delivery (AF)	Total Annual Delivery (AF)
1983	11/1 - 10/30	11	117	9,699	2,761	30,370
1984	10/1 - 11/30	2	103	162	133	265
1985	-	-				
1986	-	-				
1987	-	-				
1988	-	-				
1989	-	-				
1990	-	-				
1991	-	-				
1992	-	-				
1993	-	-				
1994	-	-				
1995	-	-				
1996	-	-				
1997	-	-				
1998	2/1 - 3/31, 5/1 - 6/30	4	28	115,756	29,703	148,515
1999	11/1 - 2/28	4	7,118	173,889	57,992	231,969
2000	3/1 - 4/30	2	4,128	14,586	9,357	18,714
2001	-	-				
2002	-	-				
2003	6/1 - 6/30	1	20,998	20,998	20,998	20,998
2004		-				
2005	3/1 - 7/31	5	11,391	170,912	80,230	401,148
2006	1/1 - 1/31, 3/1 - 7/31	6	2,372	40,792	16,545	99,269
Total		35.0	N/A	N/A	N/A	951,248
Average (Flood Years)		4.4	N/A	N/A	N/A	118,906
Average (1983 to 2006)		1.5	N/A	N/A	N/A	39,635
Min		1.0	N/A	N/A	N/A	265
Max		11.0	N/A	N/A	N/A	401,148

Table 4.5 - Central Valley Project Section 215 Irrigation and M&I Spill Water Rates (\$/ AF)

Year	Water Marketing				Conveyance				Friant Surcharge		Restoration Fund		Trinity PUD Assesment		Total	
	Capital		O&M		Capital		O&M									
	Irrig.	M&I	Irrig.	M&I	Irrigation	M&I	Irrig *	M&I	Irrig.	M&I	Irrig.	M&I	Irrig.	M&I	Irrig.	M&I
2004	-	-	7.59	5.01	5.80	17.05	-	5.32	7.00	7.00	7.82	15.64	-	-	28.21	50.02
2005	-	-	6.61	3.89	5.60	10.10	-	5.16	7.00	7.00	7.93	15.87	-	-	27.14	42.02
2006	-	-	6.09	4.36	5.32	6.10	-	14.17	7.00	7.00	8.24	16.49	-	-	26.65	48.12
2007	-	-	6.86	5.76	5.33	6.51	-	7.19	7.00	7.00	8.58	17.15	-	-	27.77	43.61
2008	-	-	6.53	4.22	5.32	6.76	-	7.74	7.00	7.00	8.79	17.57	-	-	27.64	43.29
2009	-	-	5.99	3.48	5.50	6.67	-	19.96	7.00	7.00	9.06	18.12	-	-	27.55	55.23
2010	-	-	6.01	3.20	6.12	6.46	-	12.21	7.00	7.00	9.11	18.23	0.11	0.11	28.35	47.21
2011	-	-	6.53	3.79	5.31	5.63	-	15.16	7.00	7.00	9.29	18.59	0.05	0.05	28.18	50.22

Table 5.1 - Soil Behavior Types and Estimated Permeability

SBT Zone No.	SBT Zone	Estimated Permeability (ft/sec)
1	sensitive fine grained	3×10^{-8}
2	organic soil	3×10^{-7}
3	clay	1×10^{-9}
4	clay & silty clay	3×10^{-8}
5	clay & silty clay	3×10^{-8}
6	sandy silt & clayey silt	3×10^{-6}
7	silty sand & sandy silt	3×10^{-6}
8	sand & silty sand	3×10^{-4}
9	sand	3×10^{-2}
10	sand	3×10^{-2}
11	very dense/stiff soil*	3×10^{-6}
12	very dense/stiff soil*	1×10^{-8}

*heavily overconsolidated and/or cemented

Table 6.1 - Model Assumptions for Existing Conditions (EC) Baseline

No.	Data Type	Assumptions
1	Land Use	2005 Land Use by West Yost.
2	Agricultural Water Demand	Based on 2004 Land Use and Crop Acreage and subject to 1964-2004 hydrology.
3	Crop Acreage	2004 Crop Acreage
4	Urban Water Demand	2005 Urban Demand Estimate by West Yost
5	Recharge @ Leaky Ares	Use historical recharge rates for 1973-2004. For 1964-2004 use 1973-2004 recharge rates based on San Joaquin Hydrology Index
4	Recharge @ FMFCD Ponds	For 1994-2004 use historical recharge rates. For 1964-1993 use 1994-2004 recharge rates based on San Joaquin Hydrology Index. Use ponds that are active in 2004. Use 2000-2004 average recharge ratios for distribution of total recharge to individual ponds.
5	Recharge @ creeks and streams	Use 2004 conditions
6	Surface Water Treatment Plant	Use full capacity rates (32.5 TAF/yr) with no flow in November for maintenance)
7	Wastewater Treatment Plant Total Flows	78,400 AF
8	San Joaquin Settlement Flow Assumptions	No
9	Municipal Wells Pumping	Use wells that are active in 2005. Use 2005 pumping rates minus surface water plant's 2005 flows. Proportionally reduce pumping rate of each well.
10	Surface Water Deliveries – Kings River	Use historical deliveries and diversions. Adjust for SWTP flows.
11	Surface Water Deliveries – Friant-Kern	West Yost estimates of deliveries to FID and Fresno (60 TAF/yr, 17.9 TAF/yr for critically dry years). Adjust for SWTP
12	Land Use, Demand, Supply for Backman, Pinedale, and CSUF areas	Use 2004 conditions.
13	Initial Conditions	Use end of Sep 2004 values for groundwater levels, soil moisture, unsaturated soil moisture, and small watershed

Table 7.1 - Daily and Monthly Recharge Rates

Recharge Site	Pond Area (acres)	Low Recharge Rate Scenario		High Recharge Rate Scenario	
		Recharge Rate (ft/day)	Average Recharge Volume (Flood Years, AF/month)	Recharge Rate (ft/day)	Average Recharge Volume (Flood Years, AF/month)
Dry Creek Pond	80	0.5	1,215	1.0	2,430
RCWD Pond	80	0.5	1,220	1.0	2,440
Goldie Pond	40	1.0	1,215	2.0	2,430
Marks Pond	40	1.0	1,215	2.0	2,430
Total	240	N/A	4,865	N/A	9,730

Table 8.1 Average Annual Recharge Rates and Impact on Groundwater Storage for Flood Years

Scenario	Average Annual GW Recharge (Flood Years, AF/year)					Average Annual Changes in Water Budget Components with respect to Baseline (Flood Years, AF/year)			Impact of Recharge Operation on Groundwater Storage in RCWD (RCWD Storage Change/Total Recharge) (%)
						RCWD		Outside RCWD	
						Change in Underflow to RCWD	Change in Storage	Change in Storage and Other Water Budget Components	
	Dry Creek Pond	RCWD Pond	Goldie Pond	Marks Pond	Total				
1a - RCWD Pond - Low Recharge	-	4,370	-	-	4,370	-1,098	3,272	1,098	75%
1b - RCWD Pond - High Recharge	-	9,333	-	-	9,333	-2,792	6,542	2,792	70%
2a - Dry Creek Pond - Low Rehcharge	5,075	-	-	-	5,075	1,305	1,305	3,770	26%
2b - Dry Creek Pond - High Recharge	10,151	-	-	-	10,151	2,611	2,611	7,540	26%
3a - Goldie Pond - Low Recharge	-	-	5,075	-	5,075	1,135	1,135	3,940	22%
3b - Goldie Pond - High Recharge	-	-	10,151	-	10,151	2,261	2,261	7,890	22%
4a - Marks Pond - Low Recharge	-	-	-	5,075	5,075	1,167	1,167	3,908	23%
4b - Marks Pond - High Recharge	-	-	-	10,151	10,151	2,373	2,373	7,778	23%
5a - All Ponds - Low Rehcharge	3,922	2,545	3,922	3,922	14,311	1,279	3,938	10,373	28%
5b - All Ponds - High Recharge	7,844	5,090	7,844	7,844	28,622	2,535	7,855	20,767	27%

FIGURES

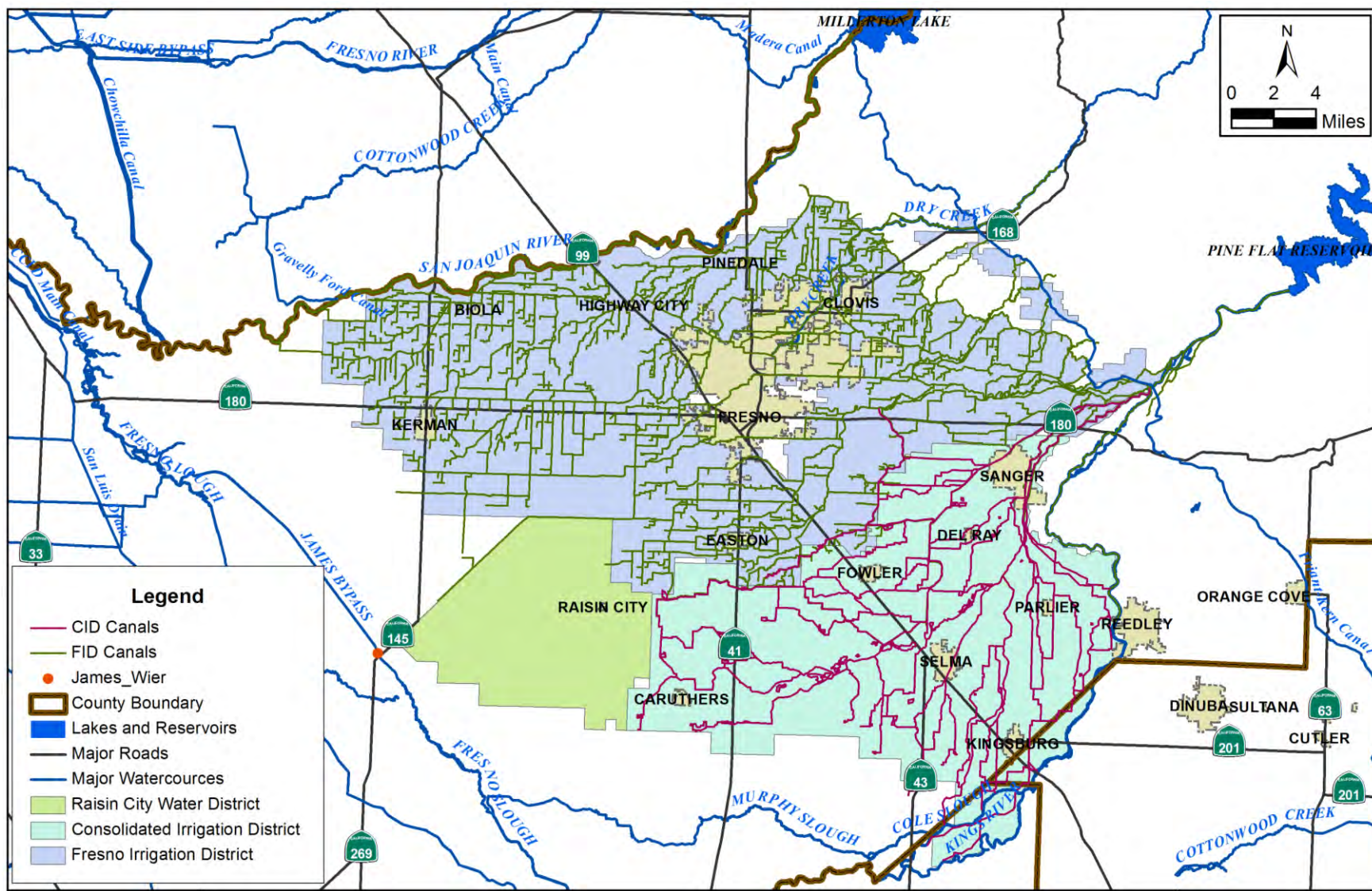


Figure 1.1 - Raisin City Water District

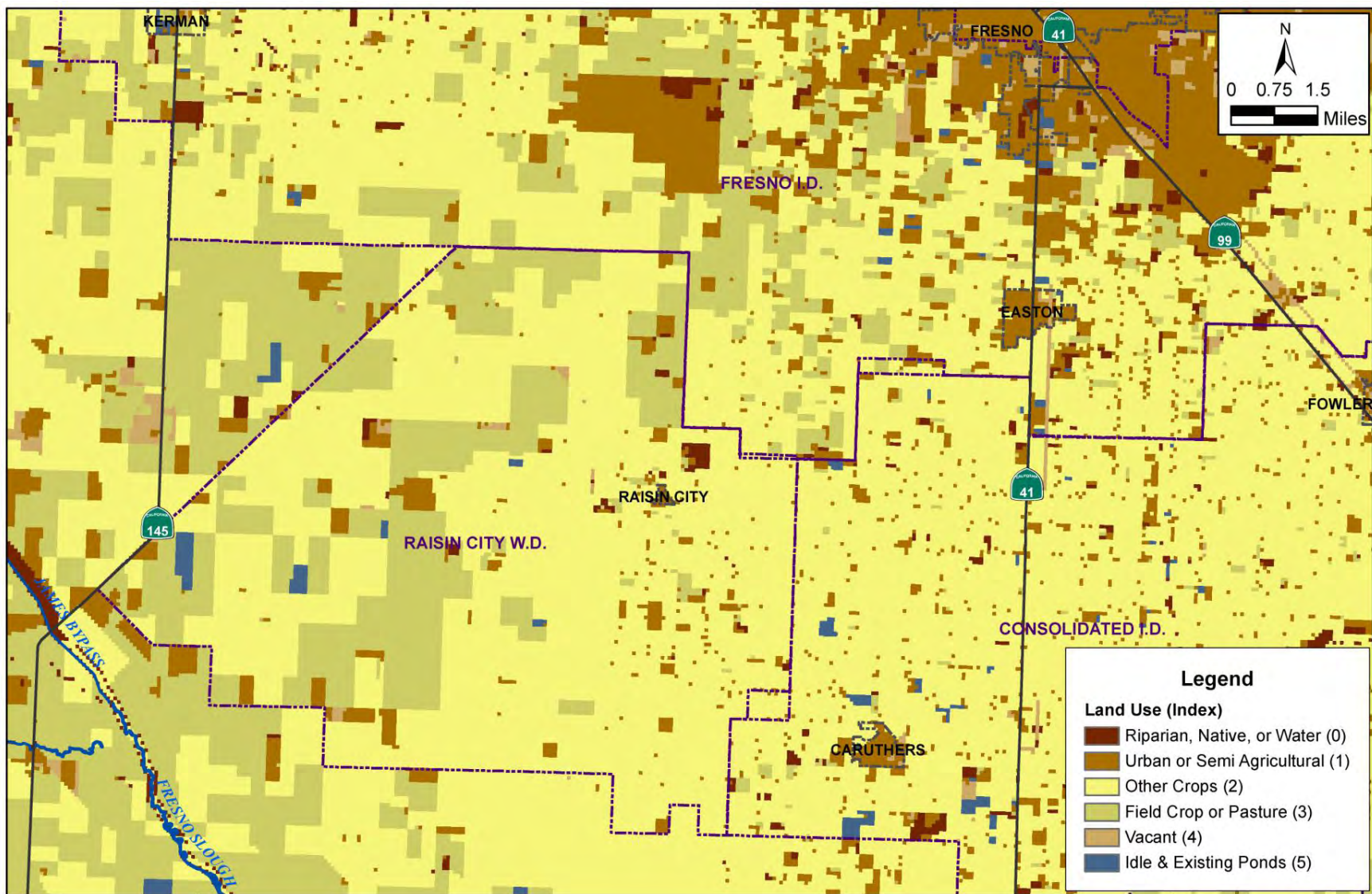


Figure 2.1 - Ranking Index for Land Use

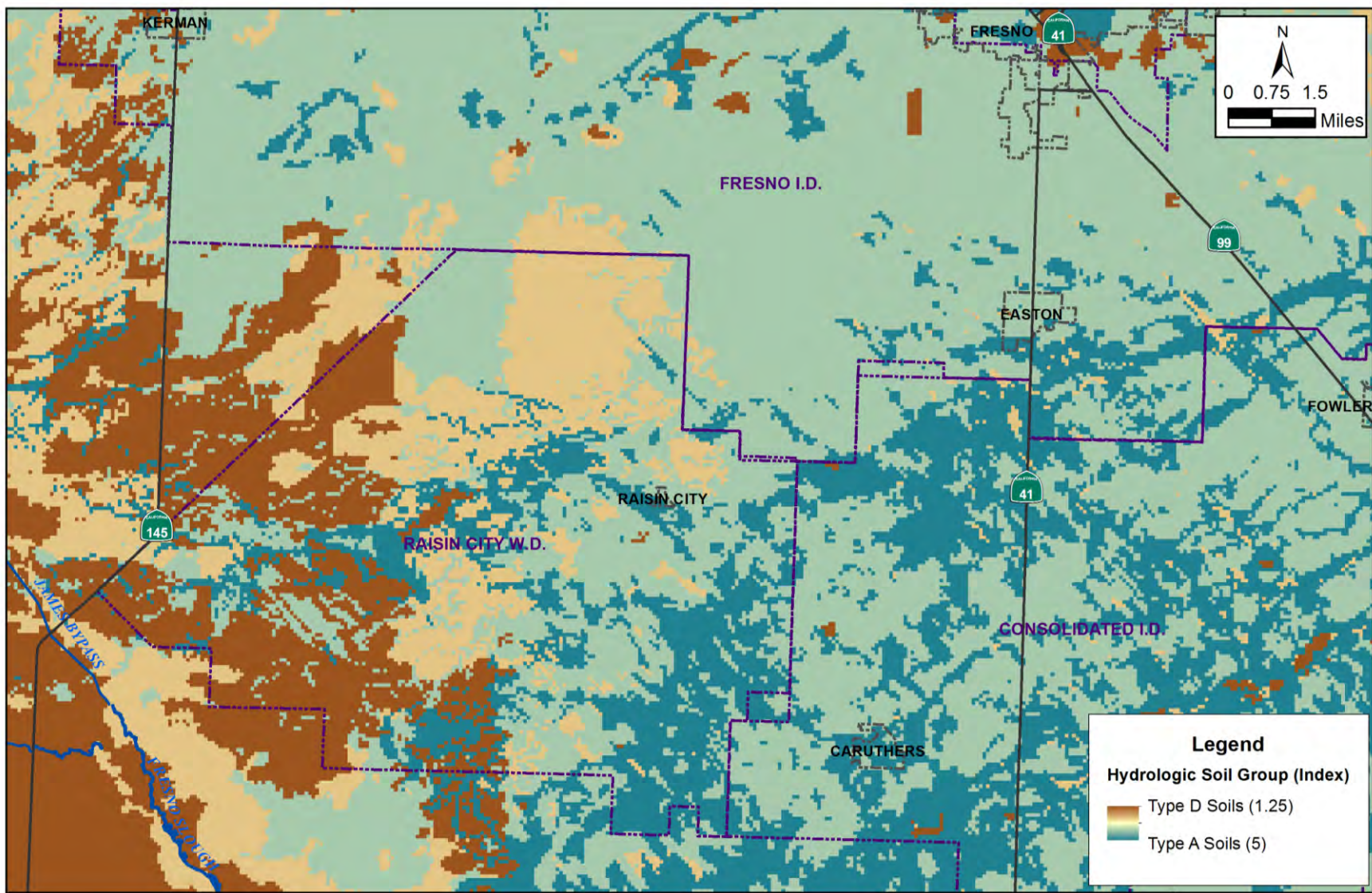


Figure 2.2 - Ranking Index for Hydrologic Soil Groups

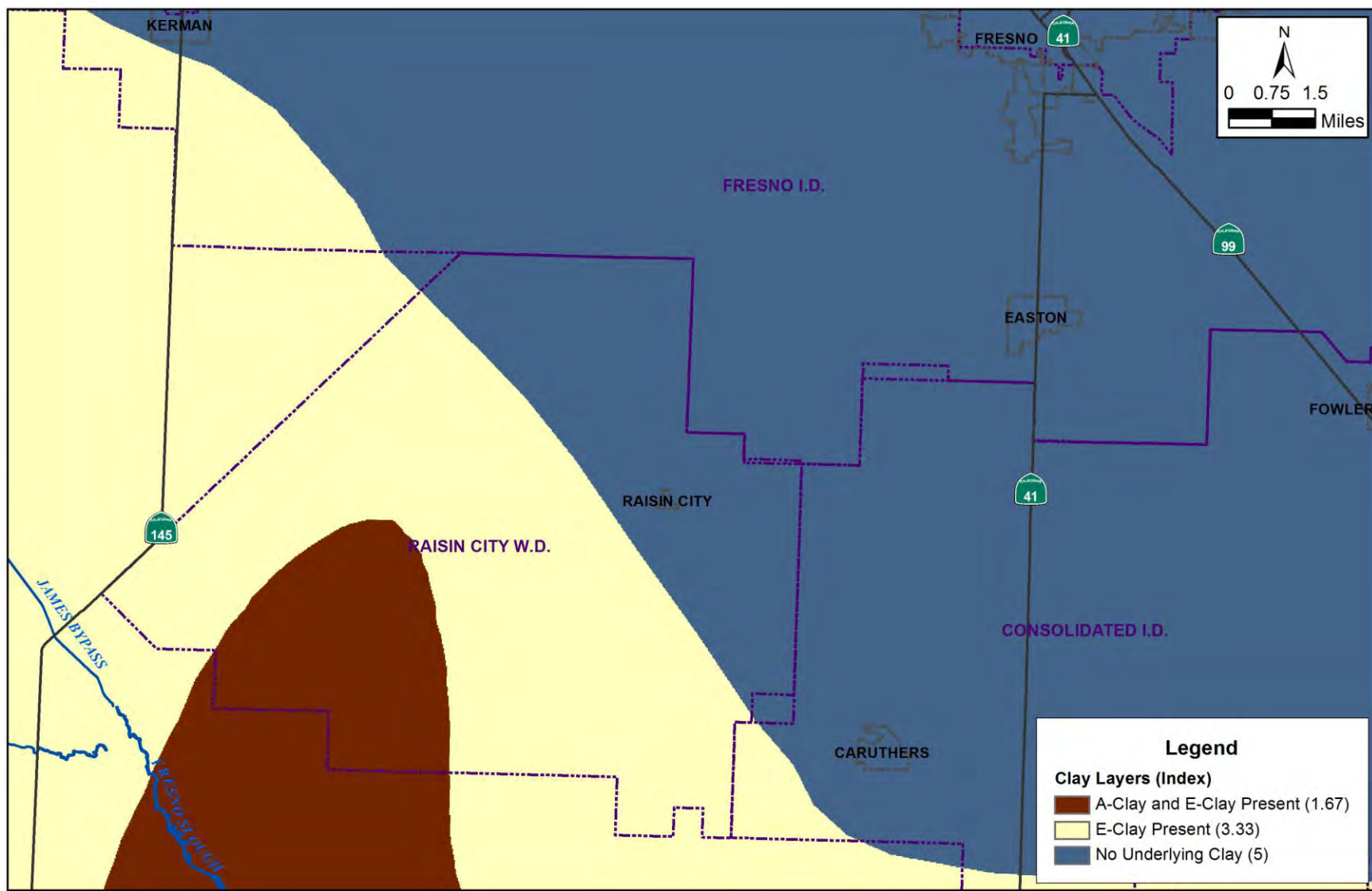


Figure 2.3 - Ranking Index for Presence of A & E Clays

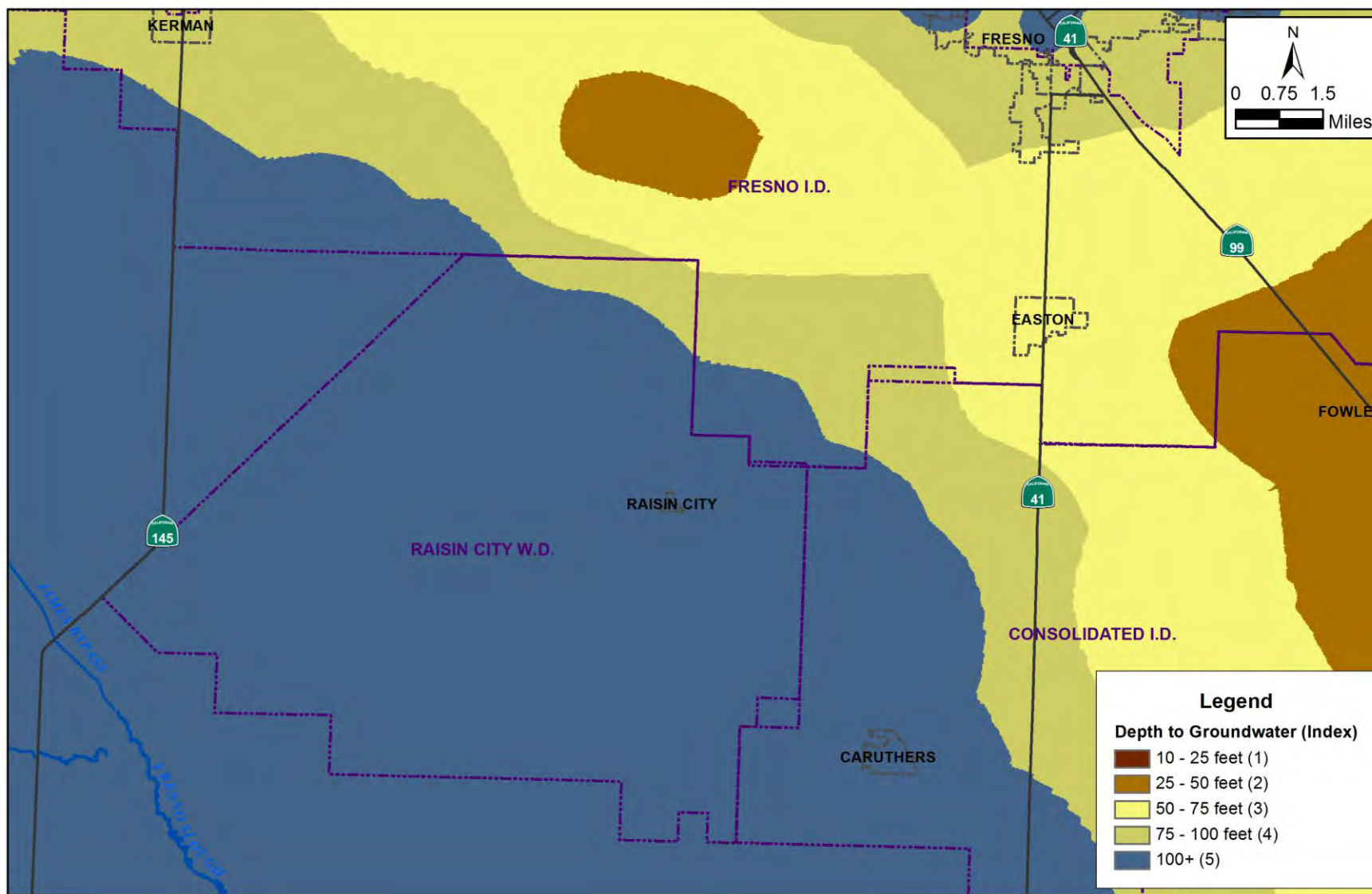


Figure 2.4 - Ranking Index for Depth to Groundwater, Spring 2003

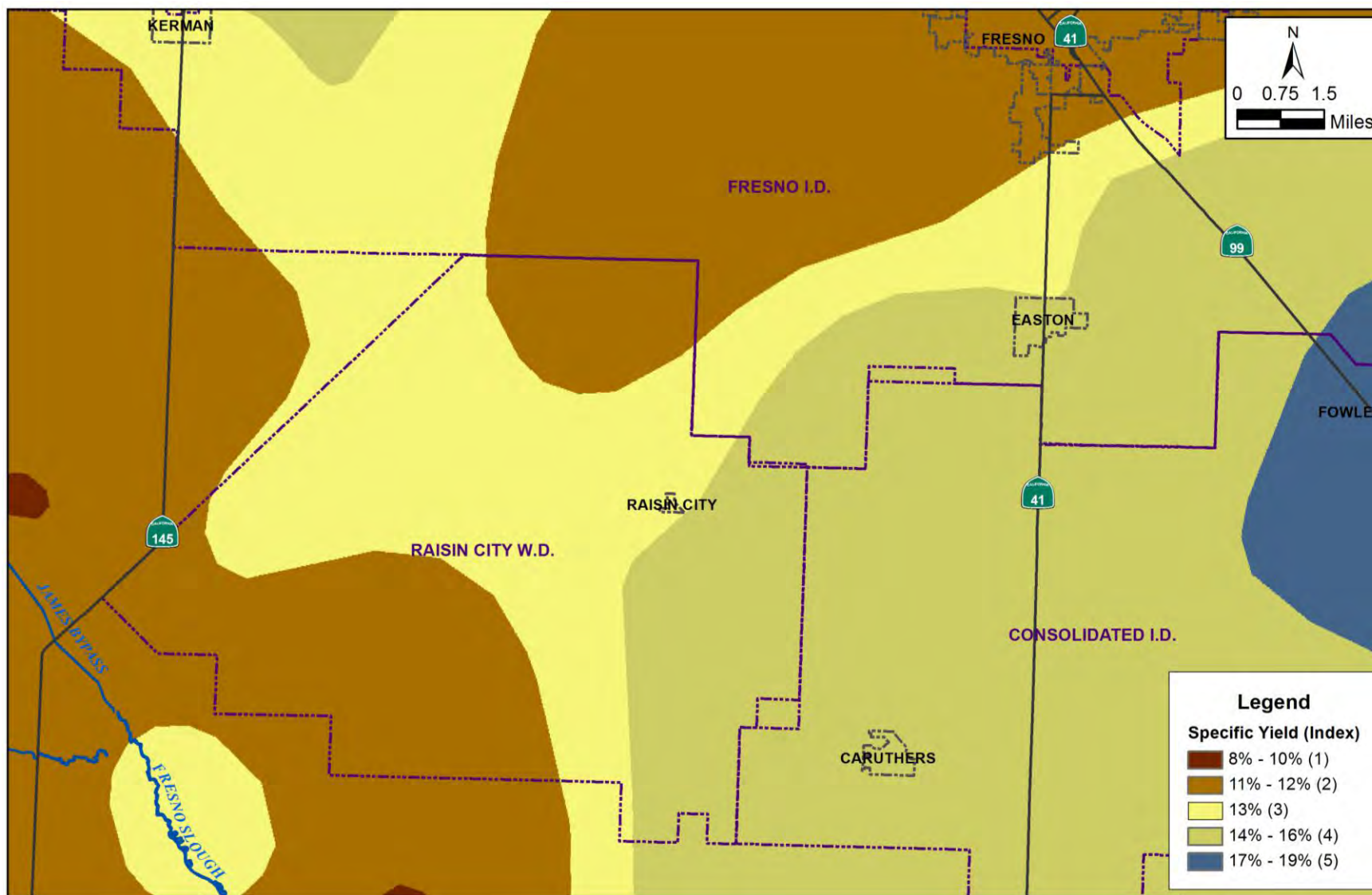


Figure 2.5 - Ranking Index for Specific Yield

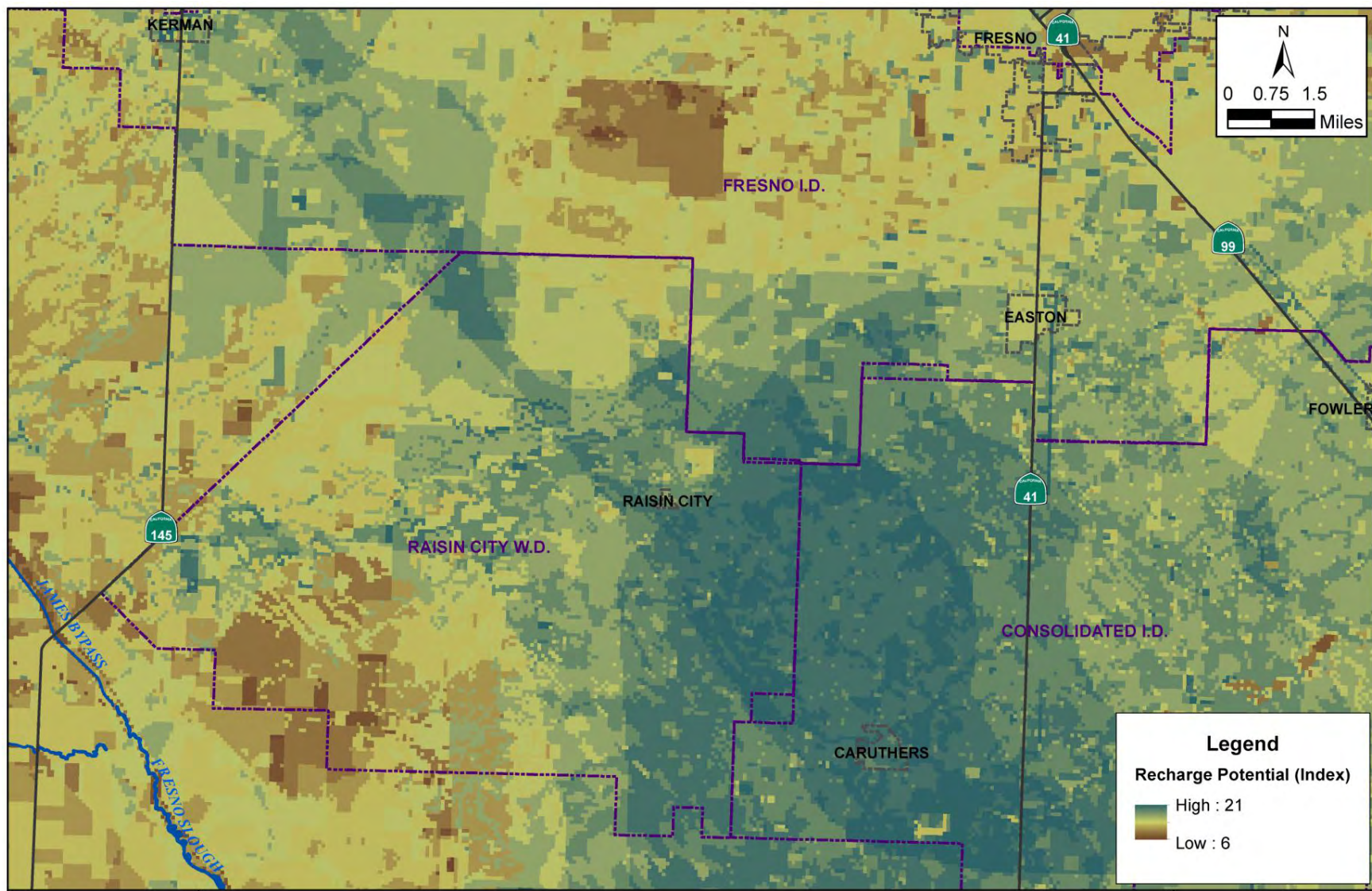


Figure 2.6 – Recharge Potential Index

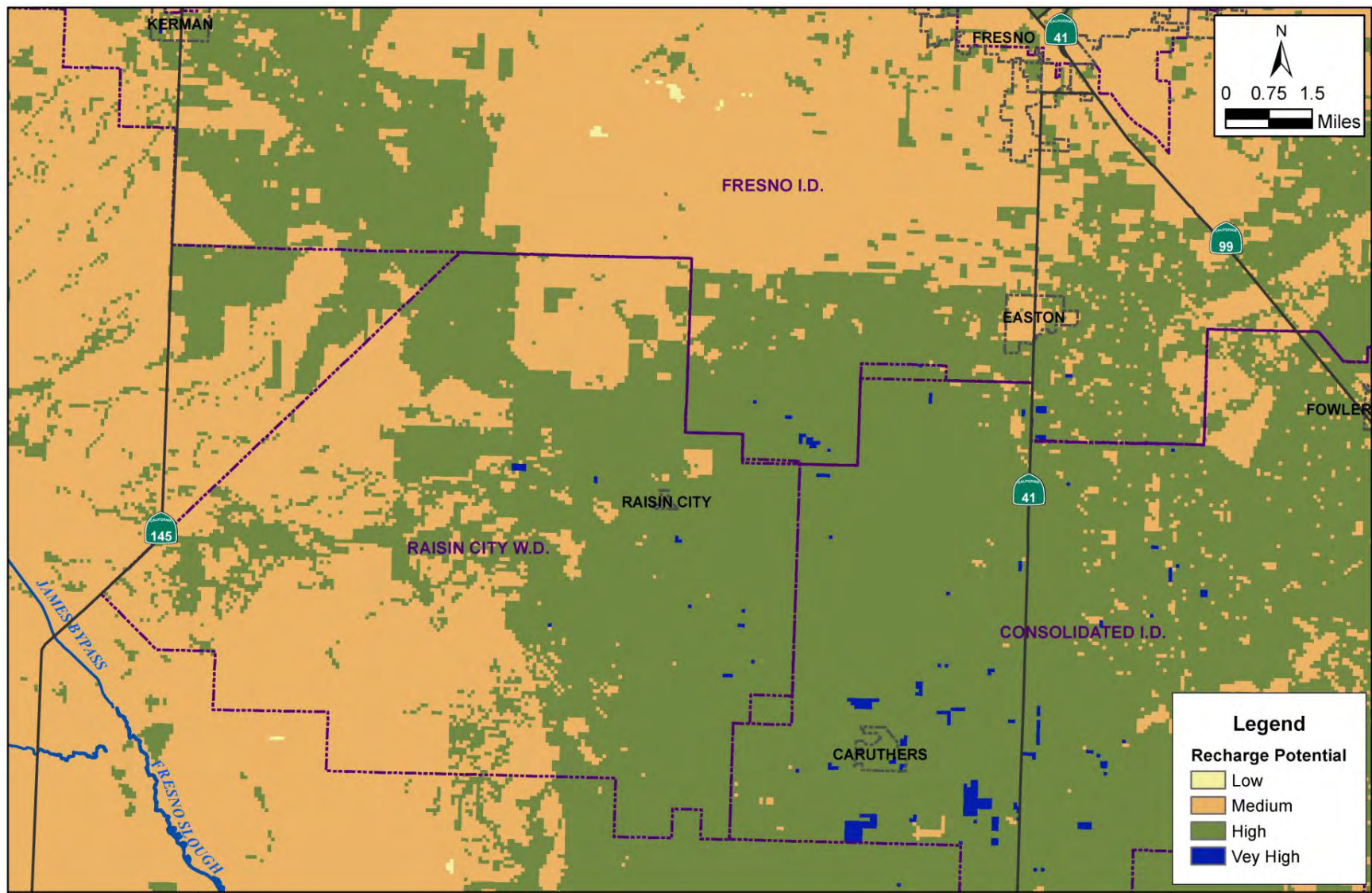


Figure 2.7 - Recharge Potential

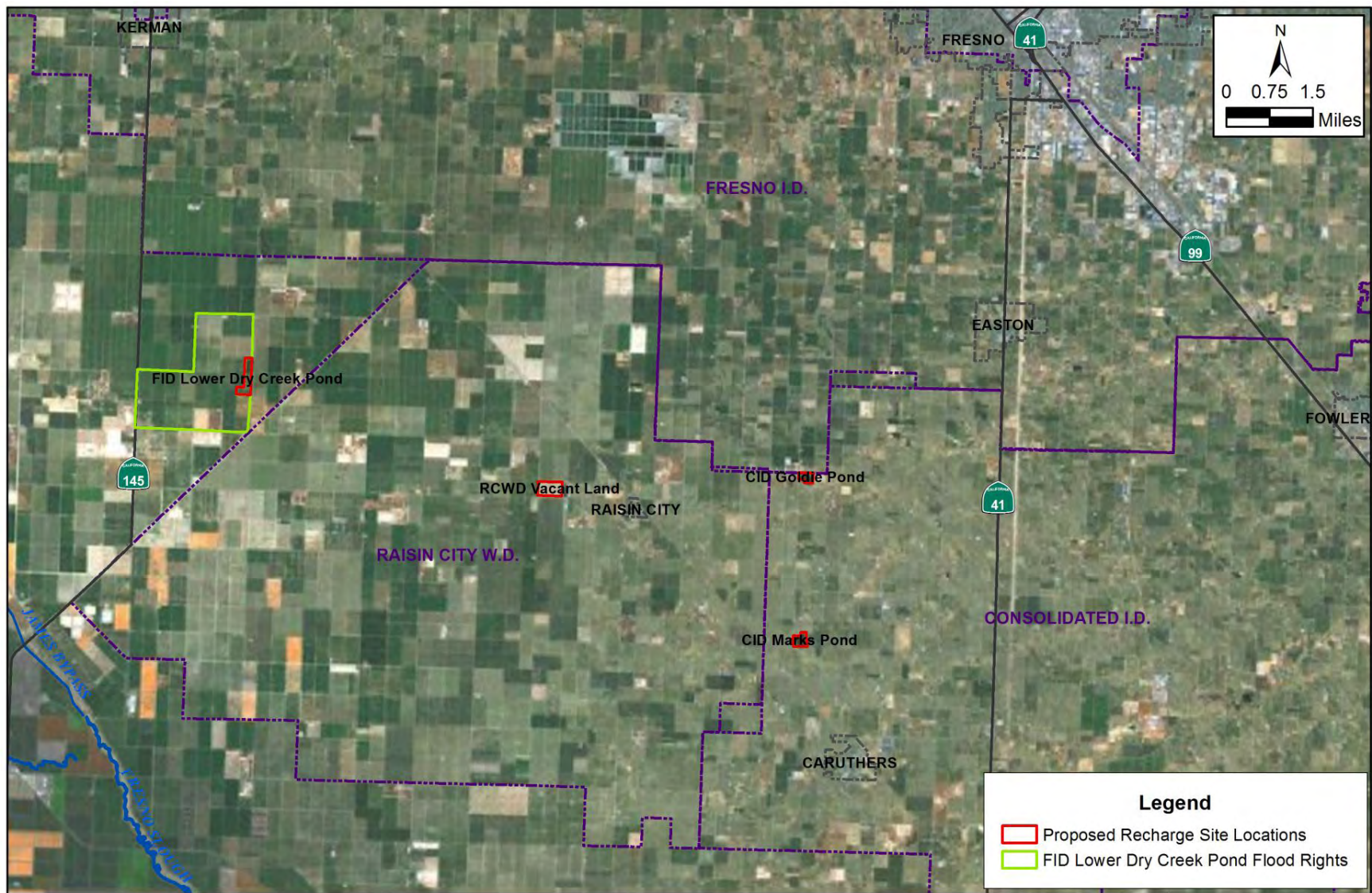


Figure 2.8 – Proposed Recharge Site Locations

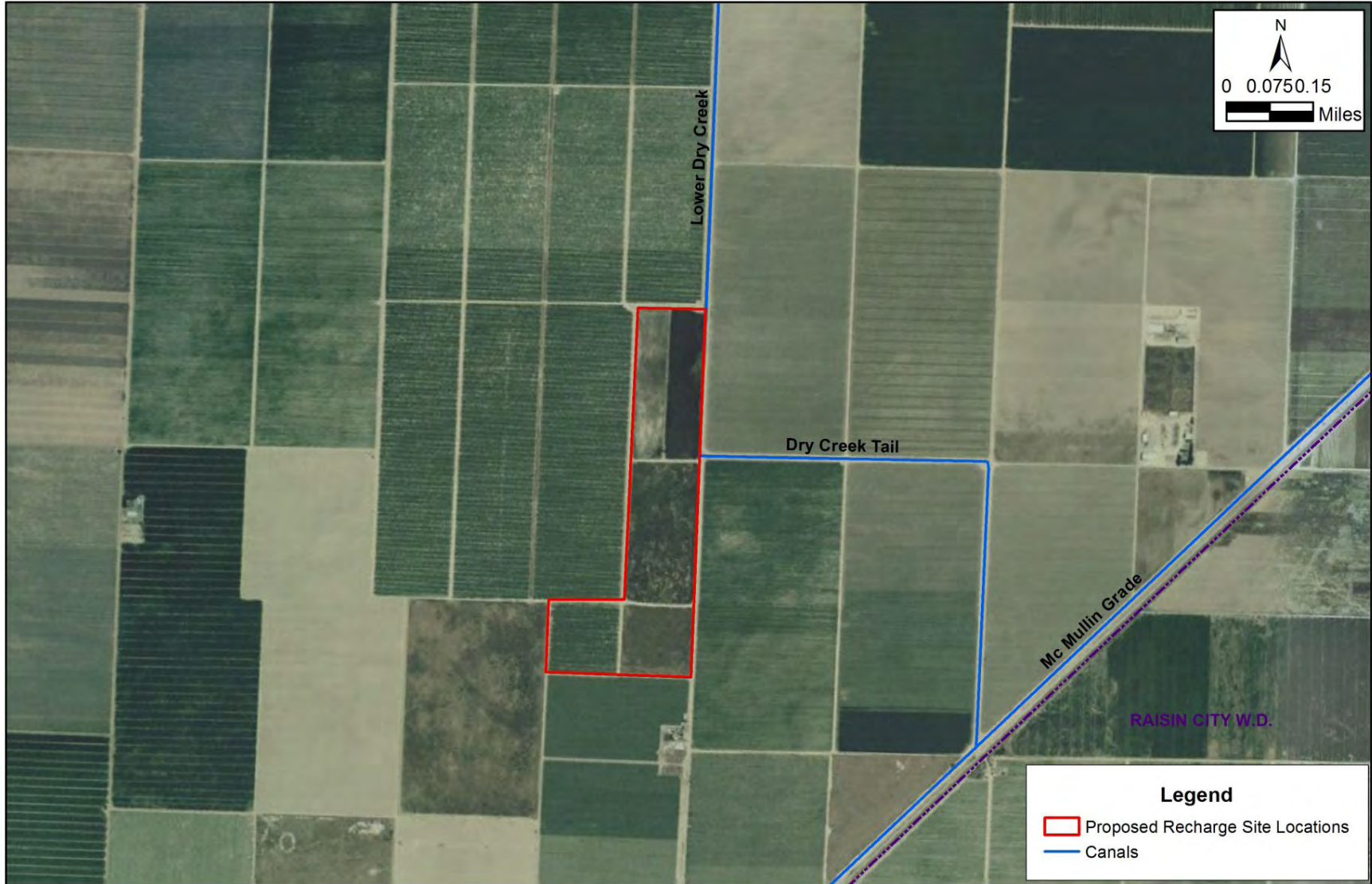


Figure 2.9.a - FID Lower Dry Creek Pond



Figure 2.9.b - RCWD Vacant Land Site

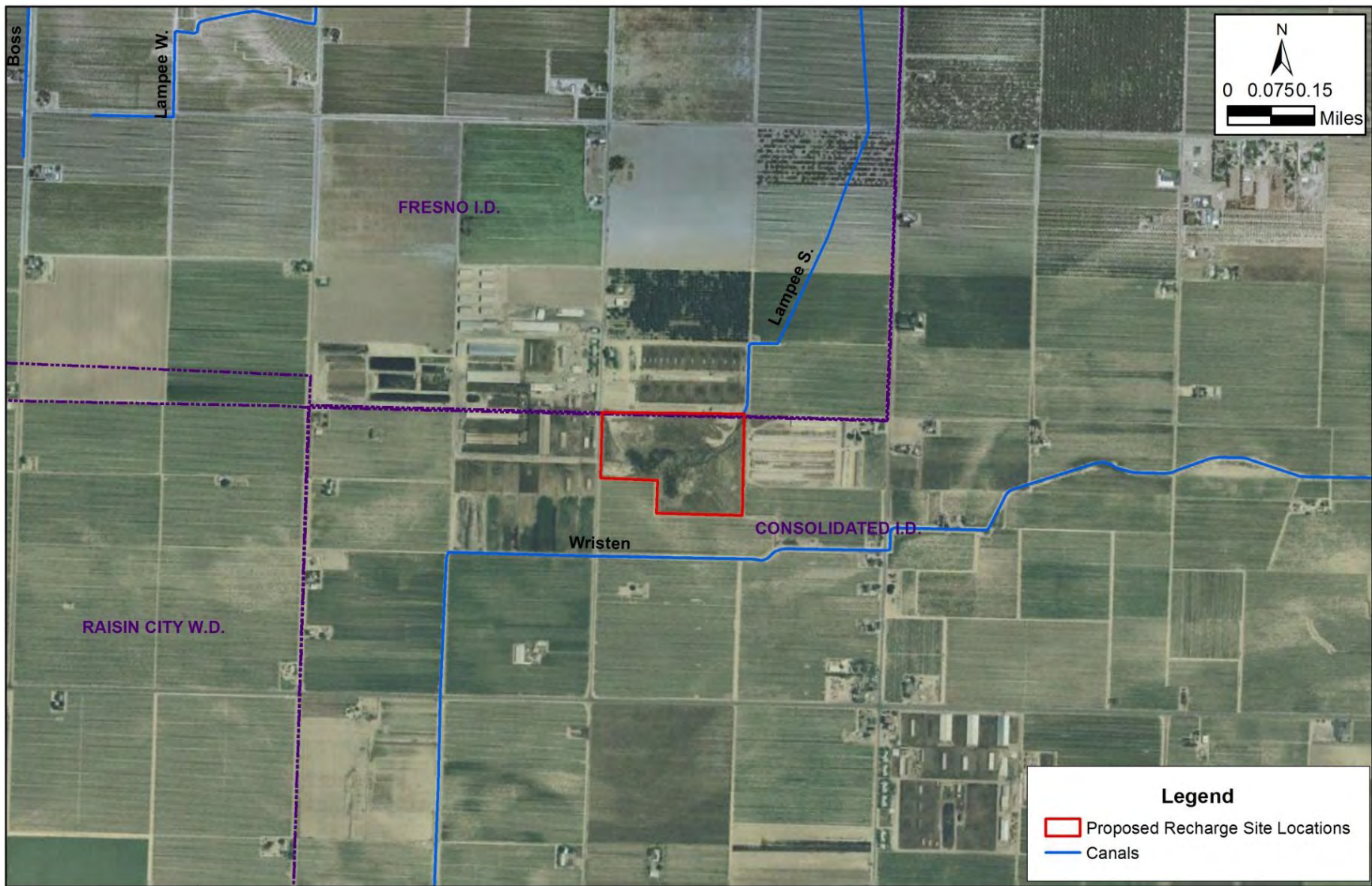


Figure 2.9.c - CID Goldie Pond

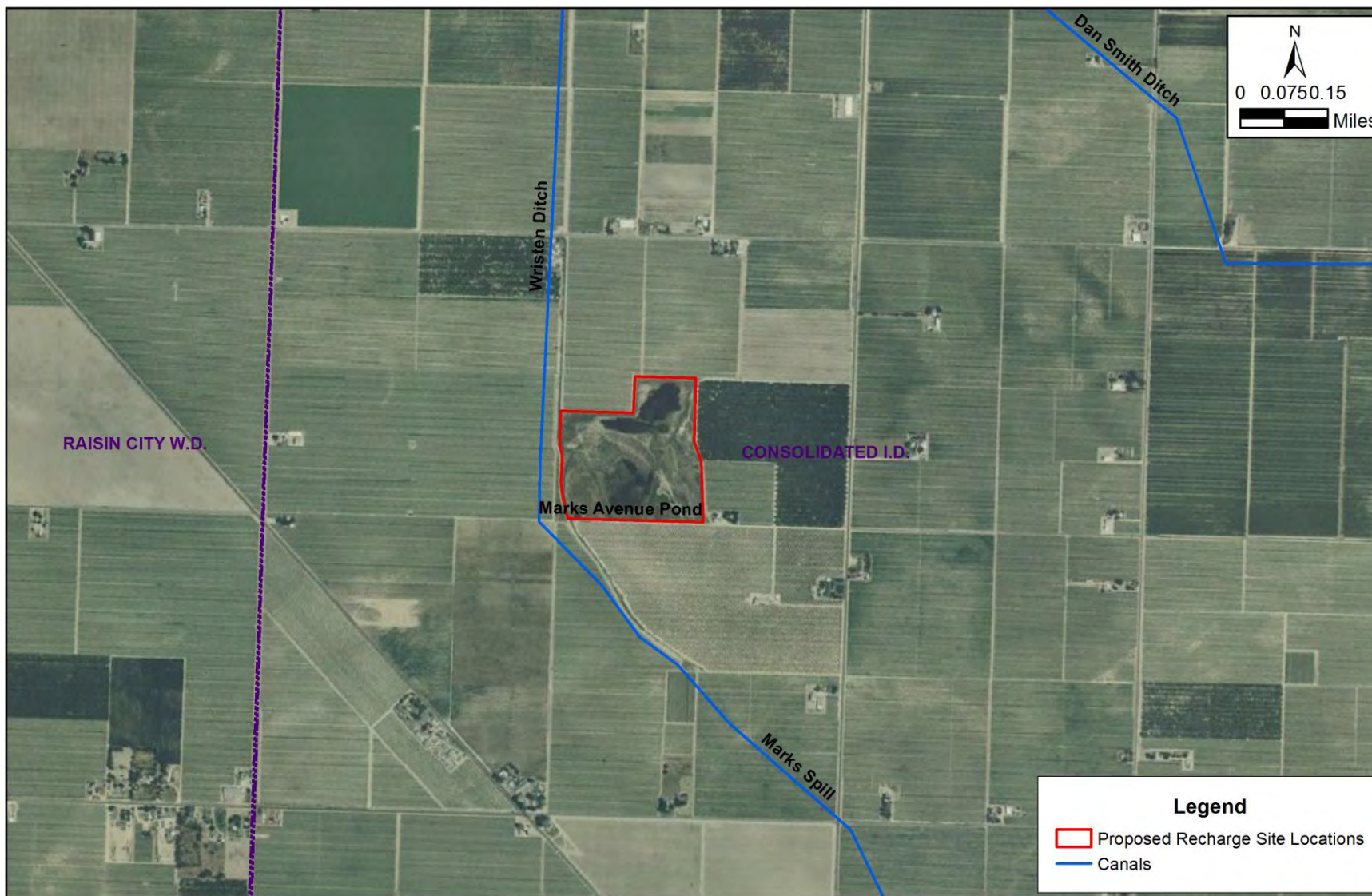


Figure 2.9.d - CID Marks Pond

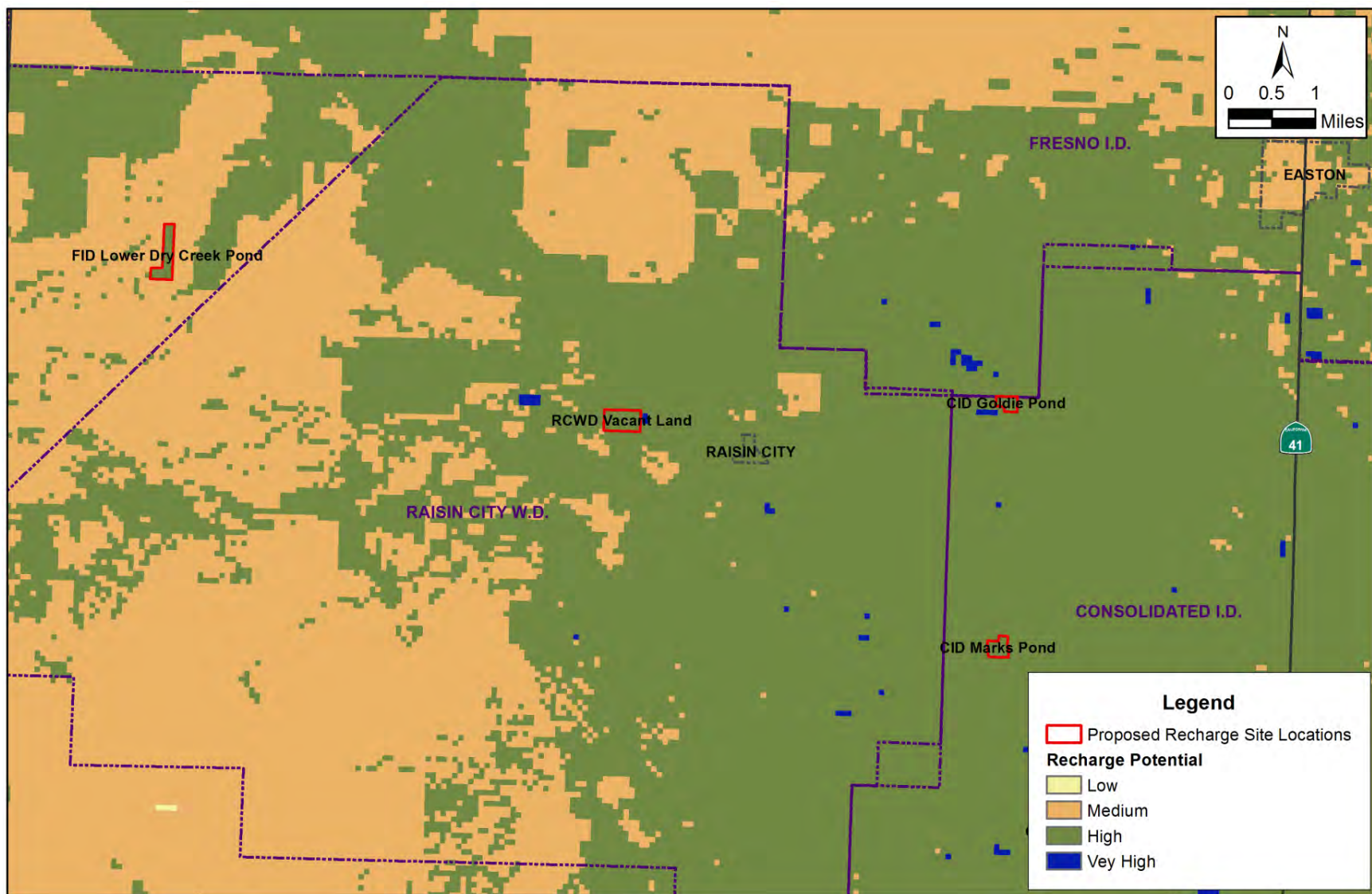


Figure 2.10 - Recharge Potential of Proposed Recharge Sites

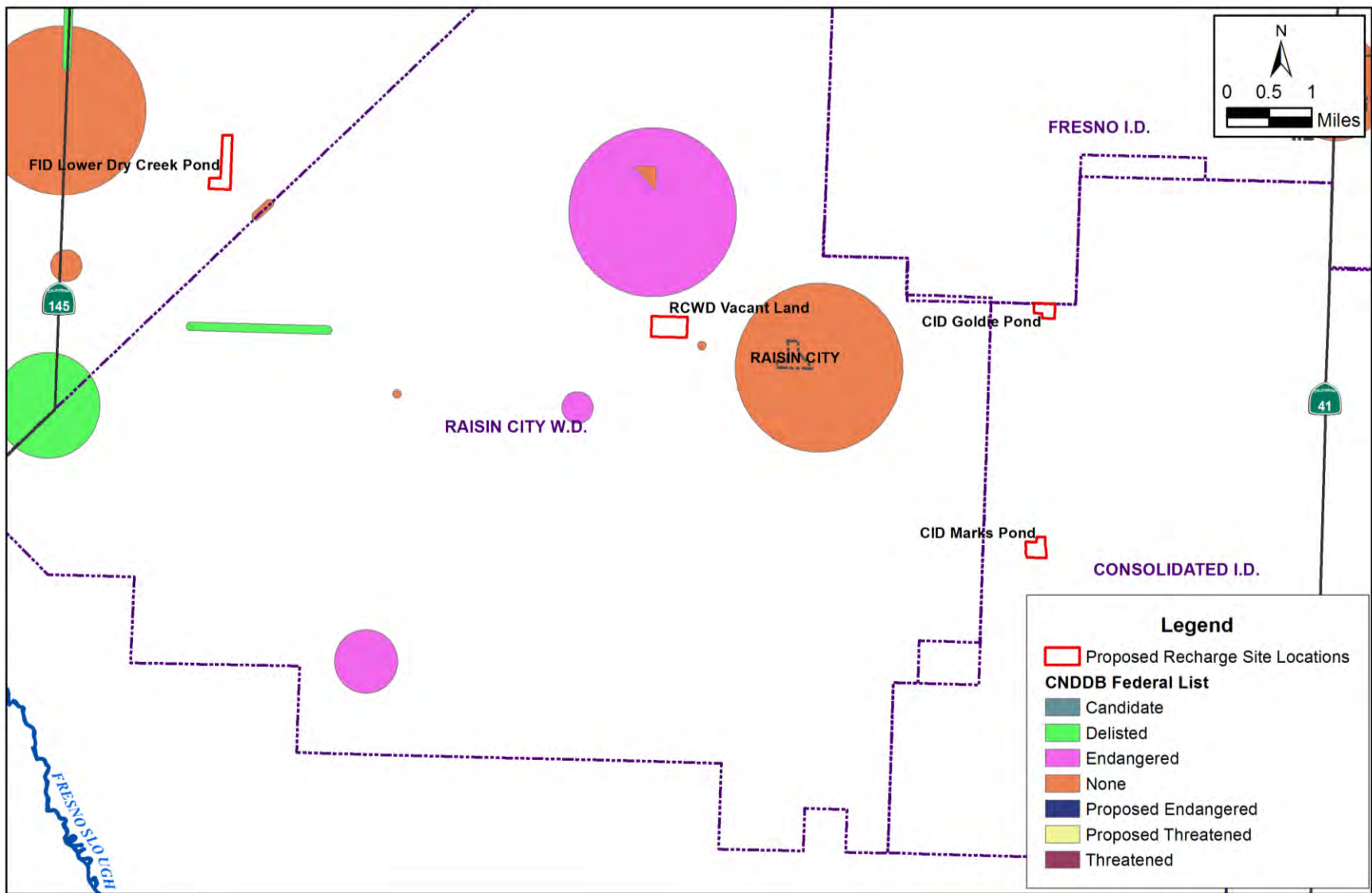


Figure 2.11.a - Areas Specified by CNDDDB Federal List for Rare and Endangered Plant, Animals and Vegetation Types

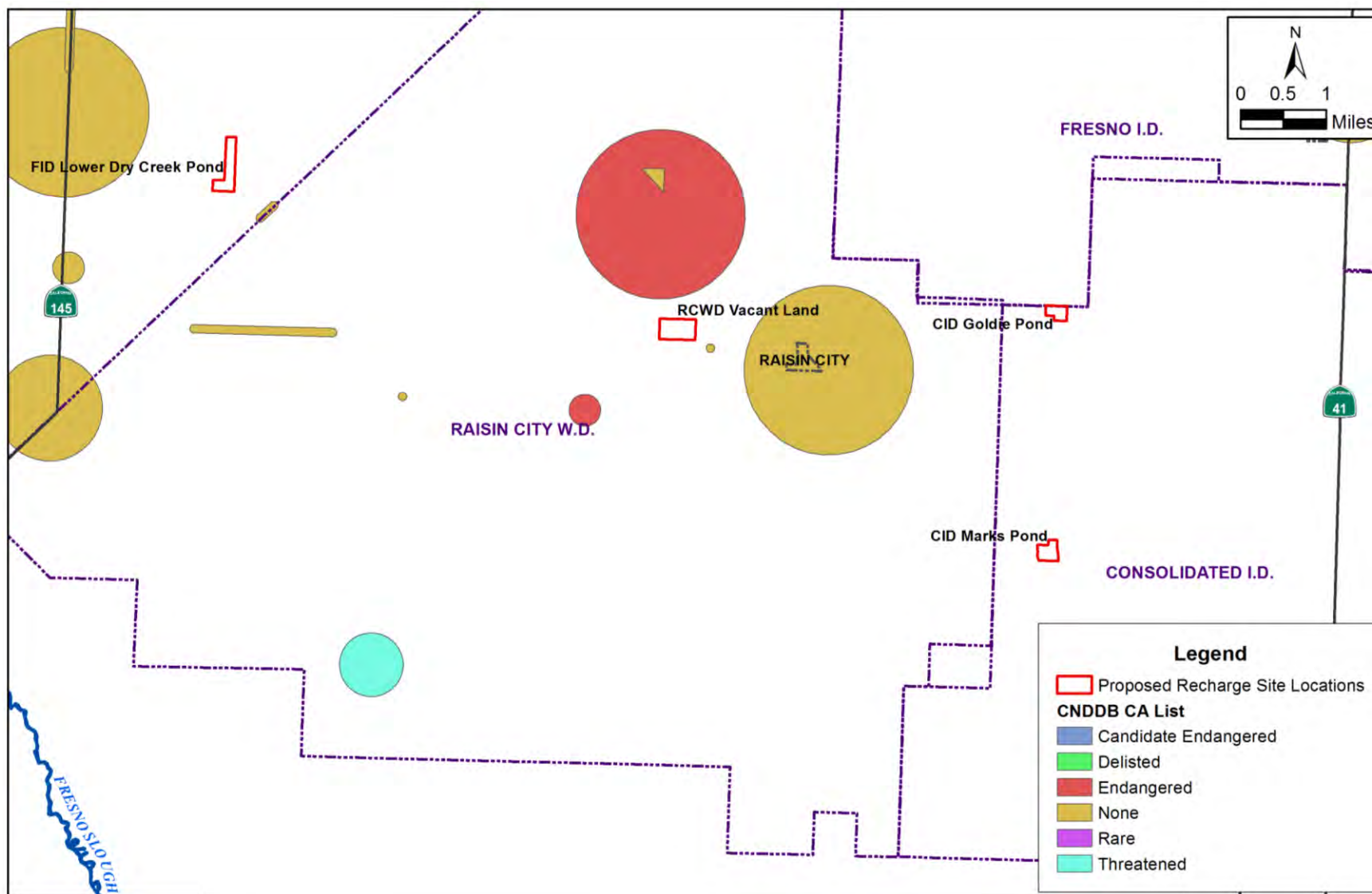


Figure 2.11.b - Areas Specified by CNDDDB CA List for Rare and Endangered Plant, Animals and Vegetation Types

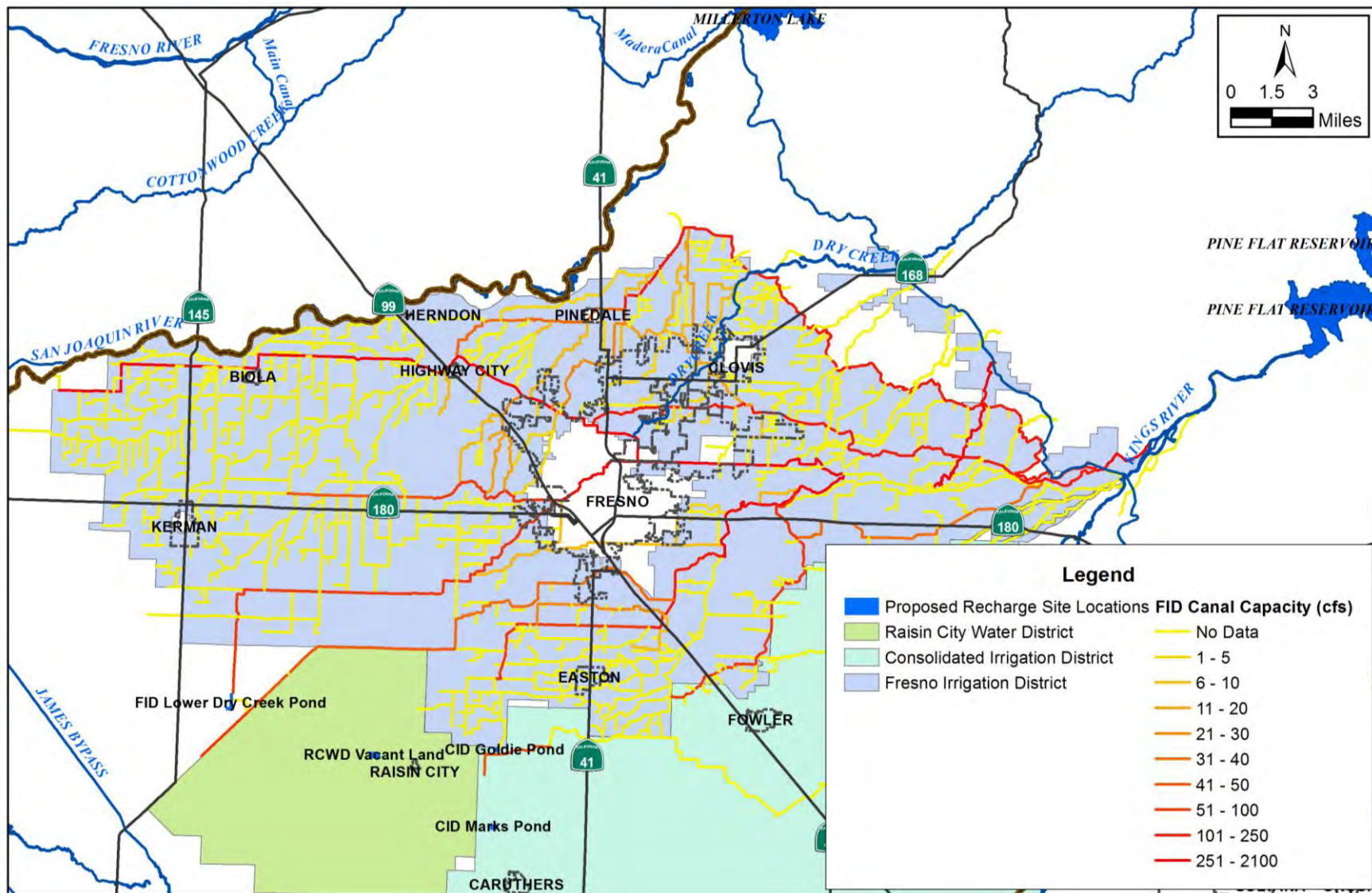


Figure 3.1 FID Canal Capacities

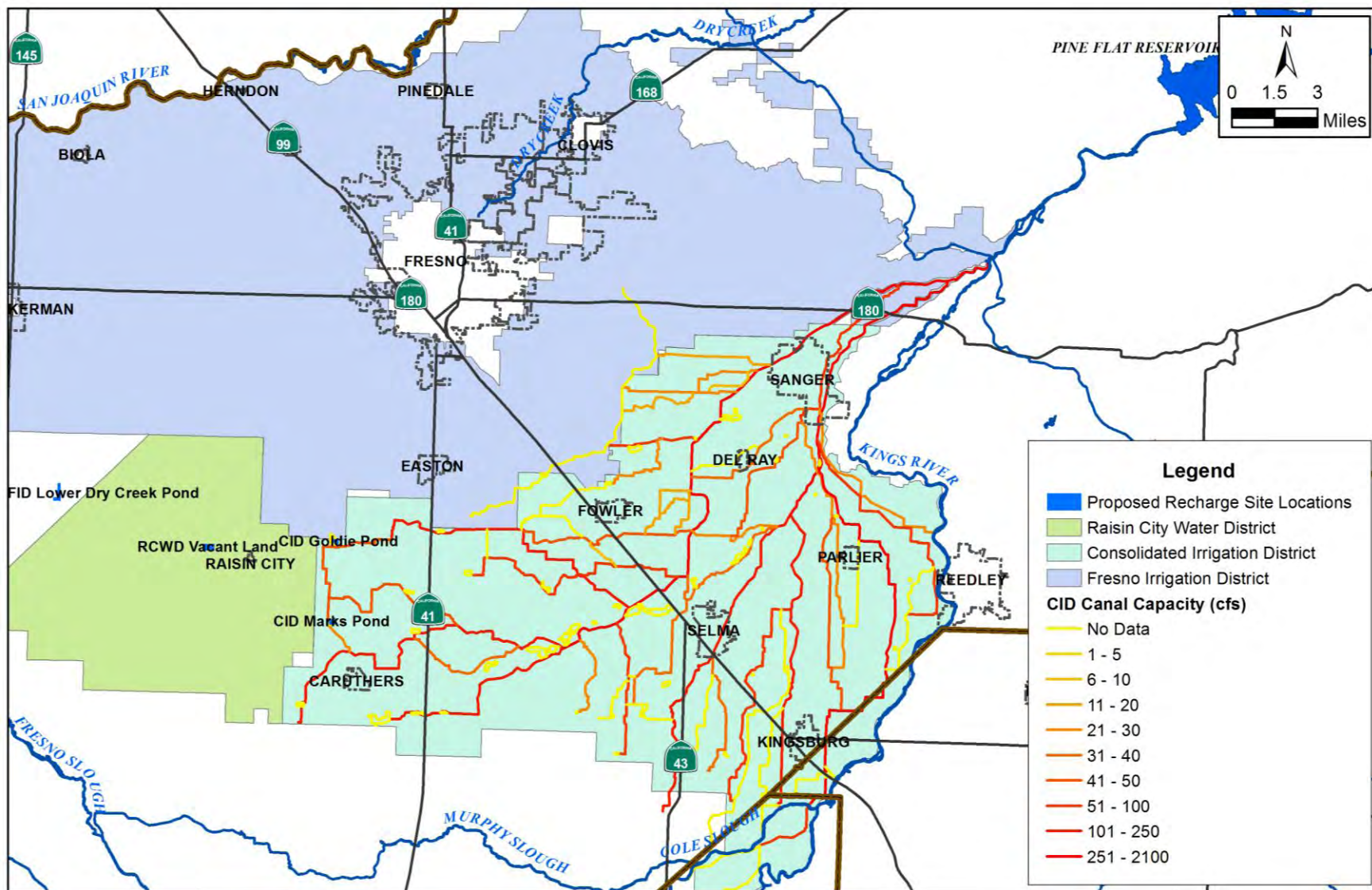


Figure 3.2 - CID Canal Capacities

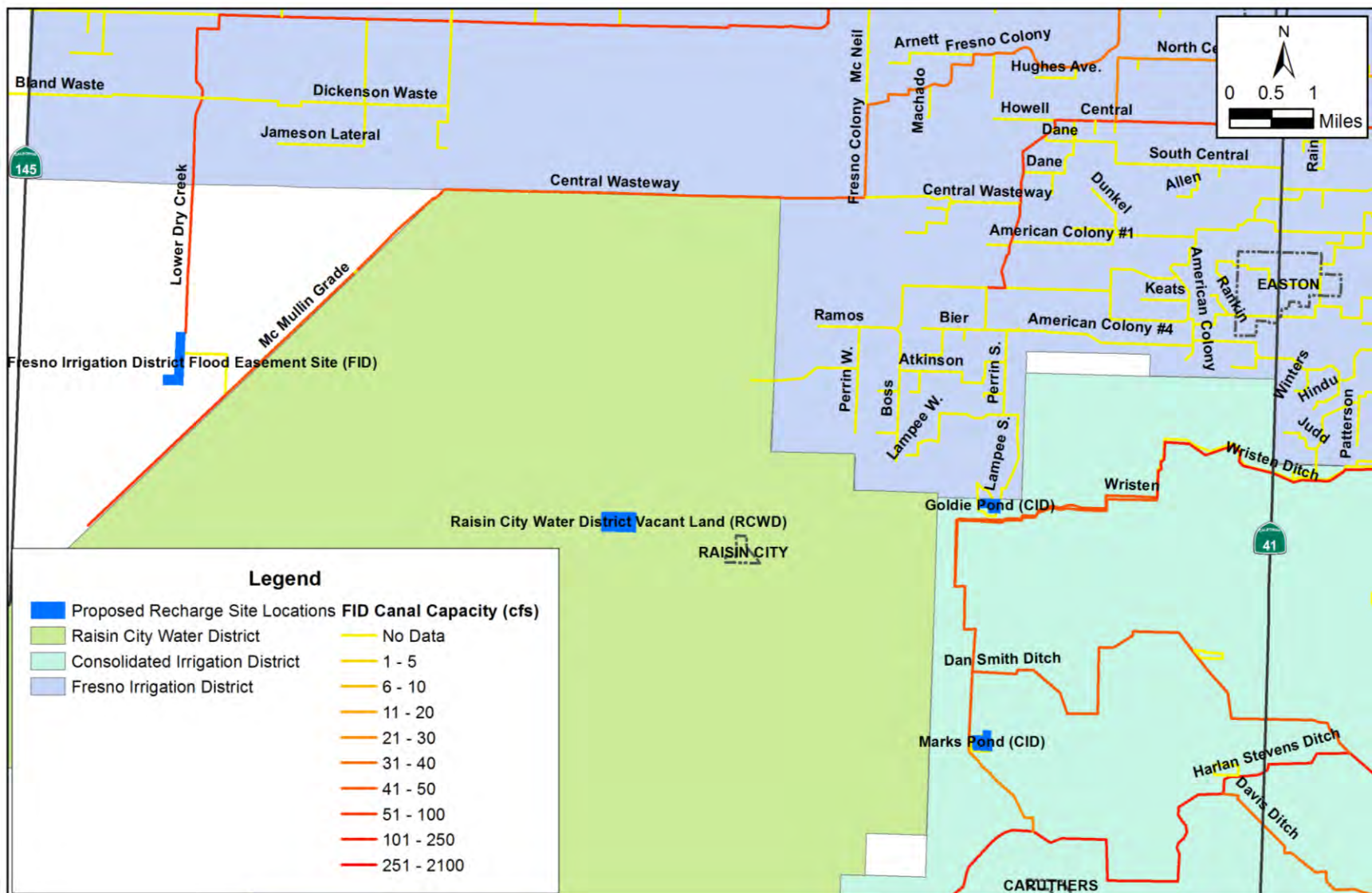


Figure 3.3 – Canal Capacities around Proposed Recharge Sites

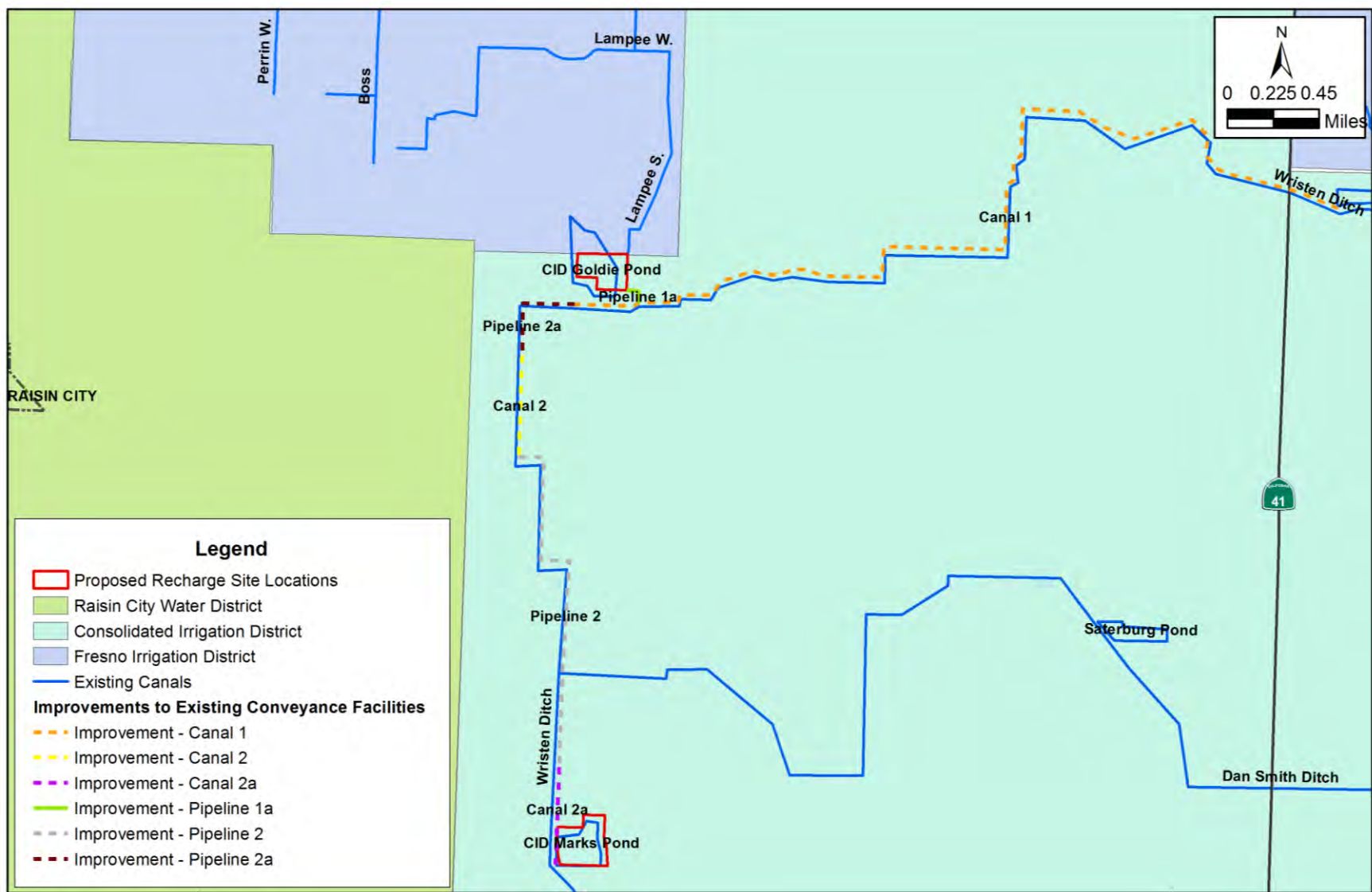


Figure 3.4 - Improvements to Existing Conveyance Facilities

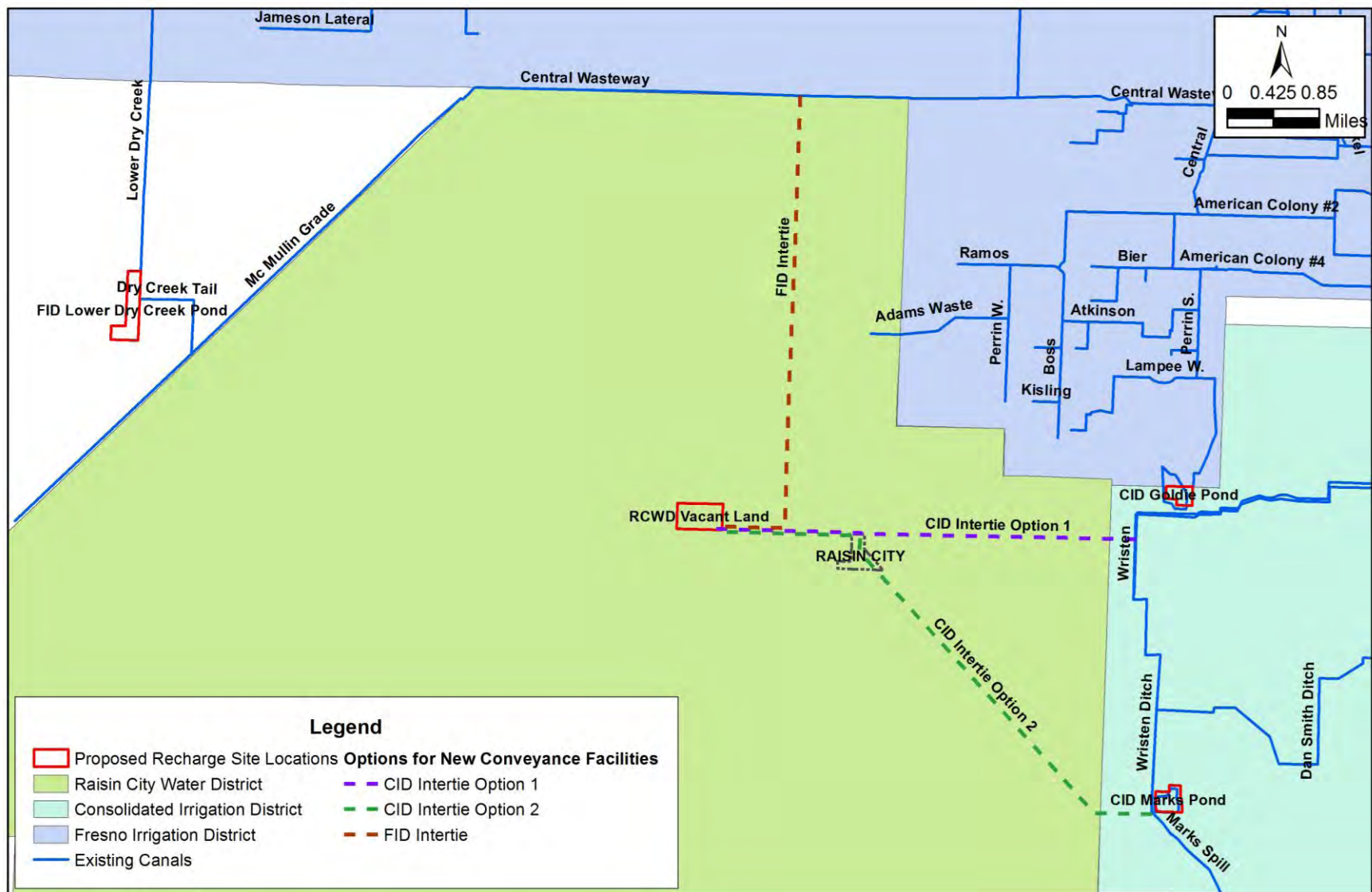


Figure 3.5 - New Conveyance Facilities

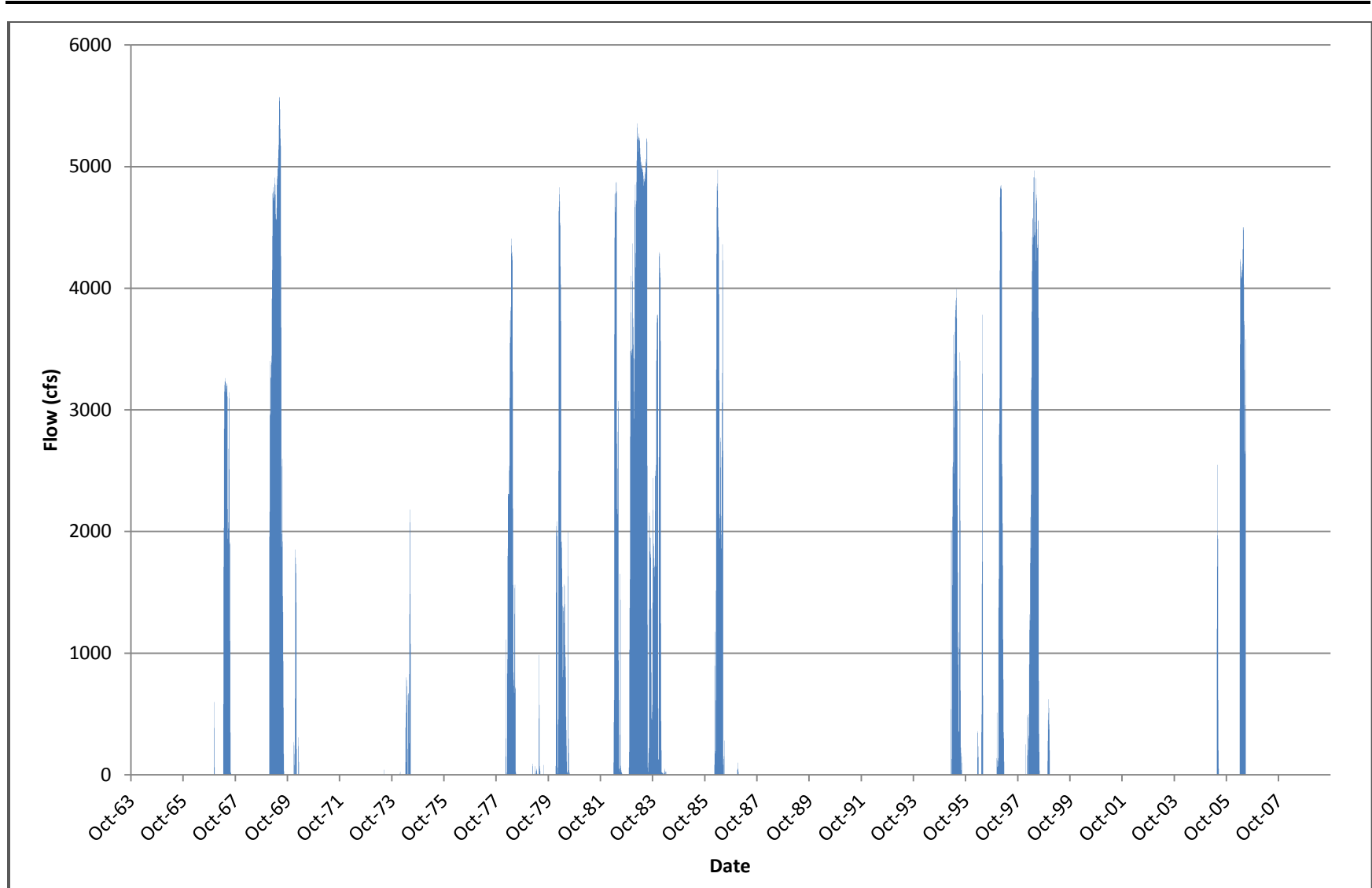


Figure 4.1 - Daily Kings River Flows at James Bypass Based on daily records from 10/01/1963 to 9/30/2009

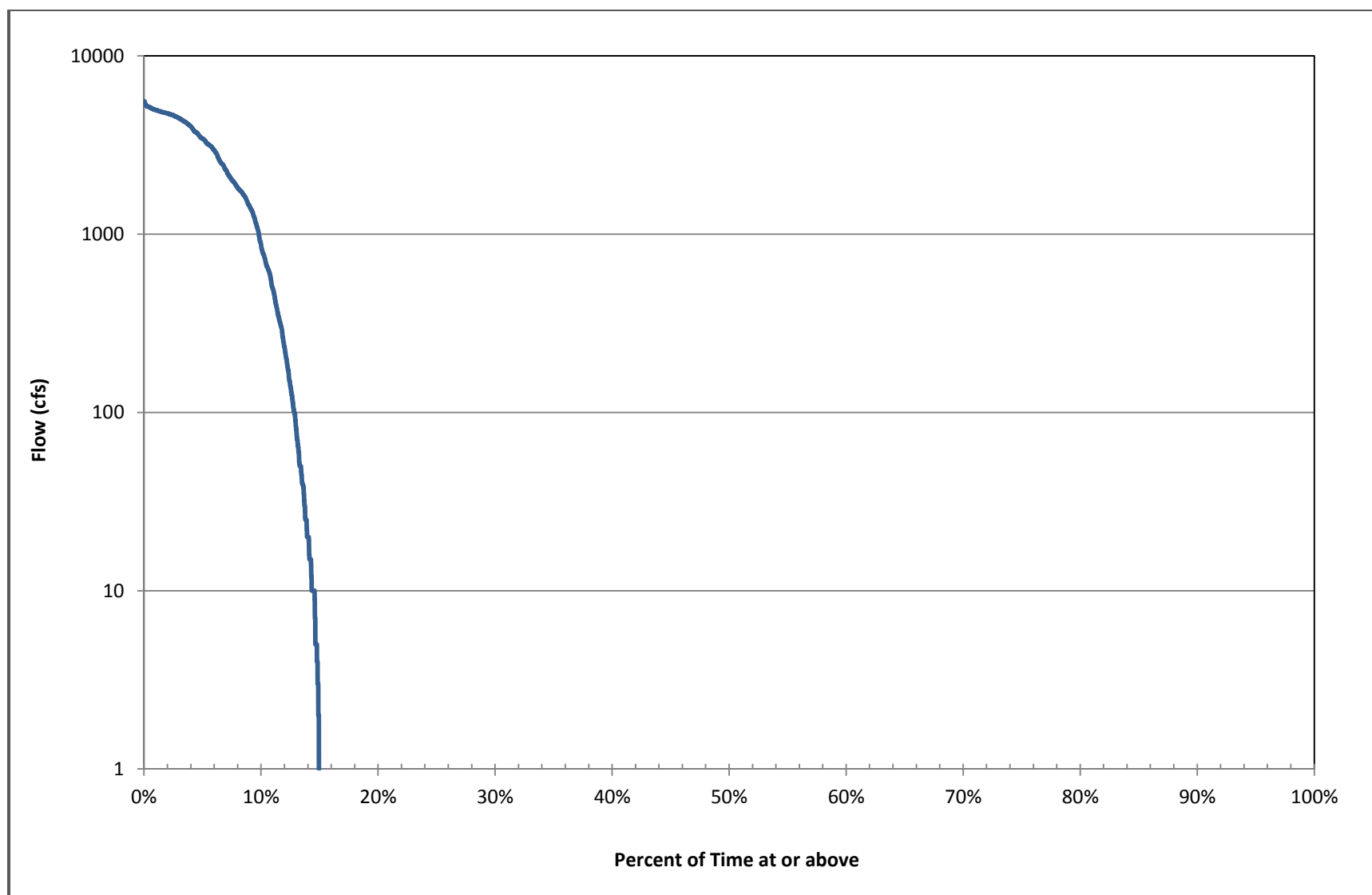


Figure 4.2 - Exceedance of Daily Kings River Flows at James Bypass

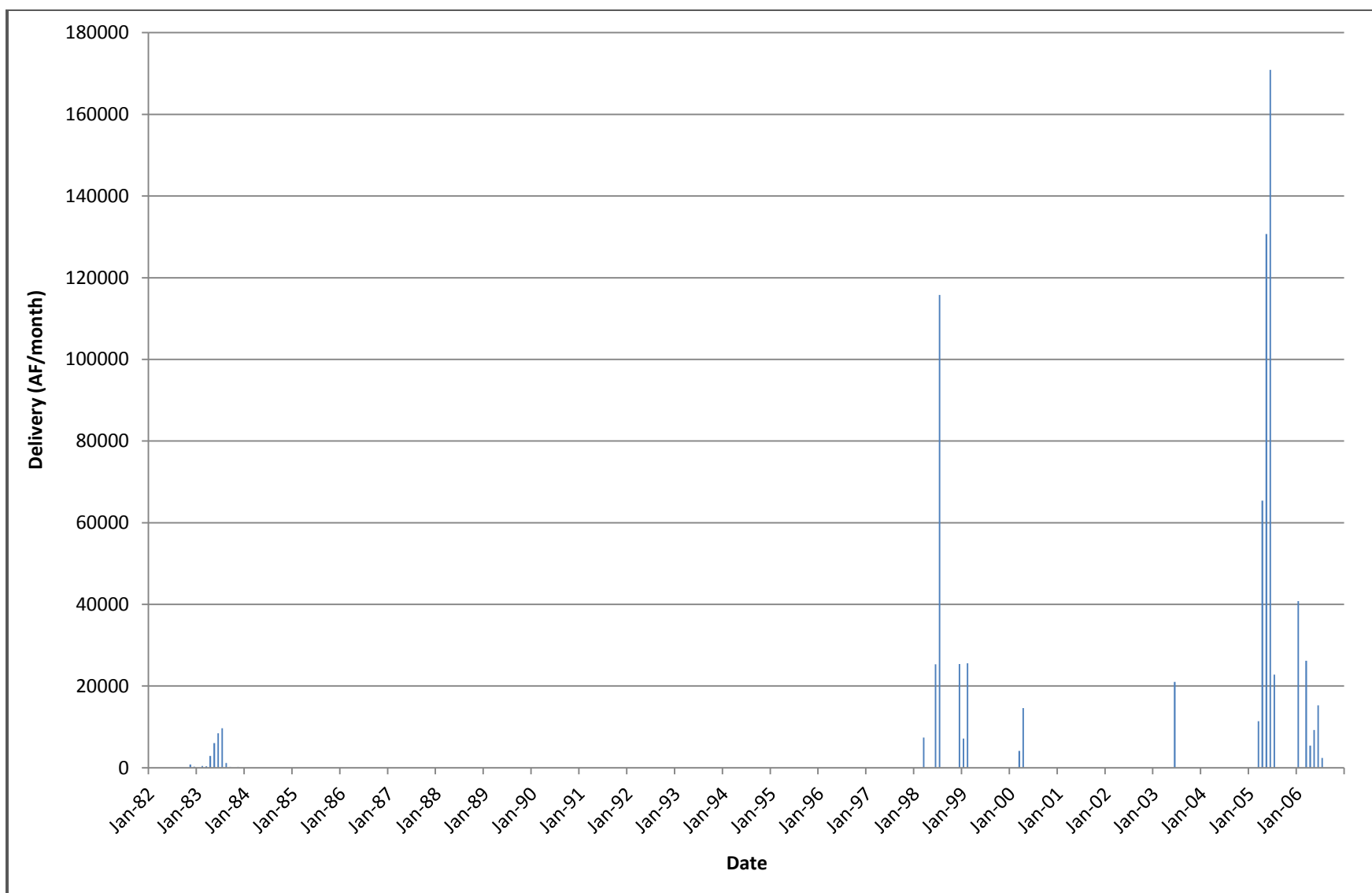


Figure 4.3 - Monthly Section 215 Deliveries Based on Monthly Records from 01/1982 to 12/2006

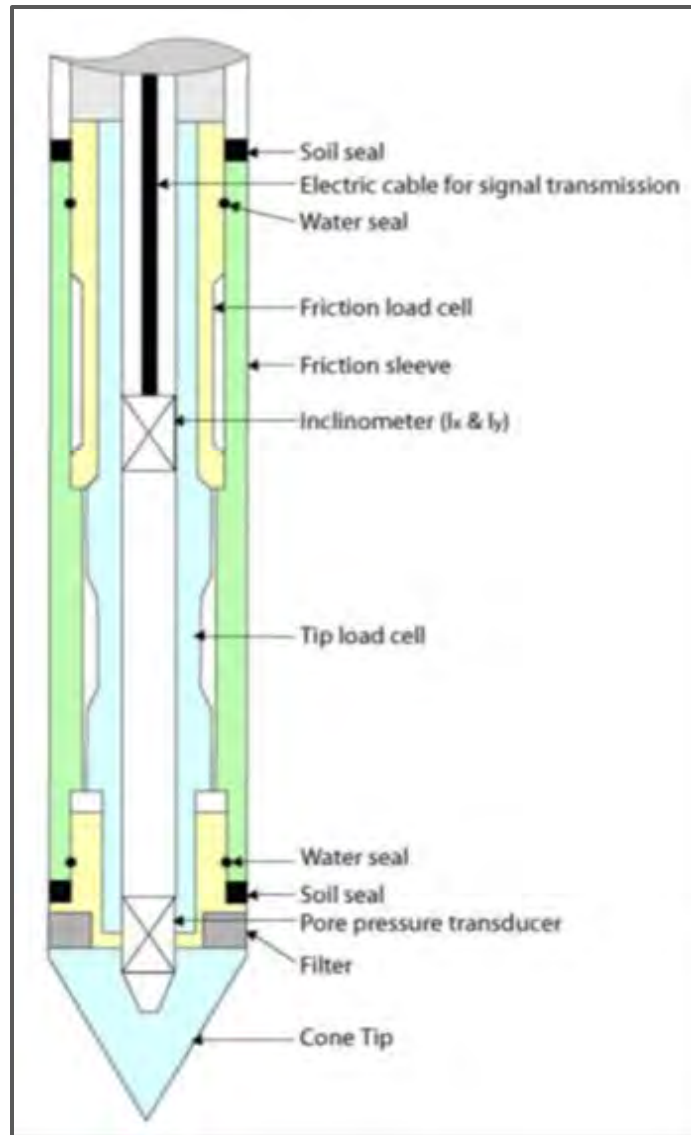


Figure 5.1 – CPT Diagram

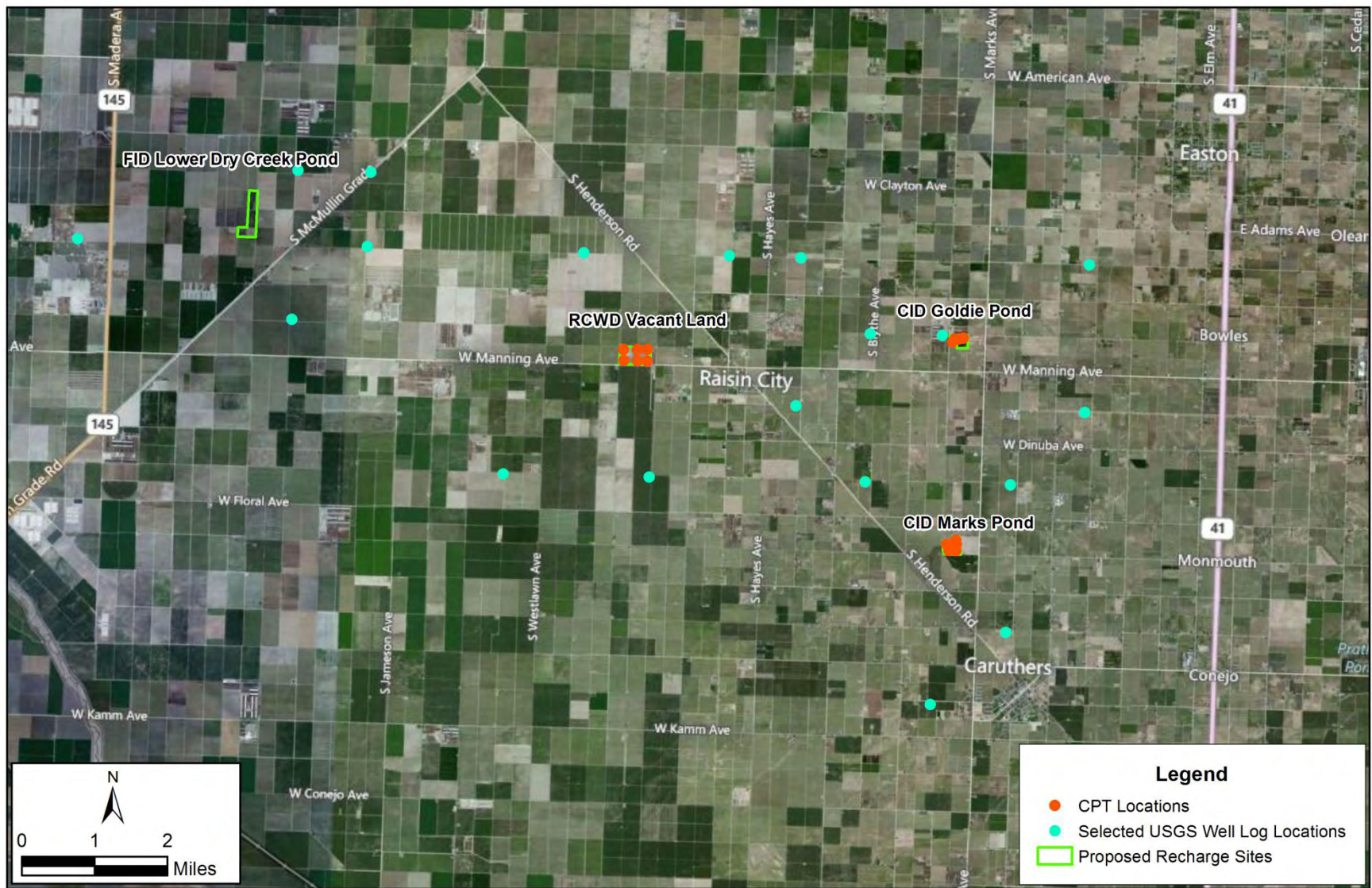


Figure 5.2 - CPT Locations and Selected USGS Well Log Locations around the Project Area

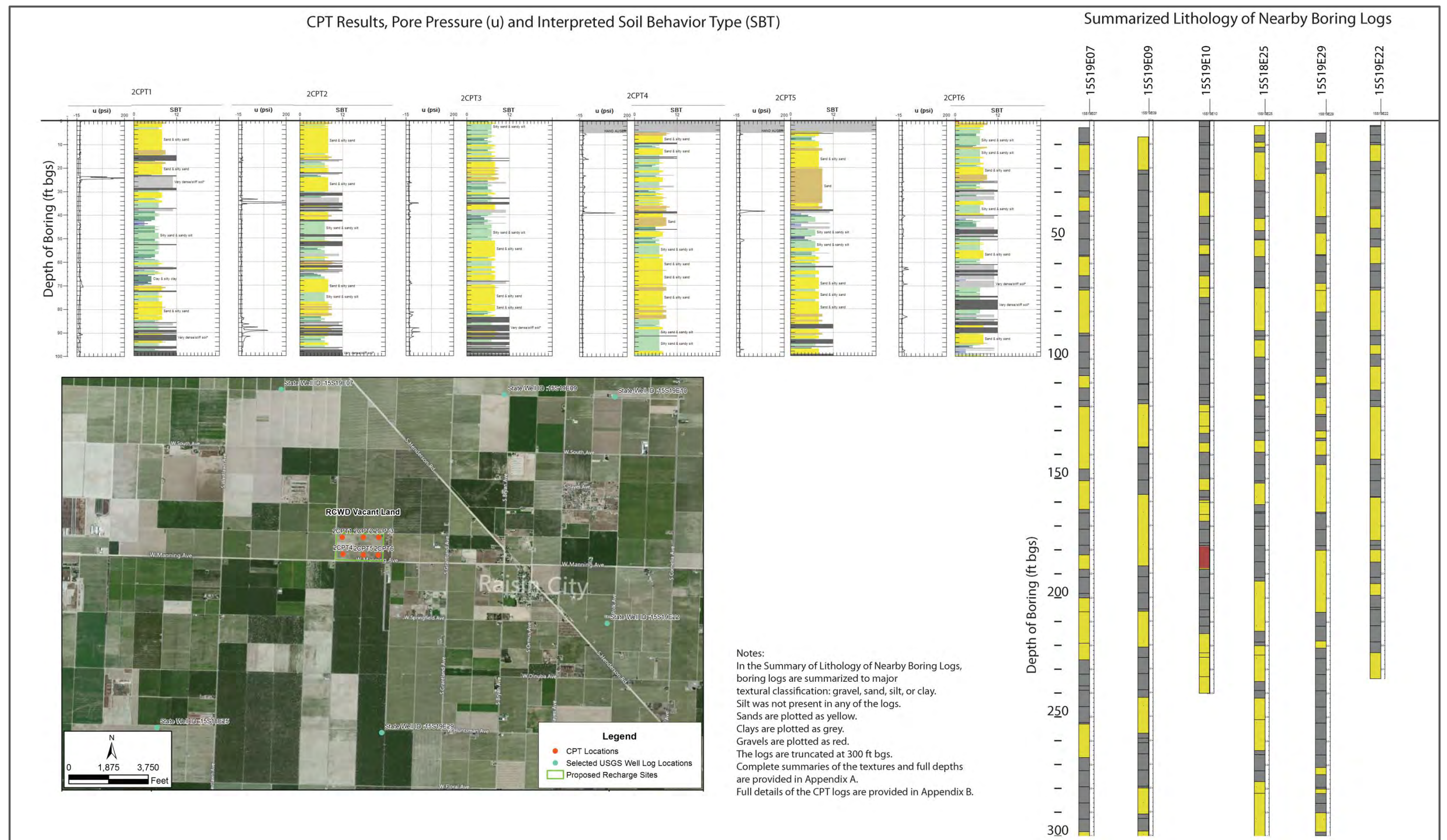


Figure 5.3 – CPT Results and Nearby Boring Logs for RCWD Vacant Land Site

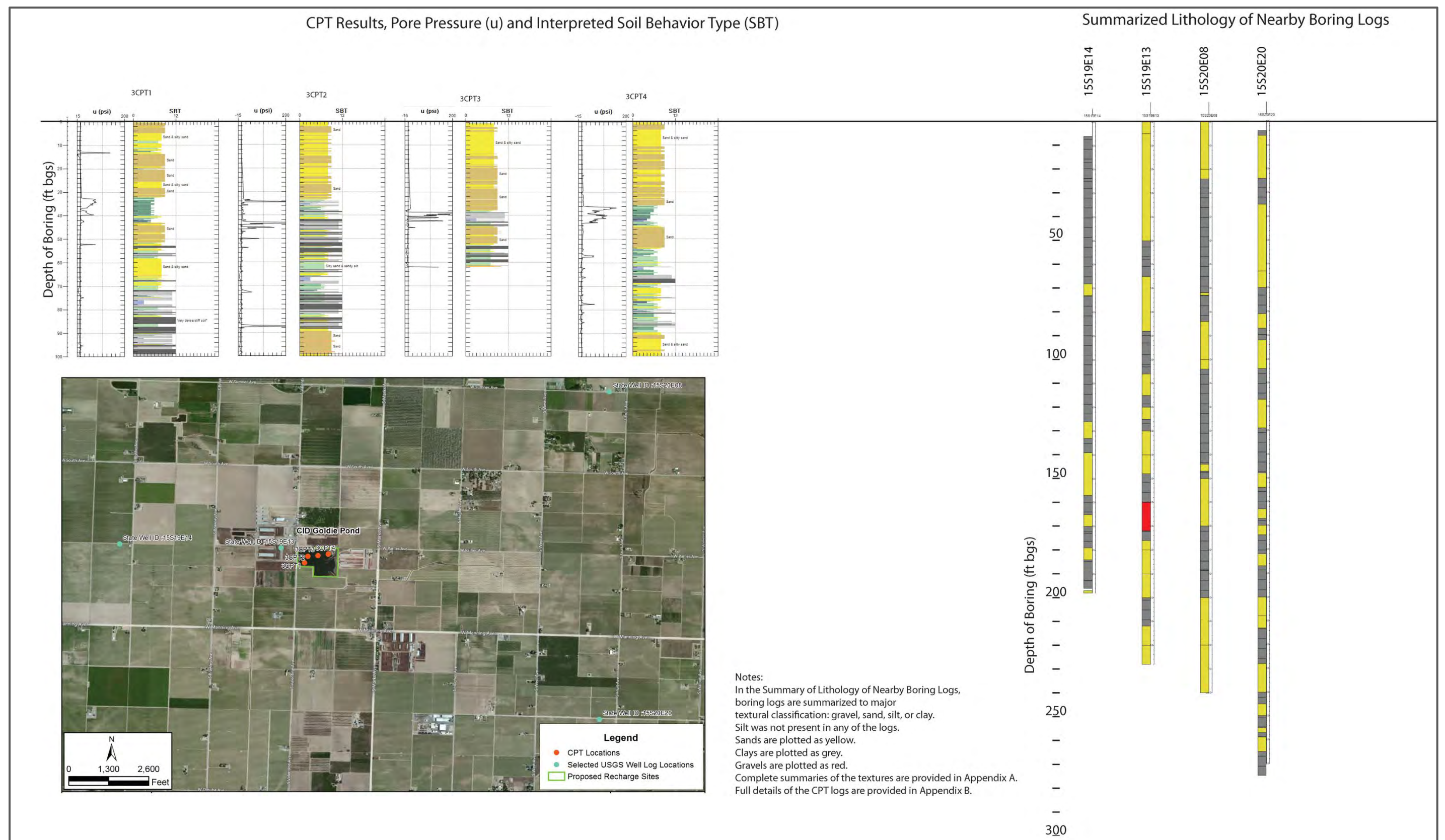
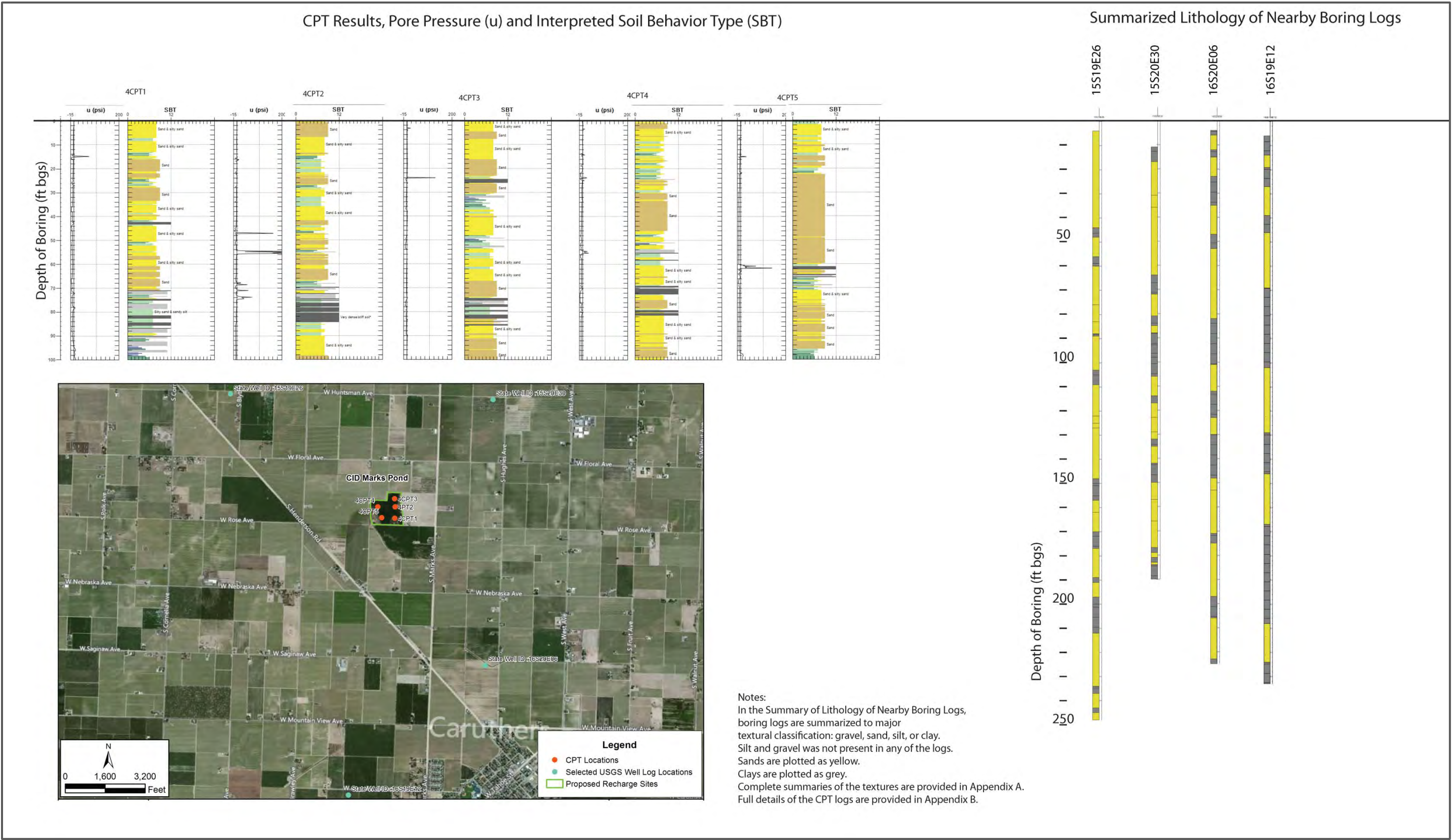


Figure 5.4 – CPT Results and Nearby Boring Logs for CID Goldie Pond Site



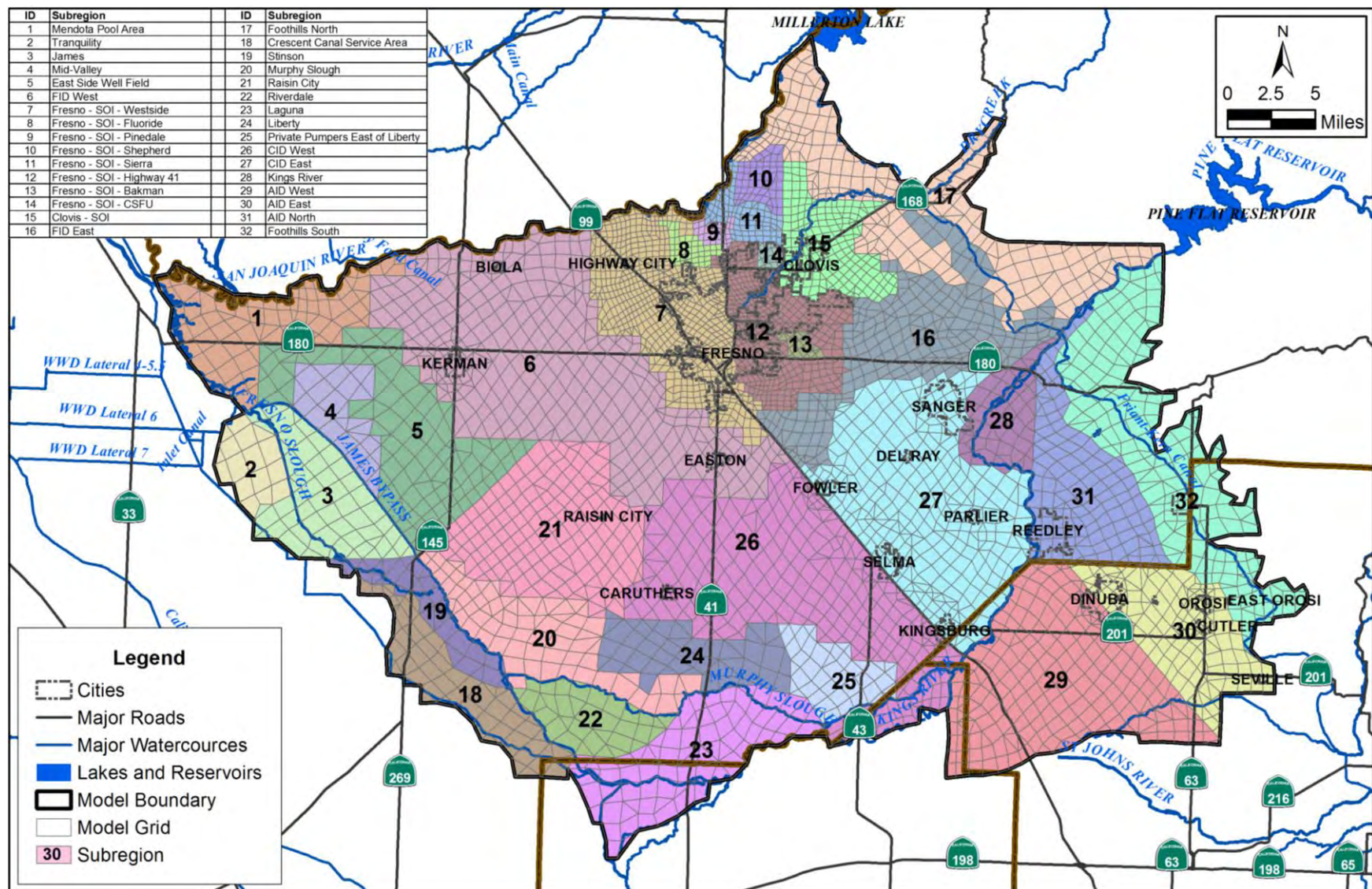


Figure 6.1 - Kings IGSM Model Grid and Subregions

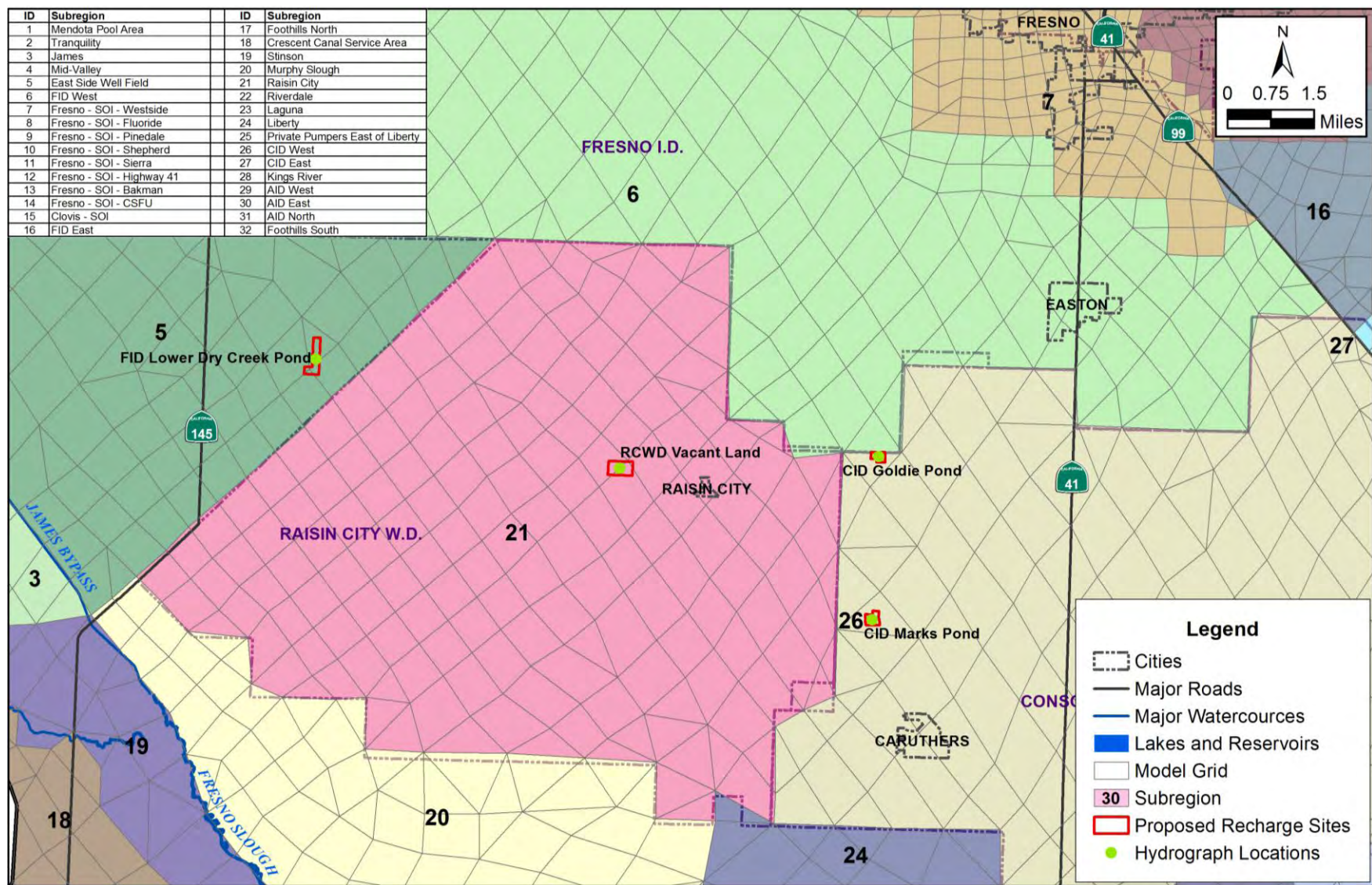


Figure 6.2 - Model Grid, Subregions, and Hydrograph Locations in the vicinity of Raisin City Water District

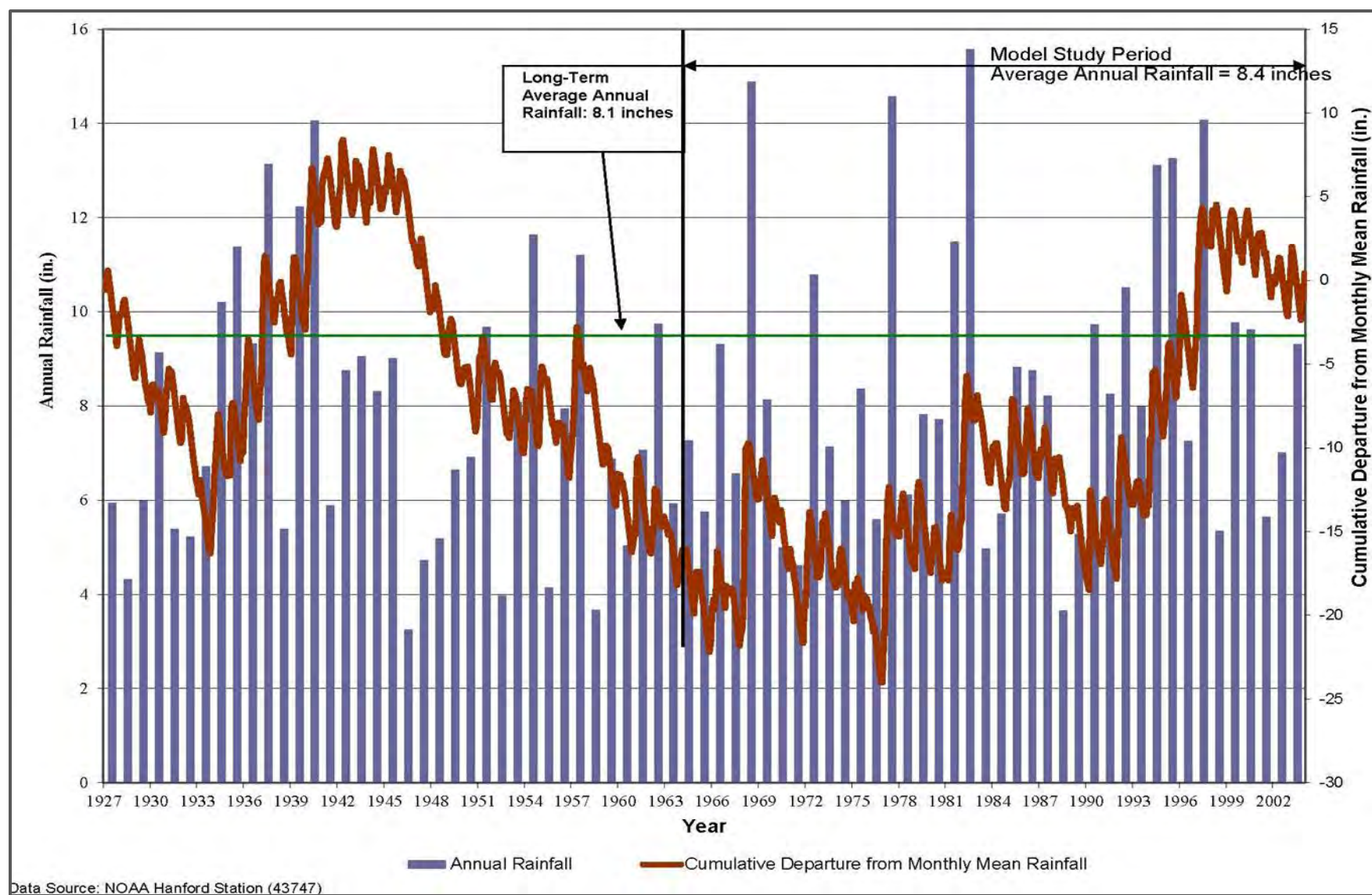


Figure 6.3 - Historical Rainfall for Project Area

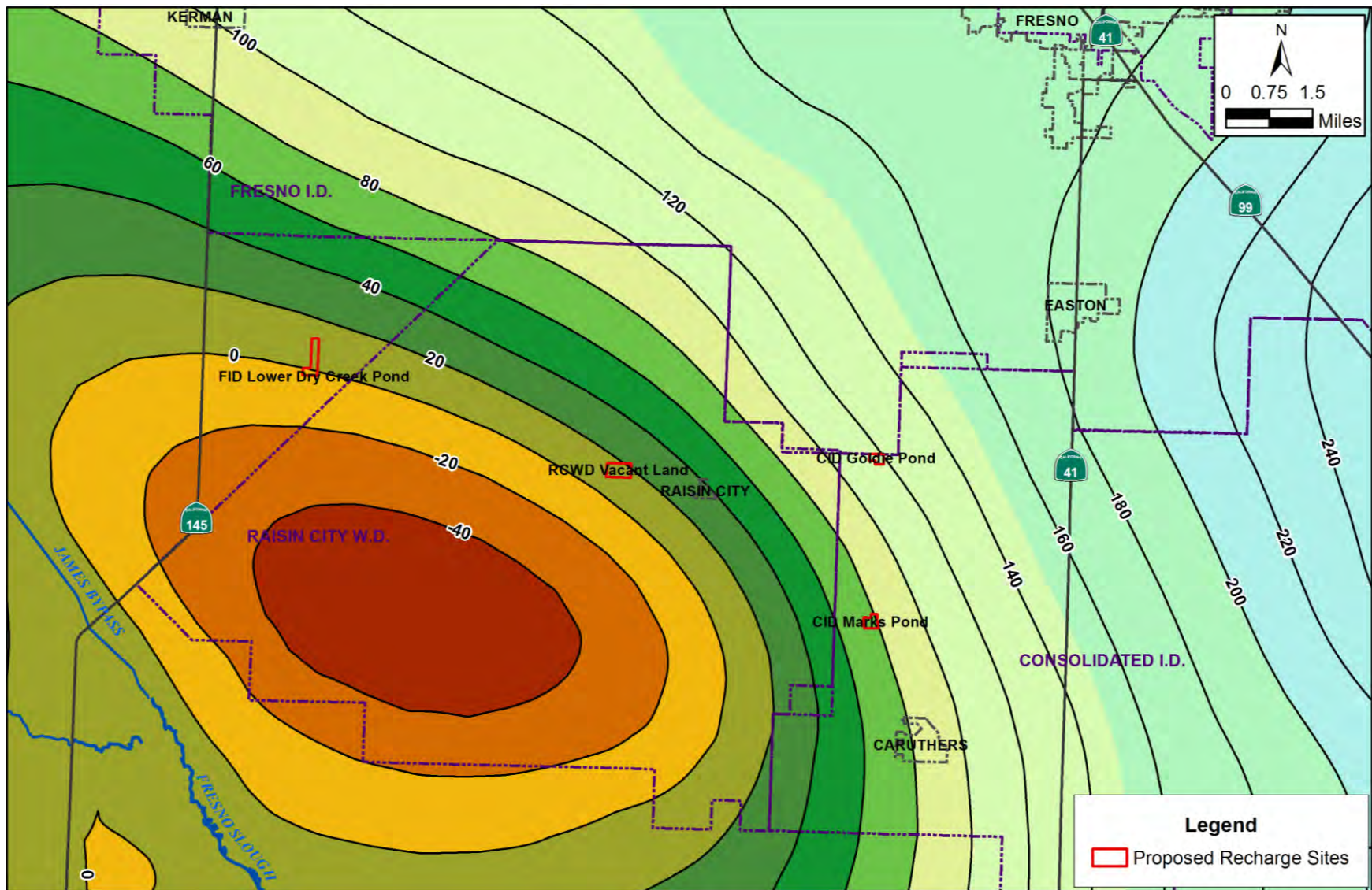


Figure 6.4 - Simulated Groundwater Levels for Wet Hydrologic Conditions (Fall 1983)

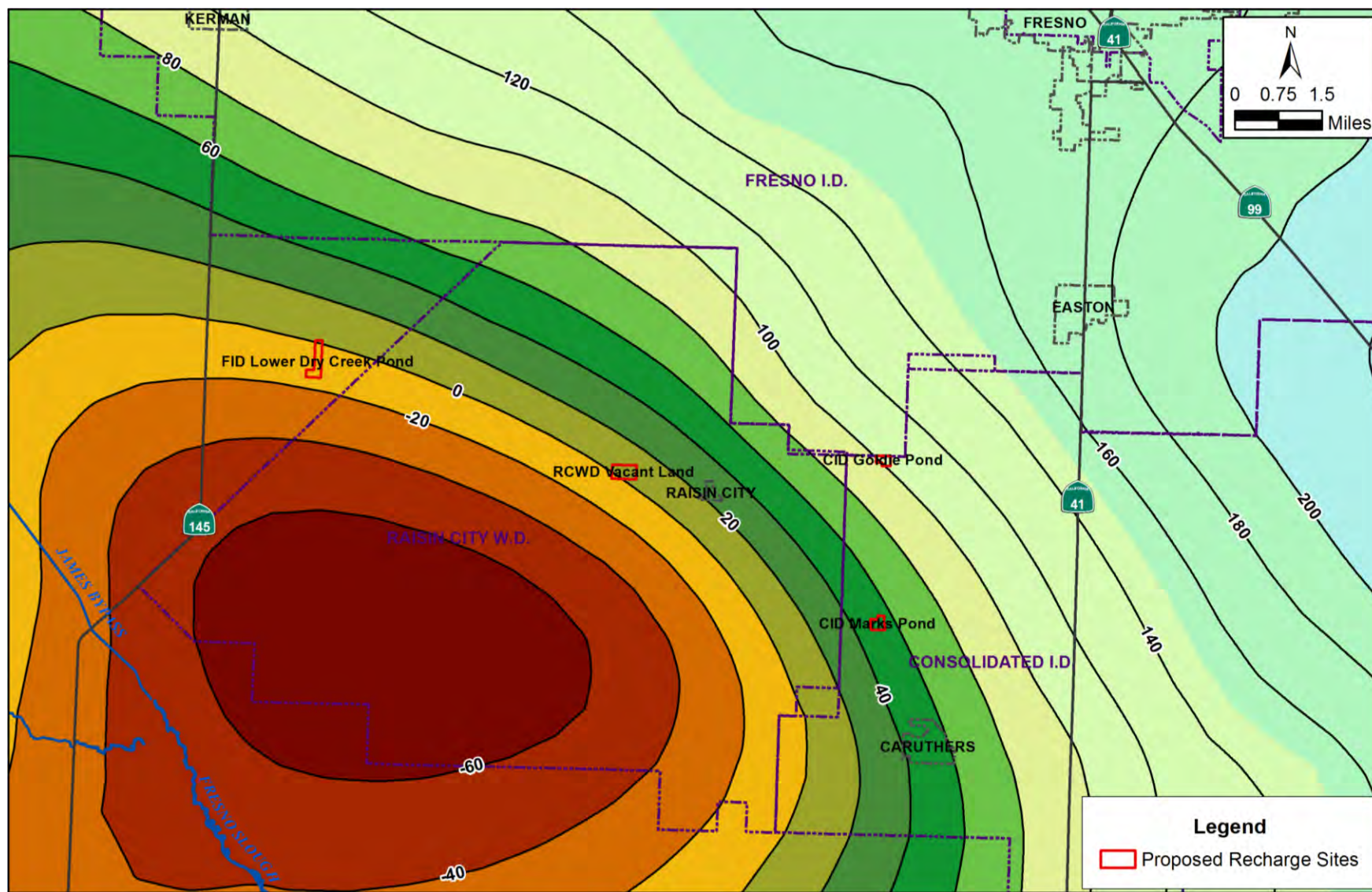


Figure 6.5 - Simulated Groundwater Levels for Average Hydrologic Conditions (Fall 2004)

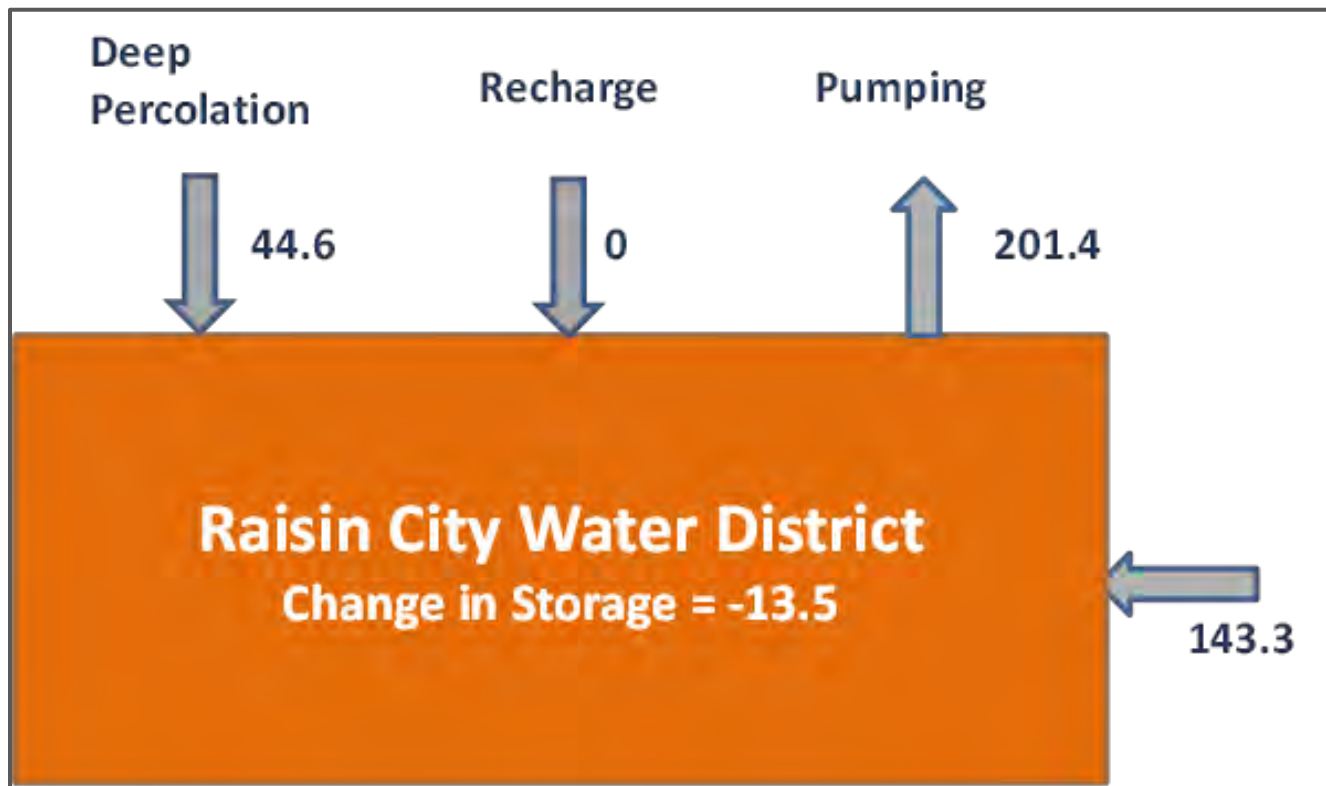


Figure 6.6 - Long-Term Annual Average Water Budget for RCWD Subregion (TAF/yr)

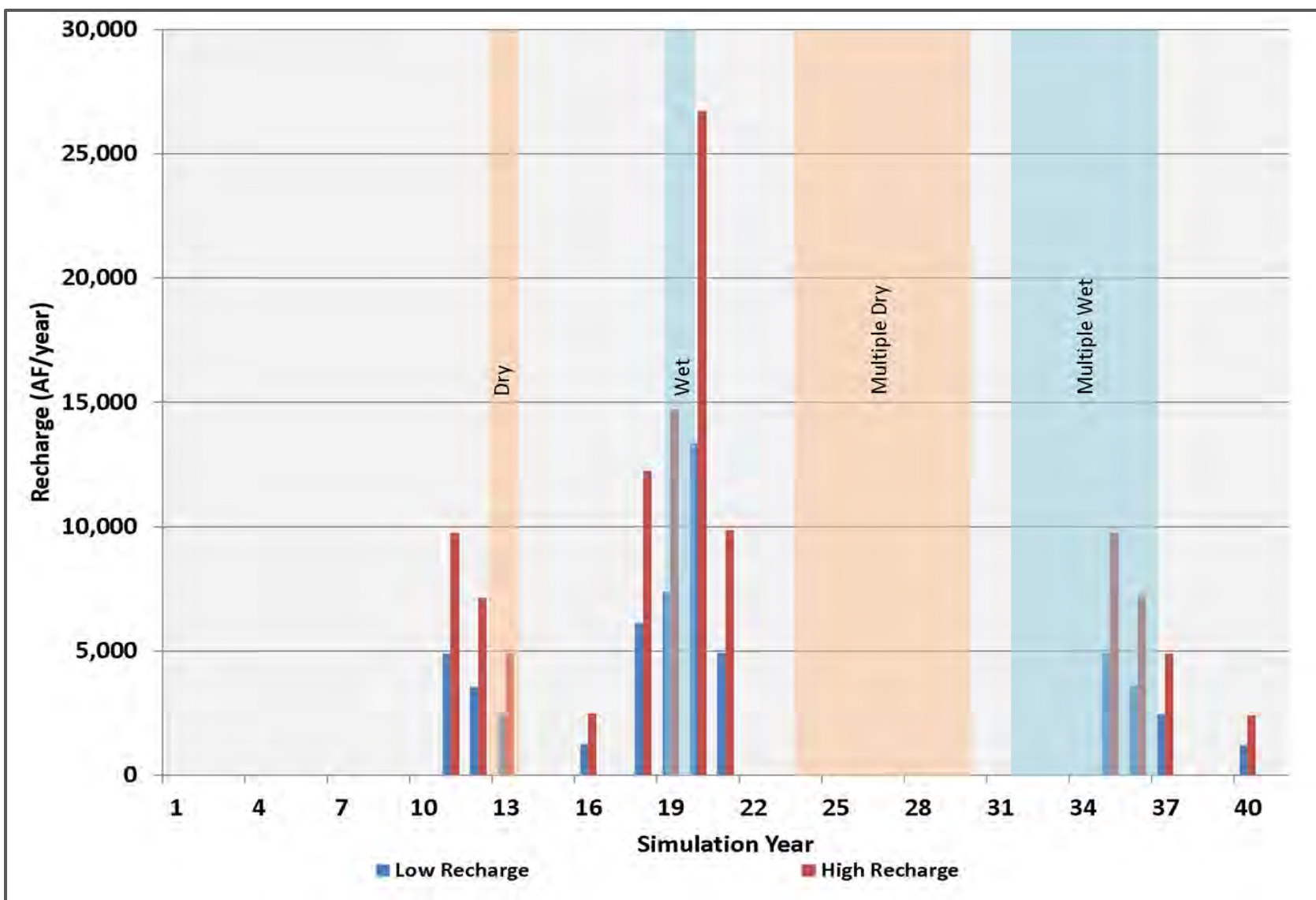


Figure 7.1 - Annual Recharge Rates for RCWD Pond

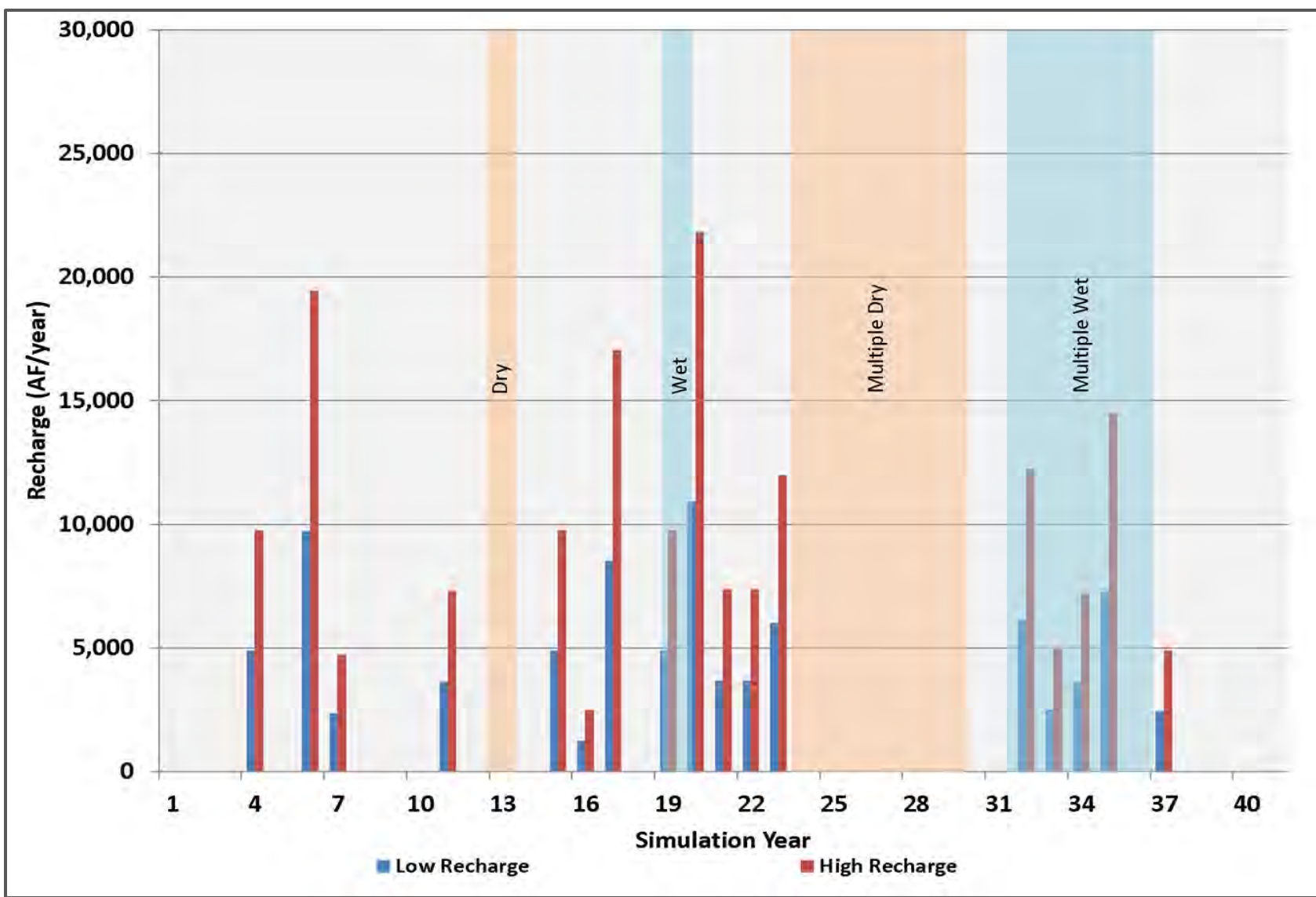


Figure 7.2 - Annual Recharge Rates for FID and CID Ponds

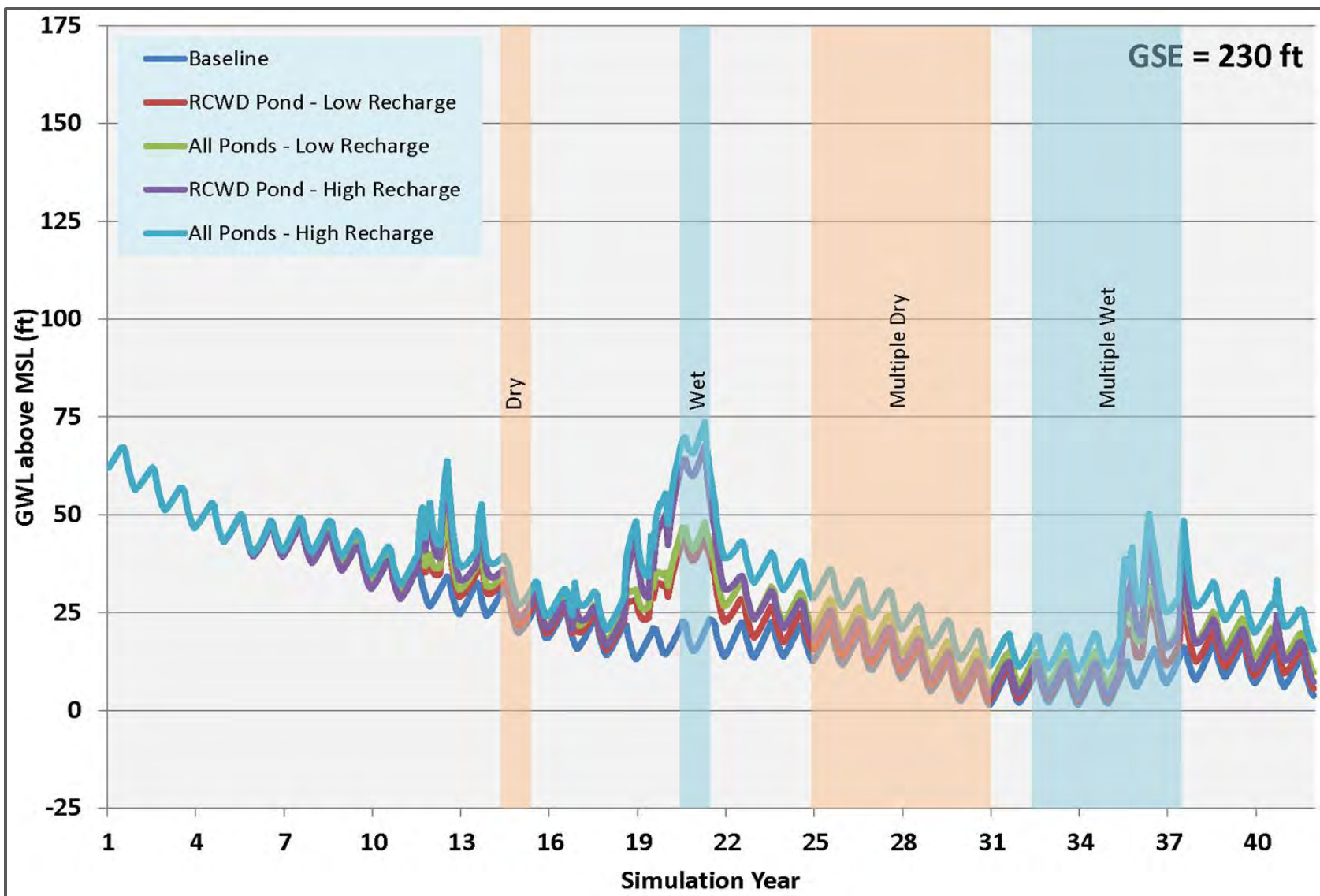


Figure 8.1 - Hydrographs of Groundwater Levels at RCWD Pond

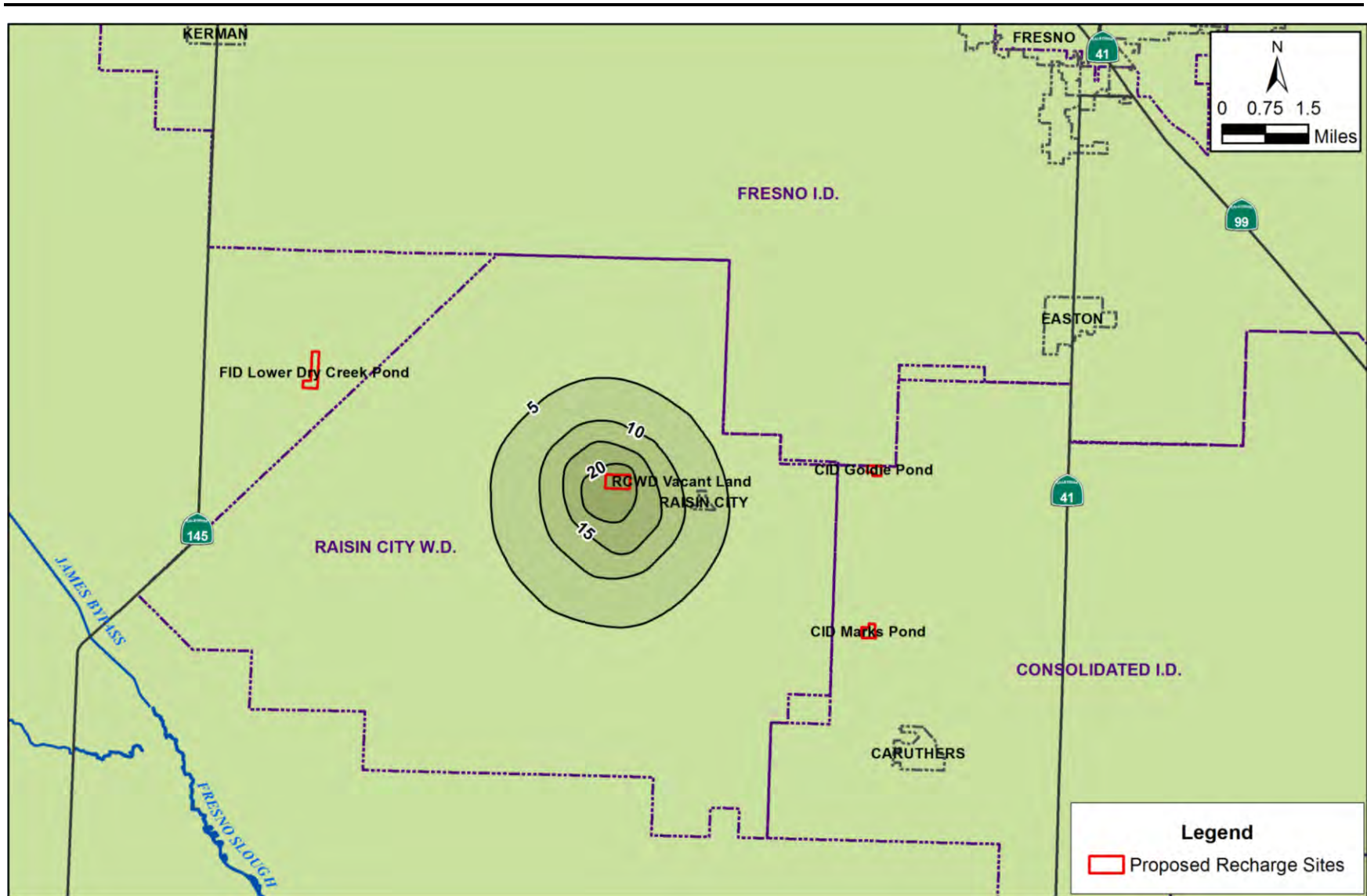


Figure 8.2 - Contour Map of Groundwater Level Increases for year 21 at RCWD Pond for Low Recharge Scenario 1a (feet)

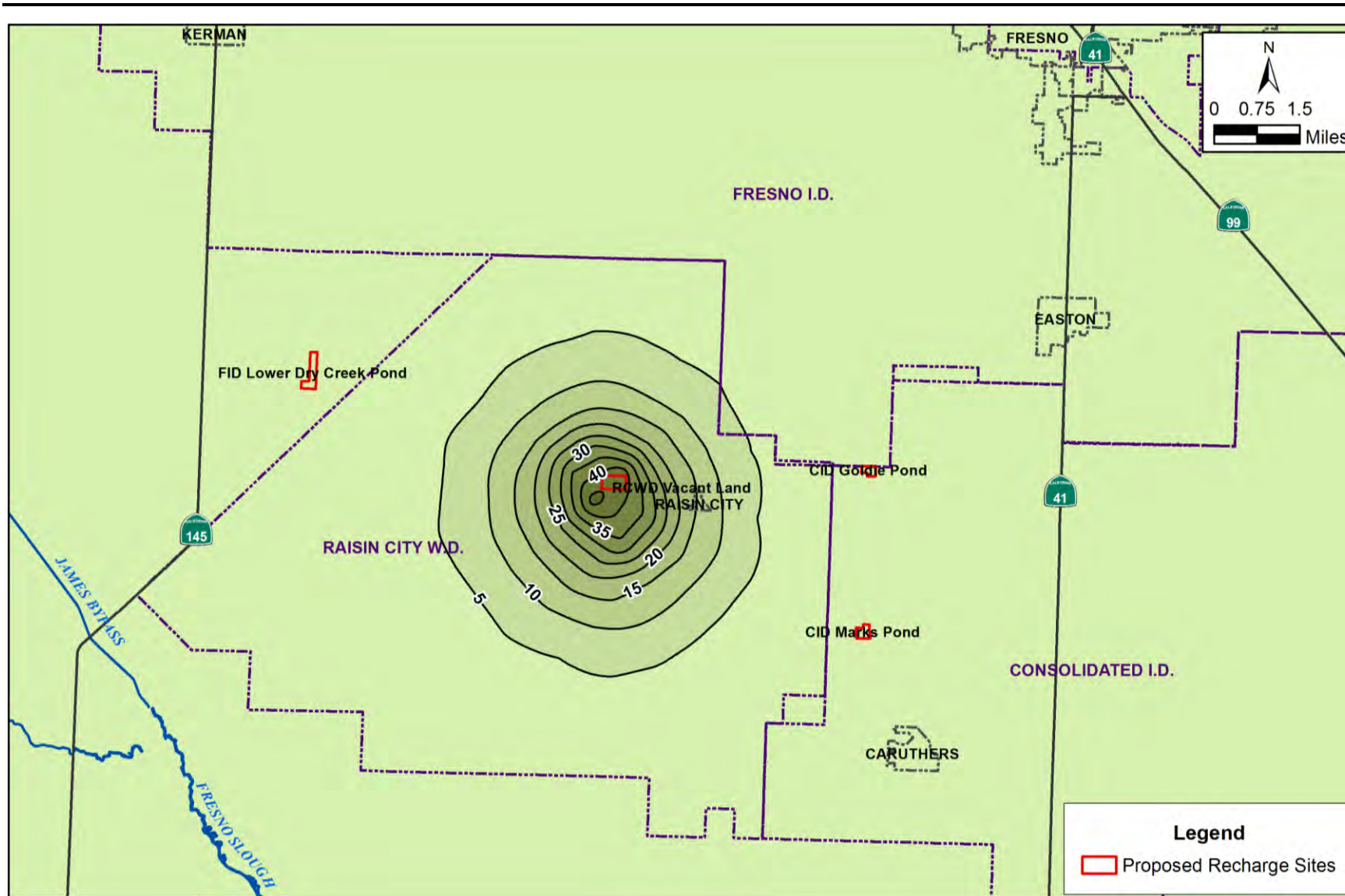


Figure 8.3 - Contour Map of Groundwater Level Increases for year 21 at RCWD Pond for High Recharge Scenario 1b (feet)

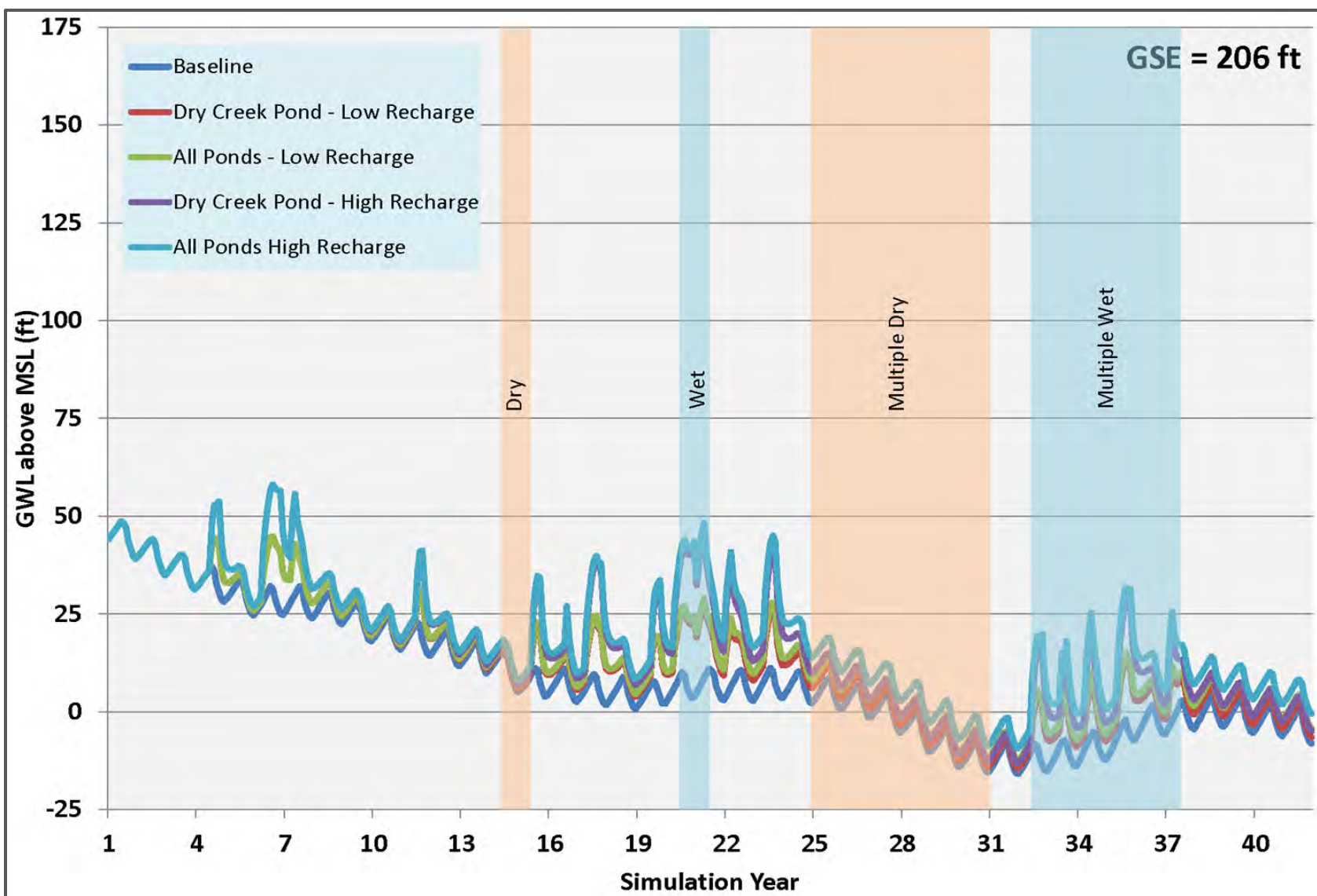


Figure 8.4 - Hydrographs of Groundwater Levels at Dry Creek Pond

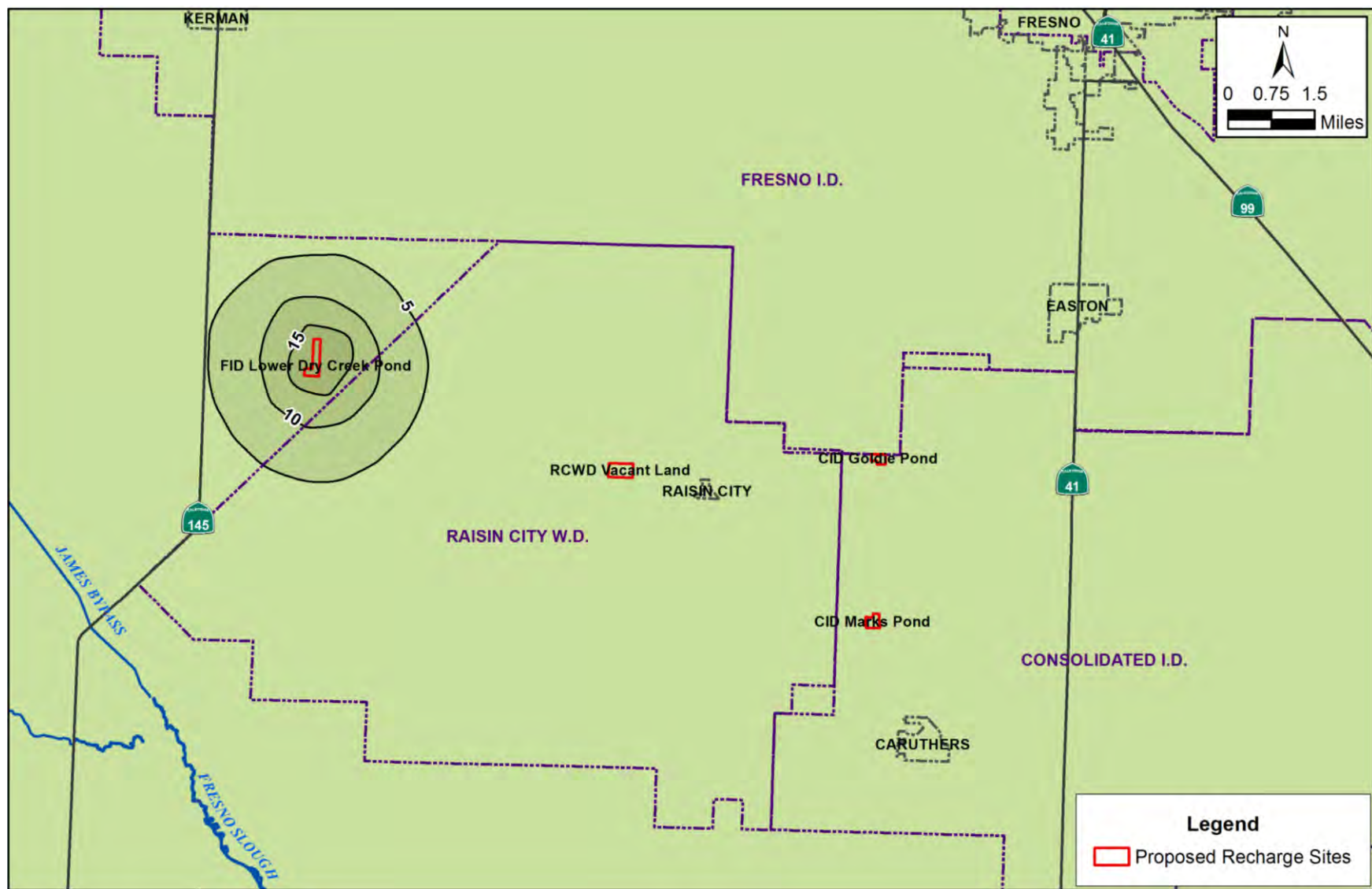


Figure 8.5 - Contour Map of Groundwater Level Increases for year 21 at Dry Creek Pond for Low Recharge Scenario 2a, (feet)

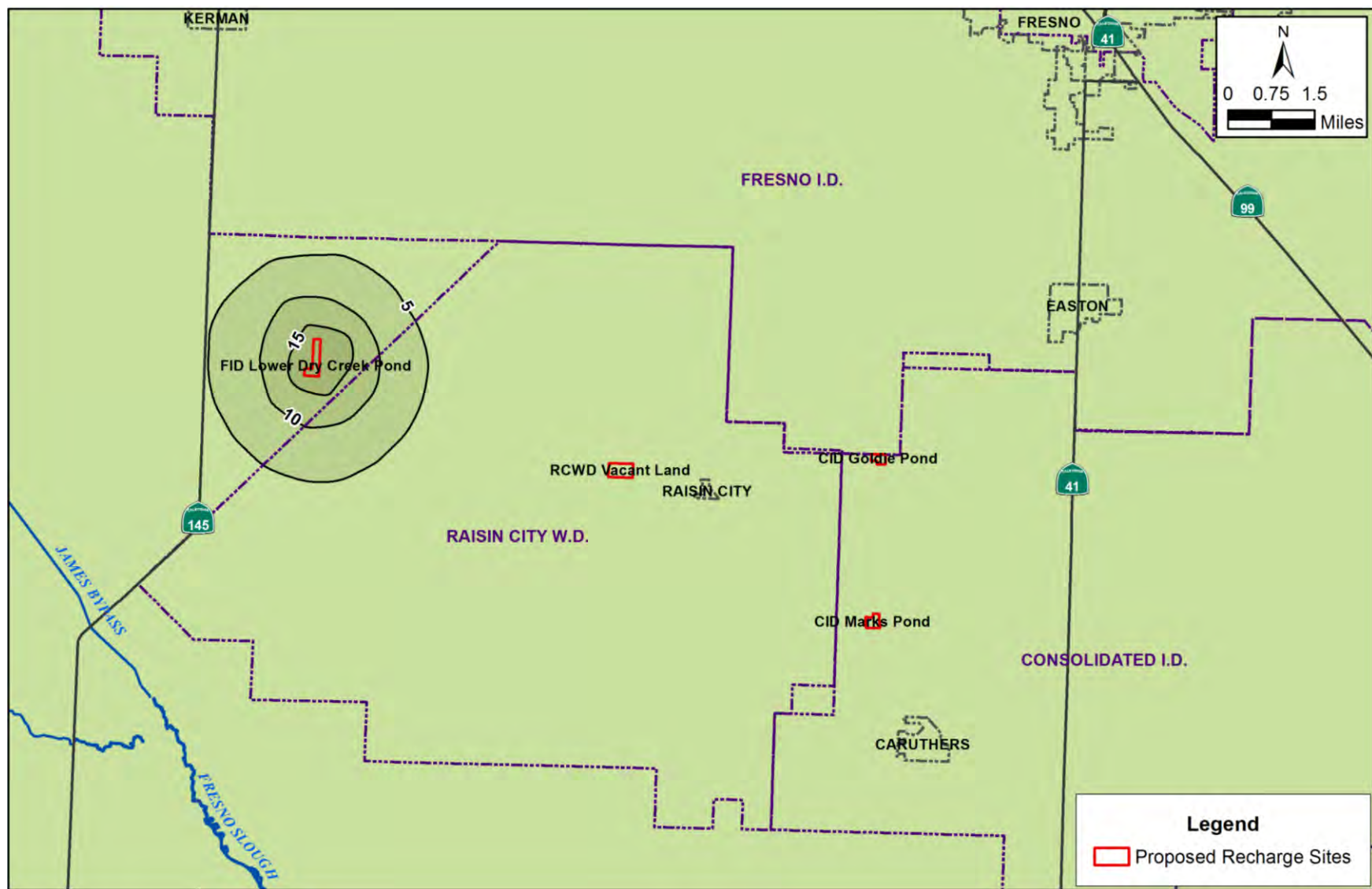


Figure 8.6 - Contour Map of Groundwater Level Increases for year 21 at Dry Creek Pond for High Recharge Scenario 2b, (feet)

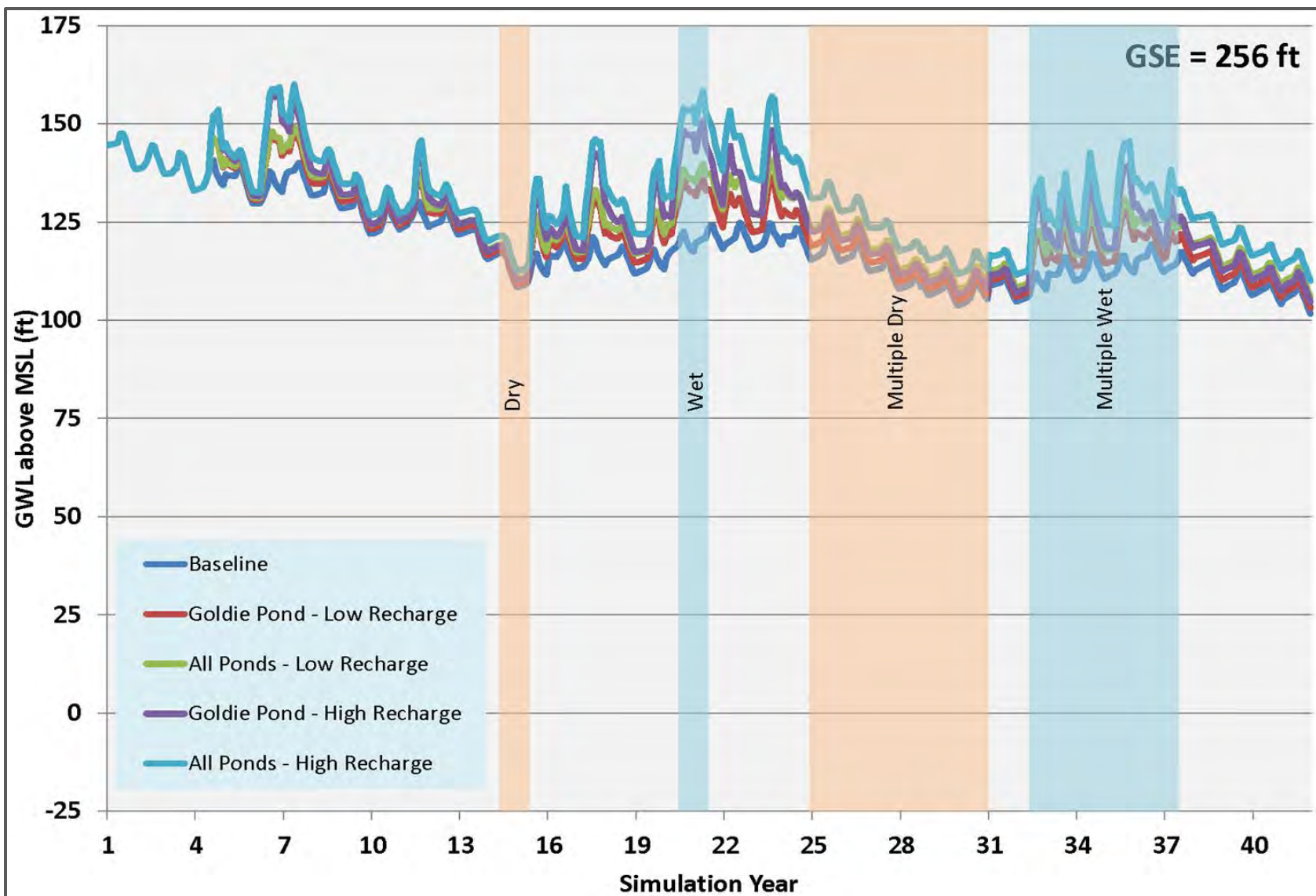


Figure 8.7 - Hydrographs of Groundwater Levels at Goldie Pond

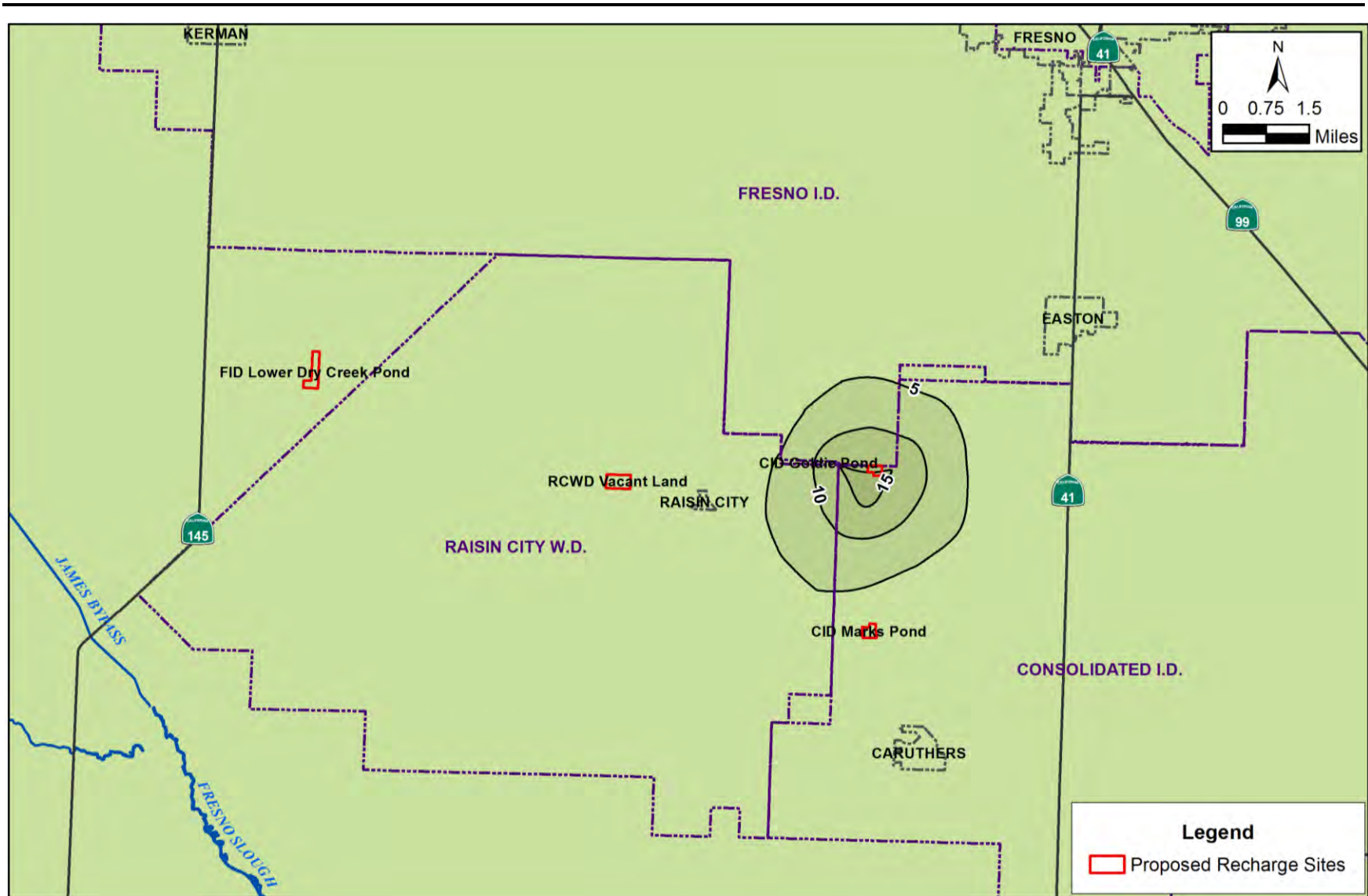


Figure 8.8 - Contour Map of Groundwater Level Increases for year 21 at Goldie Pond for Low Recharge Scenario 3a, (feet)

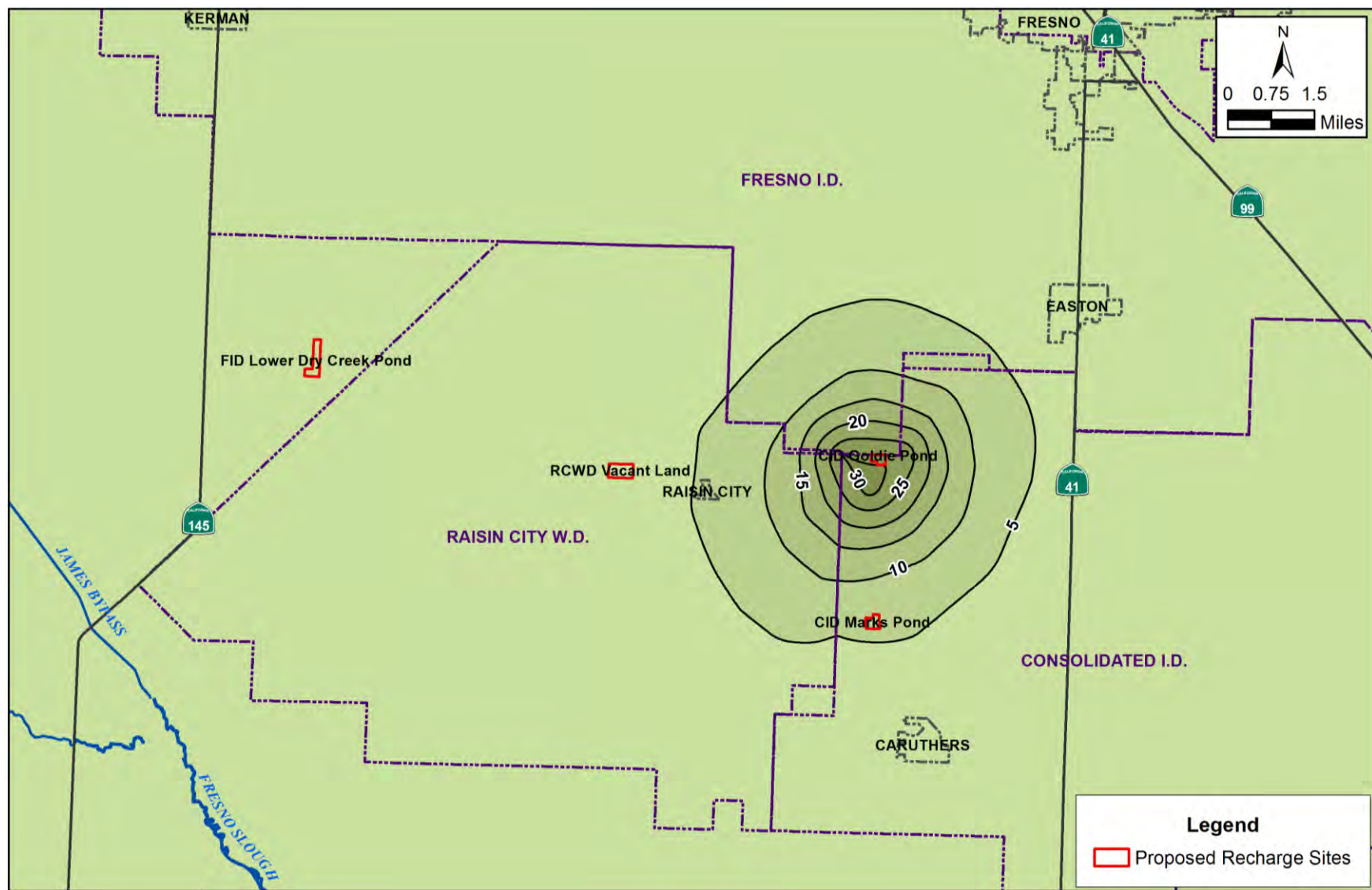


Figure 8.9 - Contour Map of Groundwater Level Increases for year 21 at Goldie Pond for High Recharge Scenario 3b, (feet)

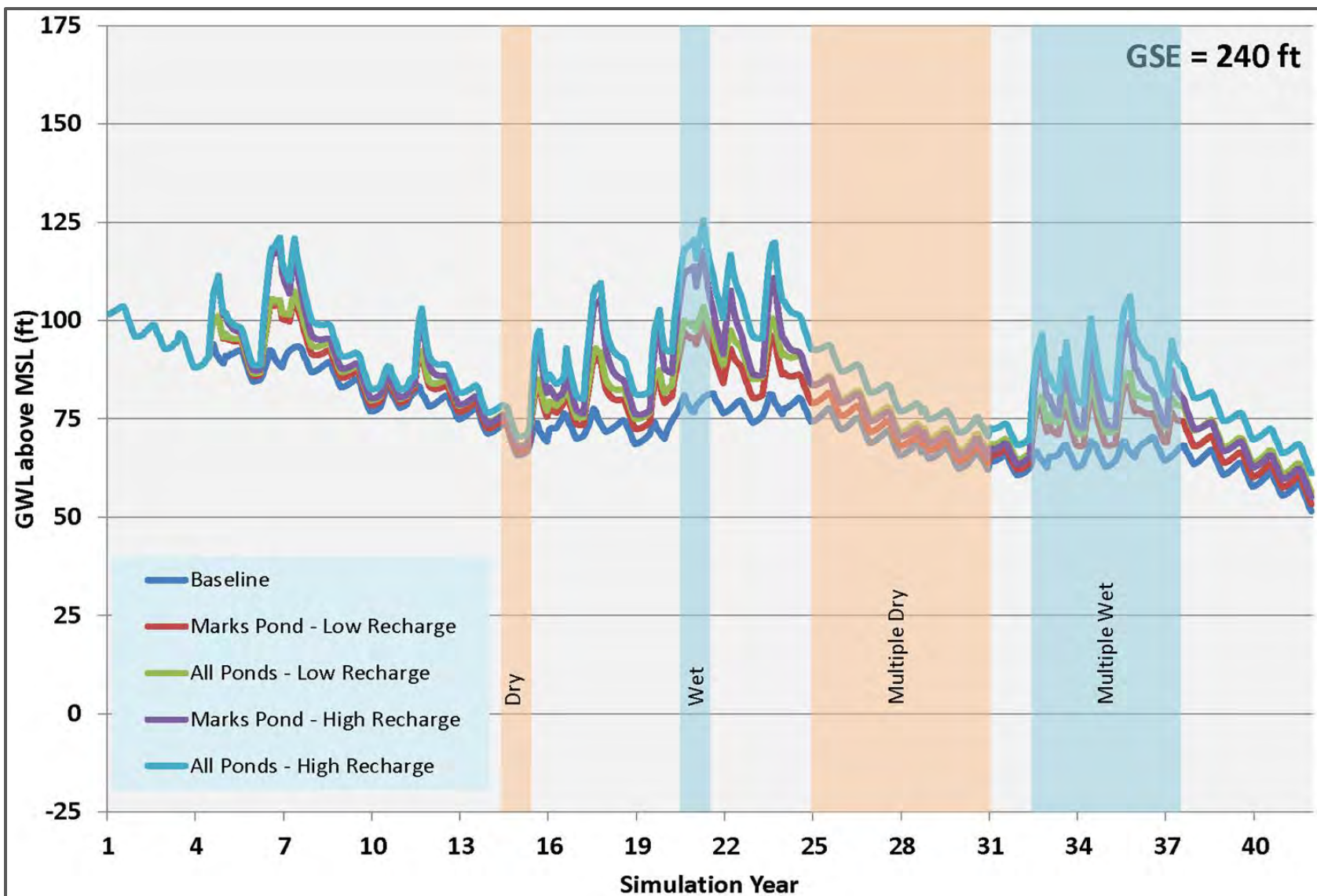


Figure 8.10 - Hydrographs of Groundwater Levels at Marks Pond

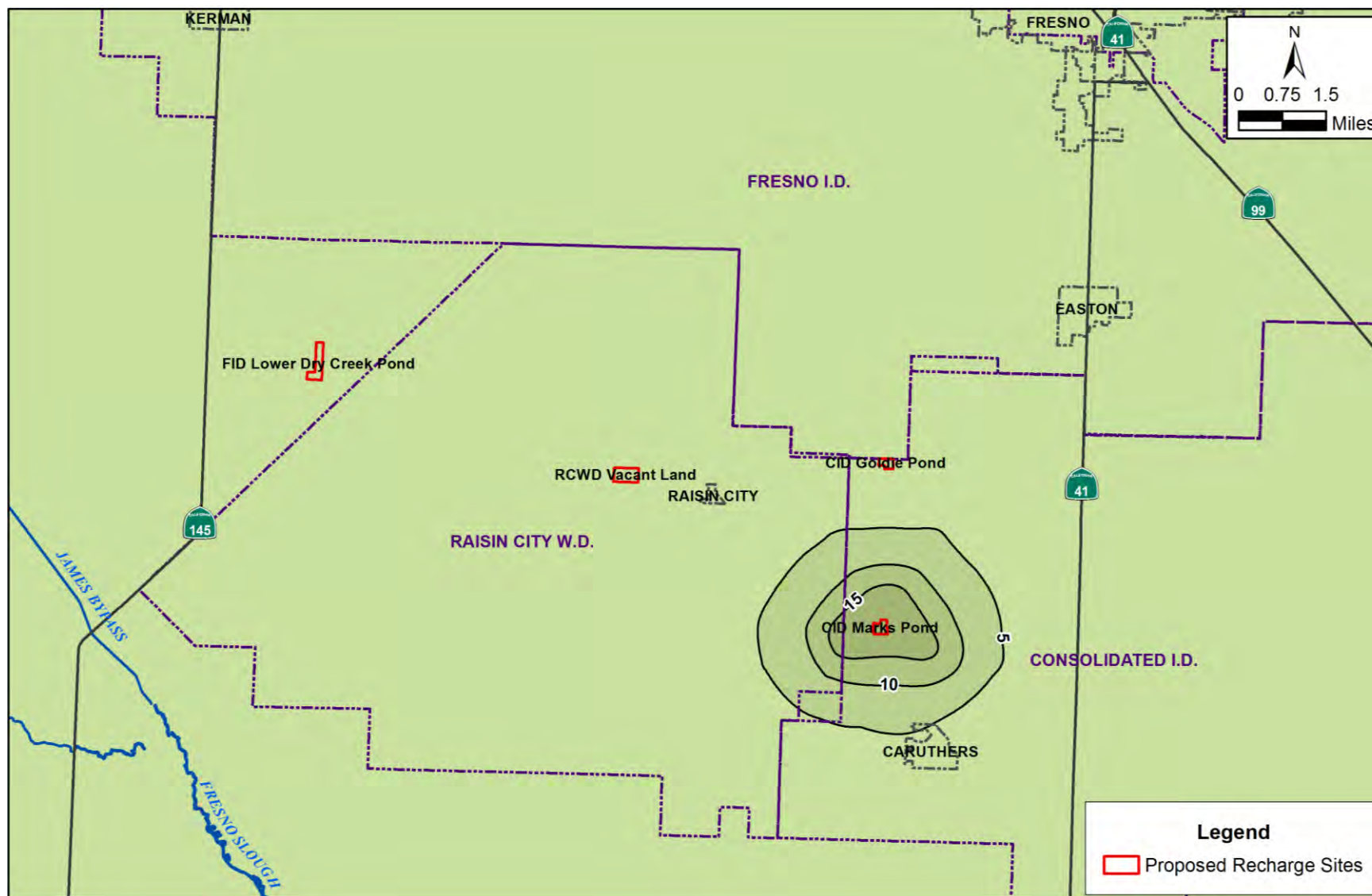


Figure 8.11 - Contour Map of Groundwater Level Increases for year 21 at Marks Pond for Low Recharge Scenario 4a, (feet)

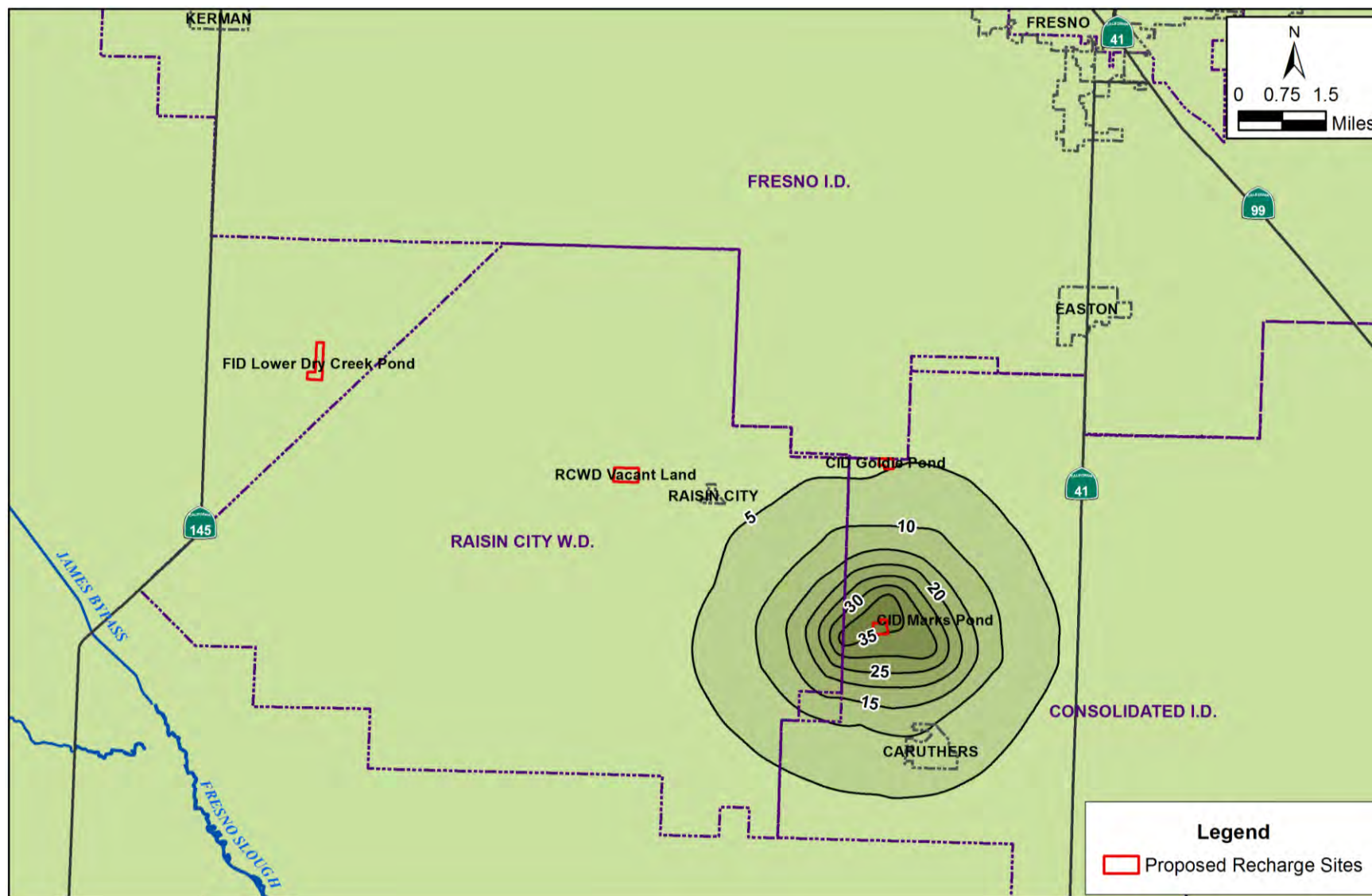


Figure 8.12 - Contour Map of Groundwater Level Increases for year 21 at Marks Pond for High Recharge Scenario 4b, (feet)

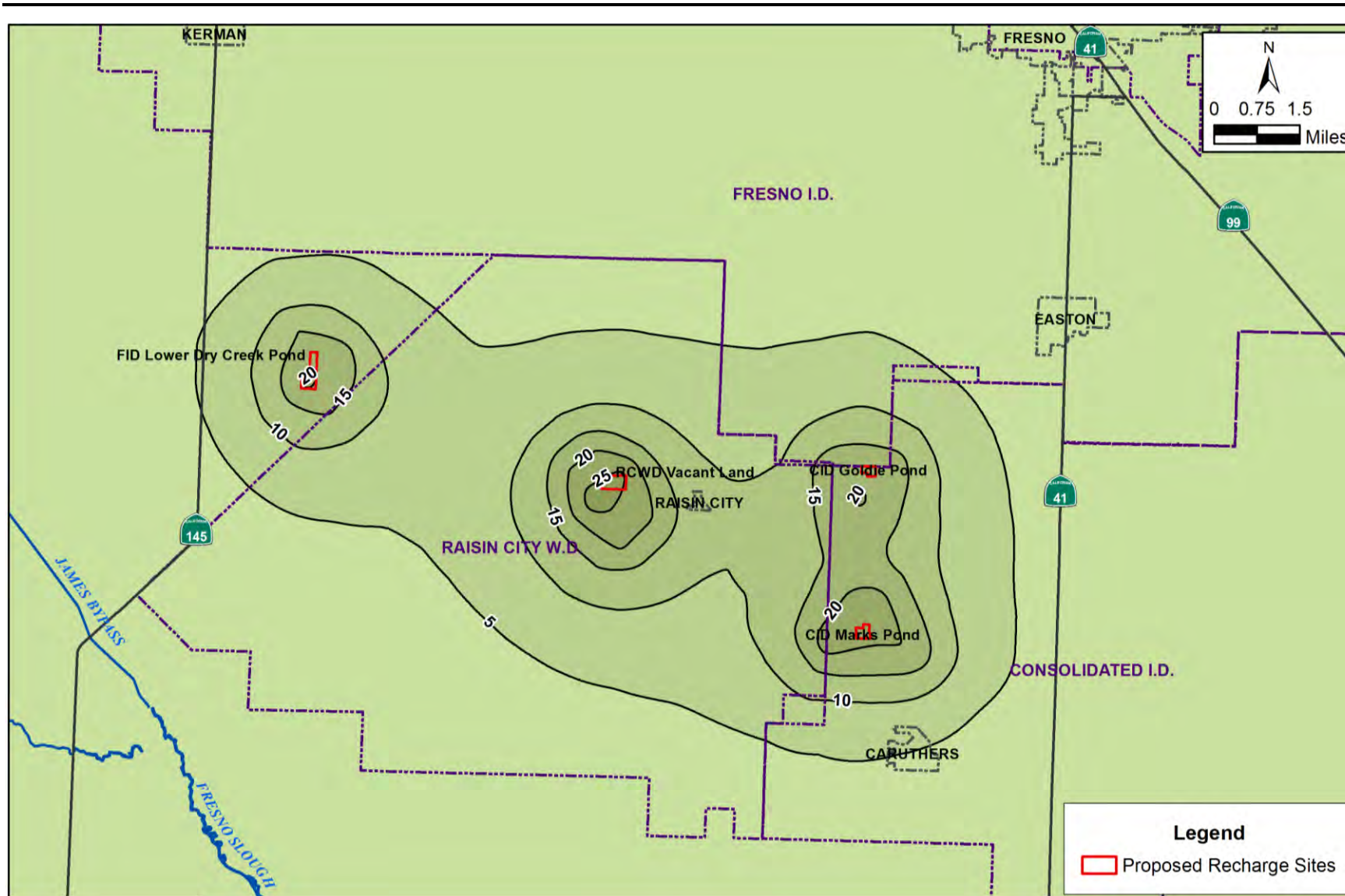


Figure 8.13 - Contour Map of Groundwater Level Increases for year 21 at All Ponds for Low Recharge Scenario 5a, (feet)

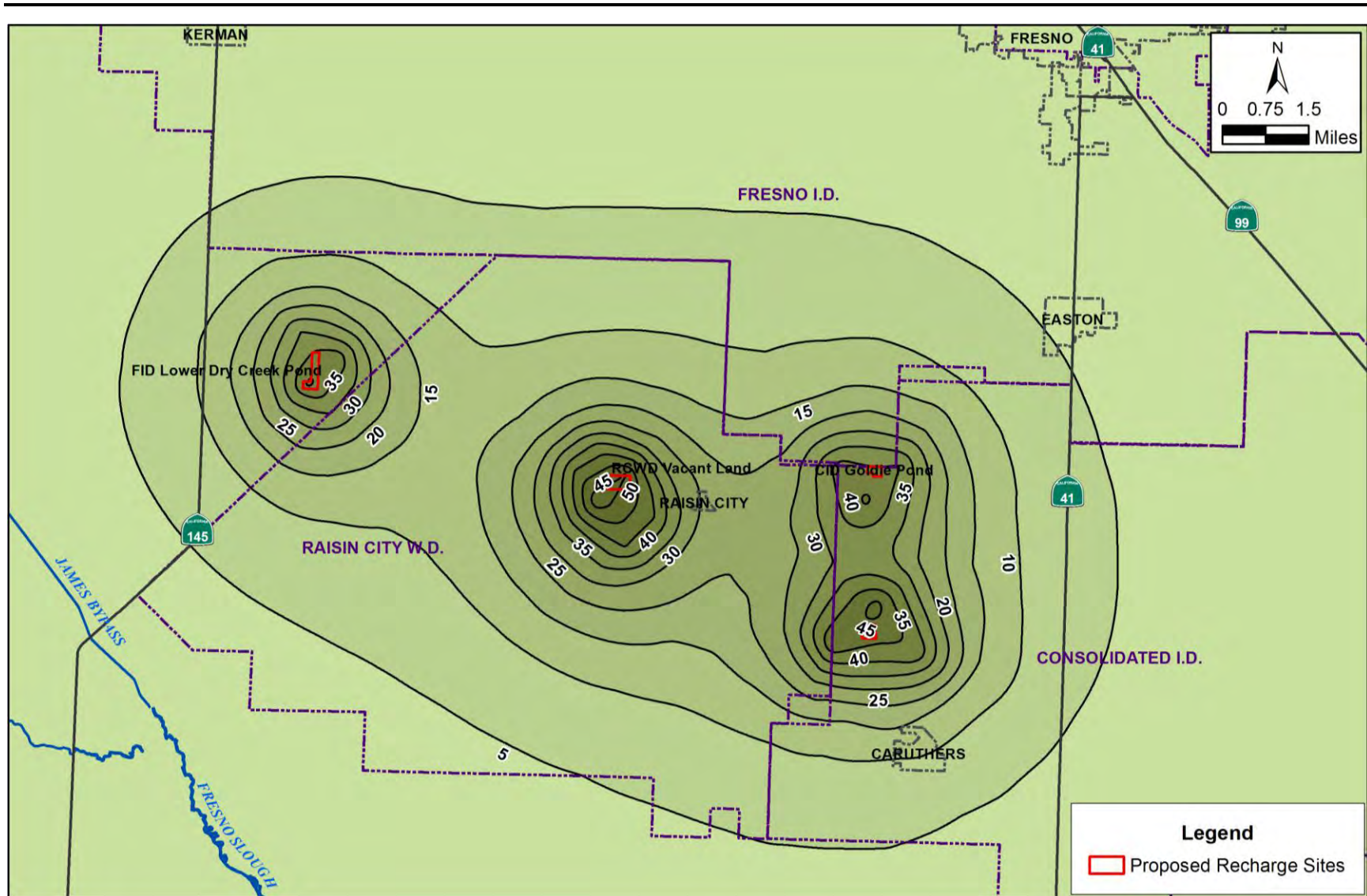


Figure 8.14 - Contour Map of Groundwater Level Increases for year 21 at All Ponds for High Recharge Scenario 5b, (feet)

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	Texture_Modifier_1	Texture_Modifier_2	Texture	Color_Qualifier	Color_1	Color_2
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723780	20842	2	7		Sandy		Loam			
723780	20843	7	12	Soft			Clay			
723780	20844	12	32	Fine			Sand			
723780	20845	32	35	Soft			Clay		Brown	
723780	20846	35	50				Sand		White	
723780	20847	50	57		Sandy		Clay		Brown	
723780	20848	57	62	Soft			Clay		Grey	
723780	20849	62	110	Coarse			Sand		Grey	
723780	20850	110	117	Soft			Clay		Grey	
723780	20851	117	125	Fine			Sand			
723780	20852	125	180	Coarse			Sand		Grey	
723780	20853	180	215	Soft			Clay		Grey	
723780	20854	215	250	Coarse			Sand		Grey	
723780	20855	250	260	Soft			Clay		Brown	
723780	20856	260	288	Soft			Clay		Grey	
723780	20857	288	301	Coarse			Sand		Grey	
723780	20858	301	307	Soft			Clay		Grey	
723780	20859	307	320	Coarse			Sand		Grey	
723780	20860	320	338	Soft			Clay		Blue	
723780	20861	338	344	Coarse			Sand		Blue	
723780	20862	344	345	Fine	Sandy		Silt		Blue	
723780	20863	345	370	Coarse			Sand		Blue	
723780	20864	370	380	Soft			Clay		Blue	
723780	20865	380	382		Sandy	Silty	Clay		Blue	
723780	20866	382	395	Soft			Clay		Blue	
723780	20867	395	400	Fine			Sand		Blue	
723780	20868	400	410		Sandy		Clay		Blue	
723780	20869	410	420	Coarse			Sand		Blue	
723780	20870	420	446	Soft			Clay		Blue	
723780	20871	446	448	Coarse			Sand		Brown	
723780	20872	448	450	Soft			Clay		Brown	
723780	20873	450	471	Coarse			Sand		Brown	
723780	20874	471	475		Silty		Silt		Blue	

PWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	Texture_Modifier	Texture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
44961	20876	0	2				Top Soil			
44961	20877	2	6				Sand			
44961	20878	6	23	Hard			Clay			
44961	20879	23	38				Clay			
44961	20880	38	42	Hard			Clay		Red	
44961	20881	42	54	Fine			Sand		Red	
44961	20882	54	56	Soft			Clay			
44961	20883	56	58	Hard			Clay		Red	
44961	20884	58	64	Soft			Clay			
44961	20885	64	70	Hard			Clay		Red	
44961	20886	70	84	Medium			Sand			
44961	20887	84	104	Hard			Clay			
44961	20888	104	128		Sandy		Clay			
44961	20889	128	141	Coarse			Sand			
44961	20890	141	148		Clayey		Sand			
44961	20891	148	152	Coarse			Sand			
44961	20892	152	162		Sandy		Clay			
44961	20893	162	180	Hard			Clay			
44961	20894	180	184		Sandy		Clay			
44961	20895	184	185	Medium			Sand			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
79803	20593	0	2				Top Soil			
79803	20594	2	5				Hard Pan			
79803	20595	5	10				Sand			
79803	20596	10	16	Hard			Clay			
79803	20597	16	25		Sandy		Clay			
79803	20598	25	38				Sand			
79803	20599	38	49	Soft	Sandy		Clay			
79803	20600	49	65				Sand			
79803	20601	65	118	Cemented			Sand			
79803	20602	118	128				Sand			
79803	20603	128	216				Laminated			
79803	20604	216	236				Sand			
79803	20605	236	239		Sandy		Clay			
79803	20606	239	270	Fine			Sand			
79803	20607	270	289				Laminated			
79803	20608	289	304		Gravelly		Sand			
79803	20609	304	316				Laminated			
79803	20610	316	330	Hard			Clay		Blue	
79803	20611	330	331	Coarse			Gravel			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
83481	20958	0	20				Clay			
83481	20959	20	22				Sand			
83481	20960	22	43				Clay		Brown	
83481	20961	43	61				Sand			
83481	20962	61	65				Clay		grey	
83481	20963	65	73				Clay		Brown	
83481	20964	73	79				Sand			
83481	20965	79	109				Clay		Grey	
83481	20966	109	117				Sand			
83481	20967	117	168				Clay		Grey	
83481	20968	168	174	Fine			Sand			
83481	20969	174	197				Clay		Brown	
83481	20970	197	200	Medium			Sand			
83481	20971	200	218				Clay		Grey	
83481	20972	218	237	Medium			Sand			
83481	20973	237	271				Clay		Grey	
83481	20974	271	279	Medium			Sand			
83481	20975	279	281				Clay		Grey	
83481	20976	281	285	Medium			Sand			
83481	20977	285	291				Clay		Grey	
83481	20978	291	297	Medium			Sand			
83481	20979	297	304				Clay		Grey	
83481	20980	304	307	Fine			Sand			
83481	20981	307	310				Clay		Grey	
83481	20982	310	314	Medium			Sand			
83481	20983	314	319				Clay		Grey	
83481	20984	319	321	Medium			Sand			
83481	20985	321	343	Medium	Gravelly		Sand			
83481	20986	343	357				Clay		Grey	
83481	20987	357	378	Medium			Sand			
83481	20988	378	380	Fine			Sand			
83481	20989	380	398	Medium			Sand			
83481	20990	398	410				Clay		Grey	
83481	20991	410	422				Sand			
83481	20992	422	430		Sandy		Clay			
83481	20993	430	439		Gravelly		Sand			
83481	20994	439	458		Sandy		Clay		Grey	
83481	20995	458	478	Medium			Sand			
83481	20996	478	510		Sandy		Clay		Grey	

[illegible]

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
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89490	21258	3	10				Clay		Brown	
89490	21259	10	21				Sand			
89490	21260	21	32				Clay		Brown	
89490	21261	32	38				Sand			
89490	21262	38	57				Clay		Brown	
89490	21263	57	65	Medium			Sand			
89490	21264	65	71				Clay		Brown	
89490	21265	71	89	Medium			Sand			
89490	21266	89	107				Clay		Brown	
89490	21267	107	112	Medium			Sand			
89490	21268	112	120				Clay		Brown	
89490	21269	120	146	Coarse			Sand			
89490	21270	146	151				Clay		Brown	
89490	21271	151	163	Medium			Sand			
89490	21272	163	182				Clay		Brown	
89490	21273	182	188	Medium			Sand			
89490	21274	188	200				Clay		Brown	
89490	21275	200	206	Fine			Sand			
89490	21276	206	219		Clayey		Sandstone			
89490	21277	219	226	Coarse			Sand			
89490	21278	226	237		Sandy		Clay			
89490	21279	237	253				Clay		Brown	
89490	21280	253	267	Medium			Sand			
89490	21281	267	298				Clay		Brown	
89490	21282	298	331	Medium			Sand			
89490	21283	331	350		Sandy		Clay			
89490	21284	350	367	Fine			Sand			
89490	21285	367	370		Sandy		Clay			
89490	21286	370	376	Medium			Sand			
89490	21287	376	387				Clay		Brown	
89490	21288	387	391	Medium			Sand			
89490	21289	391	407				Clay		Blue	
89490	21290	407	416	Medium			Sand			
89490	21291	416	448		Sandy		Clay		Blue	
89490	21292	448	459	Fine			Sand			
89490	21293	459	481				Clay		Blue	
89490	21294	481	493	Fine			Sand			
89490	21295	493	496		Sandy		Clay		Blue	
89490	21296	496	500	Medium			Sand			
89490	21297	500	510				Clay		Brown	
89490	21298	510	515	Medium			Sand			
89490	21299	515	526		Sandy		Clay		Brown	
89490	21300	526	530	Fine			Sand			
89490	21301	530	555				Clay		Brown	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
89482	21332	0	7				Top Soil			
89482	21333	7	21				Sand			
89482	21334	21	47		Sandy		Clay			
89482	21335	47	59				Clay			
89482	21336	59	111		Sandy		Clay			
89482	21337	111	119				Clay		Brown	
89482	21338	119	137	Fine			Sand			
89482	21339	137	157				Clay		Brown	
89482	21340	157	187	Fine			Sand			
89482	21341	187	206				Clay		Brown	
89482	21342	206	221				Sand			
89482	21343	221	242		Sandy		Clay			
89482	21344	242	257				Sand			
89482	21345	257	261		Sandy		Clay			
89482	21346	261	280				Clay		Brown	
89482	21347	280	291	Medium			Sand			
89482	21348	291	298				Clay		Brown	
89482	21349	298	309	Coarse			Sand			
89482	21350	309	311		Sandy		Clay		Brown	
89482	21351	311	315	Medium			Sand			
89482	21352	315	338				Clay		Blue	
89482	21353	338	345	Coarse			Sand			
89482	21354	345	350				Clay		Blue	
89482	21355	350	358	Medium			Sand			
89482	21356	358	370				Clay		Blue	
89482	21357	370	378	Medium			Sand			
89482	21358	378	390				Clay		Blue	
89482	21359	390	394	Medium			Sand			
89482	21360	394	436				Clay		Brown	
89482	21361	436	442	Medium			Sand			
89482	21362	442	449		Sandy		Clay		Brown	
89482	21363	449	453	Medium			Sand			
89482	21364	453	460				Clay		Brown	
89482	21365	460	465	Medium			Sand			
89482	21366	465	471				Clay		Brown	
89482	21367	471	474	Medium			Sand			
89482	21368	474	480		Sandy		Clay		Brown	
89482	21369	480	484	Coarse			Sand			
89482	21370	484	490				Clay		Brown	
89482	21371	490	494	Medium			Sand			
89482	21372	494	498				Clay		Brown	
89482	21373	498	502	Medium			Sand			
89482	21374	502	510				Clay		Brown	
89482	21375	510	524		Gravelly		Sand			
89482	21376	524	535				Clay		Brown	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
146572	21415	0	10		Sandy		Clay		Brown	
146572	21416	10	20				Clay		Green	
146572	21417	20	30				Clay			
146572	21418	30	40	Fine	Clayey		Sand			
146572	21419	40	52				Clay		Green	
146572	21420	52	56	Packed			Sand			
146572	21421	56	65		Sandy		Clay		Red	
146572	21422	65	70	Fine			Sand			
146572	21423	70	74				Sand			
146572	21424	74	116		Sandy		Clay		Brown	
146572	21425	116	119				Clay		Green	
146572	21426	119	122	Medium			Sand			
146572	21427	122	128	Medium			Sand			
146572	21428	128	131	Fine			Sand			
146572	21429	131	135				Clay		Brown	
146572	21430	135	139				Sand			
146572	21431	139	150				Clay		Red	
146572	21432	150	155	Medium			Sand			
146572	21433	155	159				Clay			
146572	21434	159	160	Medium			Sand			
146572	21435	160	165	Fine			Sand			
146572	21436	165	168	Coarse	rocky		Sand			
146572	21437	168	177				Clay		Green	
146572	21438	177	179		Sandy		Clay		Brown	
146572	21439	179	188	Coarse	Sandy		Gravel			
146572	21440	188	208	Joint			Clay			
146572	21441	208	215	Joint			Clay		Green	
146572	21442	215	223	Packed			Sand			
146572	21443	223	225				Sand			
146572	21444	225	233	Fine			Sand			
146572	21445	233	240	Medium			Sand			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
85491	21014	0	2				Top Soil	Light		
85491	21015	2	6	Medium			Sand		Brown	
85491	21016	6	9	Brittle			Clay		Grey	
85491	21017	9	11	Medium			Sand		Brown	
85491	21018	11	13	Soft			Clay		Brown	
85491	21019	13	25	Medium			Sand		Brown	
85491	21020	25	41	Medium			Clay		Brown	
85491	21021	41	46	Coarse	Clayey		Sand		Brown	
85491	21022	46	50	Soft			Clay		Brown	
85491	21023	50	57	Medium			Sand		Brown	
85491	21024	57	70	Soft			Clay		Brown	
85491	21025	70	88	Coarse			Sand		Brown	
85491	21026	88	92	Hard			Clay		Grey	
85491	21027	92	99	Coarse			Sand		Brown	
85491	21028	99	115	Hard			Clay		Brown	
85491	21029	115	117	Fine			Sand		Brown	
85491	21030	117	125	Soft			Clay		Brown	
85491	21031	125	134	Brittle			Clay		Grey	
85491	21032	134	139	Medium			Sand		Brown	
85491	21033	139	152		Sandy		Clay		Brown	
85491	21034	152	161	Medium			Sand		Brown	
85491	21035	161	164	Soft			Clay		Brown	
85491	21036	164	170	Medium	Sandy		Clay			
85491	21037	170	193	Brittle			Clay		Brown	
85491	21038	193	214	Medium			Sand		Brown	
85491	21039	214	220	Soft			Clay		Brown	
85491	21040	220	224	Fine	Clayey		Sand		Brown	
85491	21041	224	235	Coarse			Sand		Grey	
85491	21042	235	242	Soft			Clay		Grey	
85491	21043	242	251	Medium			Sand		Grey	
85491	21044	251	264	Medium	Clayey		Sand			
85491	21045	264	277	Soft			Clay		Grey	
85491	21046	277	282	Medium			Sand		Grey	
85491	21047	282	321	Coarse			Sand		Grey	
85491	21048	321	325	Fine			Sand		grey	
85491	21049	325	336	Fine			Sand		Grey	
85491	21050	336	340		Sandy		Clay		Grey	
85491	21051	340	345	Soft			Clay		Blue	

BWR_Log_Number	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	Texture_Modifier	Texture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
70468	21581	0	5				Top Soil			
70468	21582	5	9	Medium			Clay			
70468	21583	9	17	Medium			Sand			
70468	21584	17	22	Medium			Clay		Brown	
70468	21585	22	40	Coarse			Sand		Brown	
70468	21586	40	47	Hard			Clay		Brown	
70468	21587	47	56	Coarse			Sand		Brown	
70468	21588	56	68	Medium			Clay		Brown	
70468	21589	68	80	Medium			Sand		Brown	
70468	21605	71	274	Coarse			Sand		Brown	
70468	21590	80	107		Sandy		Clay		Grey	
70468	21591	107	110	Coarse			Sand		Brown	
70468	21592	110	116	Medium			Clay		Brown	
70468	21593	116	123	Medium			Sand		Brown	
70468	21594	123	130	Medium	Sandy		Clay		Grey	
70468	21595	130	133	Medium			Sand		Grey	
70468	21596	133	134	Soft			Clay		Brown	
70468	21597	134	140	Fine			Sand		Brown	
70468	21598	140	144	Medium			Clay		Brown	
70468	21599	144	164	Coarse			Sand		Brown	
70468	21600	164	180	Medium			Clay		Brown	
70468	21601	180	206	Coarse			Sand		Brown	
70468	21602	206	218	Hard			Clay		Grey	
70468	21603	218	221	Medium			Sand		Brown	
70468	21604	221	271	Soft			Clay		Brown	
70468	21606	274	280	Medium			Clay		Grey	
70468	21607	280	282	Coarse			Sand		Grey	
70468	21608	282	290	Brittle			Clay		Grey	
70468	21609	290	298	Coarse			Sand		Brown	
70468	21610	298	314	Hard			Clay		Brown	
70468	21611	314	340	Fine			Sand		Brown	
70468	21612	340	360	Hard			Clay		Brown	
70468	21613	360	384	Coarse			Sand		Grey	
70468	21614	384	400	Medium	Sandy		Clay			
70468	21615	400	412	Soft			Clay		Grey	
70468	21616	412	417	Medium			Sand		Grey	
70468	21617	417	421	Soft			Clay		Grey	
70468	21618	421	426	Coarse			Sand		Grey	
70468	21619	426	432	Soft			Clay		Grey	
70468	21620	432	434	Fine			Sand		Grey	
70468	21621	434	443	Soft			Clay		Grey	
70468	21622	443	462	Fine			Sand		Brown	
70468	21623	462	469	Medium			Clay		Brown	
70468	21624	469	488	Coarse			Sand		Brown	
70468	21625	488	490	Hard			Clay		Brown	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
192129	21486	0	2				Top Soil			
192129	21487	2	6		Sandy		Clay			
192129	21488	6	10	Hard			Clay			
192129	21489	10	17				Sand			
192129	21490	17	21				Clay			
192129	21491	21	37		Sandy		Clay			
192129	21492	37	45				Sand			
192129	21493	45	53				Clay			
192129	21494	53	60				Sand			
192129	21495	60	71		Sandy		Clay			
192129	21496	71	88				Sand		Blue	
192129	21497	88	94	Soft			Clay		Brown	
192129	21498	94	98				Sand		Brown	
192129	21499	98	103		Sandy		Clay		Blue	
192129	21500	103	113				Sand		Blue	
192129	21501	113	120				Clay		Brown	
192129	21502	120	142				Sand		Brown	
192129	21503	142	158		Sandy		Clay		Brown	
192129	21504	158	176				Sand			
192129	21505	176	180		Sandy		Clay			
192129	21506	180	185				Sand			
192129	21507	185	194	Hard			Clay		Brown	
192129	21508	194	199				Sand			
192129	21509	199	204	Hard			Clay		Grey	
192129	21510	204	223	Hard			Clay		Brown	
192129	21511	223	234	Fine			Sand			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
335317	21469	0	4				Top Soil			
335317	21470	4	6				Hard Pan			
335317	21471	6	17	Hard			Clay			
335317	21472	17	25	Soft			Clay			
335317	21473	25	68		Sandy		Clay			
335317	21474	68	73				Sand			
335317	21475	73	126	Hard	Sandy		Clay			
335317	21476	126	133	Coarse			Sand			
335317	21477	133	139	Hard			Clay			
335317	21478	139	157	Coarse	Gravelly		Sand			
335317	21479	157	165	Hard			Clay			
335317	21480	165	170				Sand			
335317	21481	170	173	Soft	Sandy		Clay			
335317	21482	173	179	Hard			Clay			
335317	21483	179	184				Sand			
335317	21484	184	196	Hard	Sandy		Clay			
335317	21485	197	198				Sand			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
40939	21446	0	5	Fine			Sand			
40939	21447	5	50	Coarse			Sand			
40939	21448	50	58		Sandy		Clay		Brown	
40939	21449	58	65		Sandy		Clay		Green	
40939	21450	65	88	Fine			Sand			
40939	21451	88	93	Joint			Clay		Grey	
40939	21452	93	103				Clay		Red	
40939	21453	103	106		Sandy		Clay		Brown	
40939	21454	106	115	Medium			Sand			
40939	21455	115	120				Clay		Grey	
40939	21456	120	125	Fine			Sand			
40939	21457	125	130				Clay		Green	
40939	21458	130	140	Coarse			Sand			
40939	21459	140	148	Coarse			Sand			
40939	21460	148	160				Clay		Green	
40939	21461	160	172	Coarse			Gravel			
40939	21462	172	176				Clay		Brown	
40939	21463	176	180	Coarse			Sand			
40939	21464	180	190	Coarse			Sand			
40939	21465	190	200	Medium			Sand			
40939	21466	200	212				Clay		Brown	
40939	21467	212	220	Medium			Sand			
40939	21468	220	228	Coarse			Sand			

BWR_Log_Number	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	Texture_Modifier	Texture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
24711	21686	0	20				Sand			
24711	21687	20	24	Packed			Sand			
24711	21688	24	30		Sandy		Clay		Brown	
24711	21689	30	72	Joint			Clay		Brown	
24711	21690	72	73	Medium			Sand			
24711	21691	73	84		Sandy		Clay		Brown	
24711	21692	84	100	Medium			Sand			
24711	21693	100	104	Medium			Sand			
24711	21694	104	144		Sandy		Clay		Brown	
24711	21695	144	147	Coarse	rocky		Sand			
24711	21696	147	150				Clay		Red	
24711	21697	150	170	Packed			Sand			
24711	21698	170	185				Clay		Grey	
24711	21699	185	188	Joint			Clay		Brown	
24711	21700	188	200		Sandy		Clay		Green	
24711	21701	200	220	Medium			Sand			
24711	21702	220	240	Medium			Sand			

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
86384	21795	0	4		Sandy		Top Soil		Brown	
86384	21796	4	6	Medium			Clay		Brown	
86384	21797	6	24	Coarse			Sand		Brown	
86384	21798	24	35	Soft			Clay		Brown	
86384	21799	35	63	Coarse			Sand		Brown	
86384	21800	63	70	Medium	Clayey		Sand			
86384	21801	70	81		Sandy		Clay		Brown	
86384	21802	81	87	Coarse			Sand		Brown	
86384	21803	87	92	Soft			Clay		Brown	
86384	21804	92	104	Coarse			Sand		Brown	
86384	21805	104	117		Sandy		Clay		Grey	
86384	21806	117	129	Medium			Sand		Brown	
86384	21807	129	148	Hard			Clay		Brown	
86384	21808	148	154	Coarse			Sand		Grey	
86384	21809	154	163	Brittle			Clay		Brown	
86384	21810	163	167	Coarse			Sand		Brown	
86384	21811	167	170	Coarse	Sandy		Clay		Brown	
86384	21812	170	174	Coarse			Sand		Brown	
86384	21813	174	182	Hard			Clay		Brown	
86384	21814	182	187	Medium			Sand		Brown	
86384	21815	187	200		Sandy		Clay		Brown	
86384	21816	200	208	Fine			Sand		Brown	
86384	21817	208	213	Medium			Sand		Brown	
86384	21818	213	228	Brittle			Clay		Brown	
86384	21819	228	240	Coarse			Sand		Brown	
86384	21820	240	245	Medium			Clay		Brown	
86384	21821	245	250	Fine			Sand		Brown	
86384	21822	250	255	Medium			Clay		Grey	
86384	21823	255	257	Fine			Sand		Grey	
86384	21824	257	259	Brittle			Clay		Grey	
86384	21825	259	265	Coarse			Sand		Grey	
86384	21826	265	275	Medium			Clay		Grey	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	Texture_Modifier	Texture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
512111	21524	0	4		Sandy		Top Soil			
512111	21525	4	44	Fine			Sand		Brown	
512111	21526	44	48				Clay		Grey	
512111	21527	48	56	Fine			Sand		Grey	
512111	21528	56	60		Silty		Clay		Grey	Tan
512111	21529	60	76		Clayey		Sand		Grey	
512111	21530	76	83	Fine			Sand		Grey	
512111	21531	83	88		Clayey		Sand		Grey	
512111	21532	88	89				Clay		Grey	
512111	21533	89	103	Fine			Sand		Grey	
512111	21534	103	109				Clay		Grey	
512111	21535	109	122	Fine			Sand		Grey	
512111	21536	122	125		Clayey		Sand		Tan	
512111	21537	125	127	Cemented			Sand		Grey	
512111	21538	127	148	Coarse	Gravelly		Sand		Tan	
512111	21539	148	150				Clay		Grey	
512111	21540	150	157		Sandy		Clay		Tan	
512111	21541	157	162		Clayey		Sand		Brown	
512111	21542	162	170	Medium			Sand		Tan	
512111	21543	170	177		Sandy		Clay		Grey	
512111	21544	177	189	Medium			Sand		Tan	
512111	21545	189	191		Sandy		Clay		Tan	
512111	21546	191	197	Medium			Sand		Tan	
512111	21547	197	200				Clay		Grey	
512111	21548	200	212		Sandy		Clay		Red	Brown
512111	21549	212	234	Coarse	Gravelly		Sand		Tan	
512111	21550	234	237		Sandy		Clay		Grey	
512111	21551	237	243	Fine			Sand		Tan	
512111	21552	243	245		Sandy		Clay		Tan	
512111	21553	245	248	Fine			Sand		Tan	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
48223	21935	0	11				Top Soil			
48223	21936	11	17				Clay		Grey	
48223	21937	17	31				Sand			
48223	21938	31	36	Cemented	Clayey		Sand			
48223	21939	36	64				Sand			
48223	21940	64	72				Clay		Blue	
48223	21941	72	81	Packed			Sand		Blue	
48223	21942	81	85		Sandy		Clay		Brown	
48223	21943	85	88	Coarse			Sand			
48223	21944	88	93		Sandy		Clay		Grey	
48223	21945	93	98		Sandy		Clay			
48223	21946	98	106				Clay			
48223	21947	106	114	Coarse			Sand			
48223	21948	114	117				Clay		Grey	
48223	21949	117	123	Coarse			Sand			
48223	21950	123	129	Cemented			Sand			
48223	21951	129	132	Coarse			Sand			
48223	21952	132	135				Clay		Grey	
48223	21953	135	142	Coarse			Sand			
48223	21954	142	150	Hard			Clay		Red	
48223	21955	150	157	Coarse			Sand			
48223	21956	157	166	Cemented	Clayey		Sand		Grey	
48223	21957	166	177	Coarse			Sand			
48223	21958	177	179				Clay		Grey	
48223	21959	179	181	Coarse			Sand			
48223	21960	181	183				Clay		Grey	
48223	21961	183	184	Coarse			Sand			
48223	21962	184	190				Clay		Brown	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
87445	15227	0	4		Sandy		Top Soil			
87445	15228	4	6		Sandy		Clay		Grey	
87445	15229	6	12	Coarse			Sand		Grey	
87445	15230	12	15	Hard			Clay		Grey	
87445	15231	15	23	Coarse			Sand		Grey	
87445	15232	23	35	Soft			Clay		Grey	
87445	15233	35	47	Coarse			Sand		Grey	
87445	15234	47	53	Soft			Clay		Grey	
87445	15235	53	82	Coarse			Sand		Grey	
87445	15236	82	101	Soft			Clay		Grey	
87445	15237	101	112	Coarse			Sand		Grey	
87445	15238	112	123	Soft			Clay		Grey	
87445	15239	123	130	Coarse			Sand		Grey	
87445	15240	130	148	Soft			Clay		Grey	
87445	15241	148	153	Coarse			Sand		Grey	
87445	15242	153	171	Coarse			Sand		Grey	
87445	15243	171	175	Soft			Clay		Grey	
87445	15244	175	197	Coarse			Sand		Grey	
87445	15245	197	206	Soft			Clay		Grey	
87445	15246	206	223	Coarse			Sand		Grey	
87445	15247	223	225	Soft			Clay		Grey	

BWR_Log_Numbe	Texture_Key	Top_Depth	Bottom_Depth	Texture_Qualifier	exture_Modifier	exture_Modifier	Texture	Color_Qualifier	Color_1	Color_2
158607	14863	0	6		Sandy		Top Soil			
158607	14864	6	14	Soft			Clay		Grey	
158607	14865	14	19	Coarse			Sand		Grey	
158607	14866	19	27	Soft			Clay		Brown	
158607	14867	27	39	Coarse			Sand		Brown	
158607	14868	39	46	Hard			Clay		Brown	
158607	14869	46	69	Coarse			Sand		Grey	
158607	14870	69	102	Soft			Clay		Grey	
158607	14871	102	129	Coarse			Sand		Brown	
158607	14872	129	146	Soft			Clay		Grey	
158607	14873	146	167	Coarse			Sand		Grey	
158607	14874	167	208	Soft			Clay		Brown	
158607	14875	208	224	Coarse			Sand		Brown	
158607	14876	224	233	Soft			Clay		Grey	



GREGG DRILLING & TESTING, INC.
GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SERVICES

May 14, 2012

WRIME, Inc.
Attn: Jim Blanke

Subject: CPT Site Investigation
Raisin City Water District, Goldie Pond Area, Marks Pond Area
California
GREGG Project Number: 12-071MA

Dear Mr. Blanke:

The following report presents the results of GREGG Drilling & Testing's Cone Penetration Test investigation for the above referenced site. The following testing services were performed:

1	Cone Penetration Tests	(CPTU)	☒
2	Pore Pressure Dissipation Tests	(PPD)	☒
3	Seismic Cone Penetration Tests	(SCPTU)	☐
4	UVOST Laser Induced Fluorescence	(UVOST)	☐
5	Groundwater Sampling	(GWS)	☐
6	Soil Sampling	(SS)	☐
7	Vapor Sampling	(VS)	☐
8	Pressuremeter Testing	(PMT)	☐
9	Vane Shear Testing	(VST)	☐
10	Dilatometer Testing	(DMT)	☐

A list of reference papers providing additional background on the specific tests conducted is provided in the bibliography following the text of the report. If you would like a copy of any of these publications or should you have any questions or comments regarding the contents of this report, please do not hesitate to contact our office at (925) 313-5800.

Sincerely,
GREGG Drilling & Testing, Inc.

Mary Walden
Operations Manager



GREGG DRILLING & TESTING, INC.
GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SERVICES

Cone Penetration Test Sounding Summary

-Table 1-

CPT Sounding Identification	Date	Termination Depth (Feet)	Depth of Groundwater Samples (Feet)	Depth of Soil Samples (Feet)	Depth of Pore Pressure Dissipation Tests (Feet)
2-CPT1	5/08/12	100	-	-	-
2-CPT2	5/08/12	100	-	-	-
2-CPT3	5/08/12	100	-	-	-
2-CPT4	5/07/12	100	-	-	41.3
2-CPT5	5/07/12	100	-	-	-
2-CPT6	5/08/12	100	-	-	-
3-CPT1	5/09/12	100	-	-	55.0
3-CPT2	5/09/12	100	-	-	-
3-CPT3	5/09/12	62	-	-	-
3-CPT4	5/09/12	100	-	-	-
4-CPT1	5/11/12	100	-	-	-
4-CPT2	5/10/12	100	-	-	-
4-CPT3	5/10/12	100	-	-	89.6
4-CPT4	5/10/12	100	-	-	76.3
4-CPT5	5/10/12	100	-	-	-



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Using the UVIF-CPT", 53rd Canadian Geotechnical Conference Montreal, QC October pp. 733-739, 2000.

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Copies of ASTM Standards are available through www.astm.org



Cone Penetration Testing Procedure (CPT)

Gregg Drilling carries out all Cone Penetration Tests (CPT) using an integrated electronic cone system, *Figure CPT*. The soundings were conducted using a 20 ton capacity cone with a tip area of 15 cm^2 and a friction sleeve area of 225 cm^2 . The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.80.

The cone takes measurements of cone bearing (q_c), sleeve friction (f_s) and penetration pore water pressure (u_2) at 5-cm intervals during penetration to provide a nearly continuous log. CPT data reduction and interpretation is performed in real time facilitating on-site decision making. The above mentioned parameters are stored on disk for further analysis and reference. All CPT soundings are performed in accordance with revised (2007) ASTM standards (D 5778-07).

The cone also contains a porous filter element located directly behind the cone tip (u_2). It consists of porous plastic and is 5.0mm thick. The filter element is used to obtain penetration pore pressure as the cone is advanced as well as Pore Pressure Dissipation Tests (PPDT's) during appropriate pauses in penetration. It should be noted that prior to penetration, the element is fully saturated with oil under vacuum pressure to ensure accurate and fast dissipation.

The cone has the following accuracy:
1 tsf for q_c , 0.02 tsf for f_s and 0.5 psi for u_2 . In soft clays, a lower capacity cone should be used for improved accuracy.

When the soundings are complete, the test holes are grouted. The grouting procedures generally consist of pushing a hollow tremie pipe with a "knock out" plug to the termination depth of the CPT hole. Grout is then pumped under pressure as the tremie pipe is pulled from the hole. Disruption or further contamination to the site is therefore minimized.

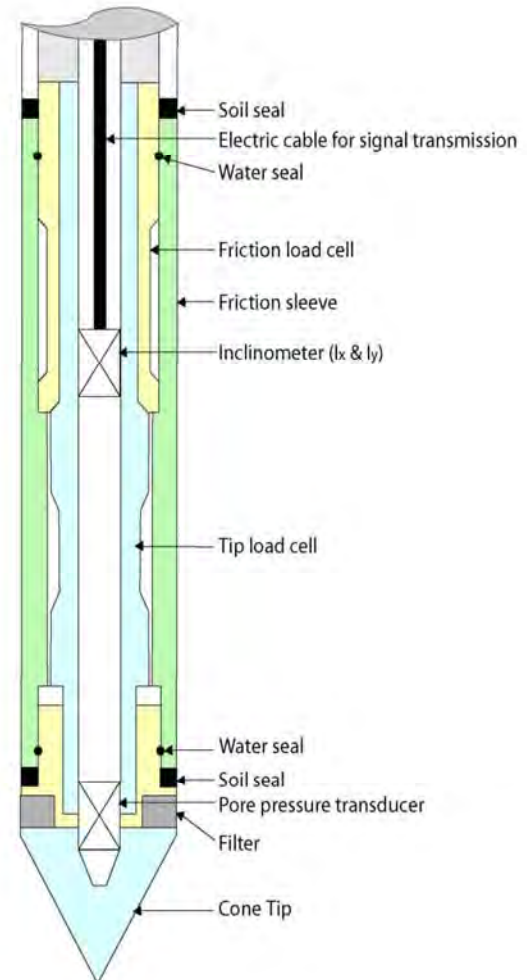


Figure CPT



Cone Penetration Test (CPT) Interpretation

Gregg has recently updated their CPT interpretation and plotting software (2007). The software takes the CPT data and performs basic interpretation in terms of soil behavior type (SBT) and various geotechnical parameters using current published empirical correlations based on the comprehensive review by Lunne, Robertson and Powell (1997). The interpretation is presented in tabular format using MS Excel. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

The following provides a summary of the methods used for the interpretation. Many of the empirical correlations to estimate geotechnical parameters have constants that have a range of values depending on soil type, geologic origin and other factors. The software uses 'default' values that have been selected to provide, in general, conservatively low estimates of the various geotechnical parameters.

Input:

- 1 Units for display (Imperial or metric) (atm. pressure, $p_a = 0.96$ tsf or 0.1 MPa)
- 2 Depth interval to average results, (ft or m). Data are collected at either 0.02 or 0.05m and can be averaged every 1, 3 or 5 intervals.
- 3 Elevation of ground surface (ft or m)
- 4 Depth to water table, z_w (ft or m) – input required
- 5 Net area ratio for cone, a (default to 0.80)
- 6 Relative Density constant, C_{Dr} (default to 350)
- 7 Young's modulus number for sands, α (default to 5)
- 8 Small strain shear modulus number
 - a. for sands, S_G (default to 180 for SBT_n 5, 6, 7)
 - b. for clays, C_G (default to 50 for SBT_n 1, 2, 3 & 4)
- 9 Undrained shear strength cone factor for clays, N_{kt} (default to 15)
- 10 Over Consolidation ratio number, k_{ocr} (default to 0.3)
- 11 Unit weight of water, (default to $\gamma_w = 62.4$ lb/ft³ or 9.81 kN/m³)

Column

- 1 Depth, z , (m) – CPT data is collected in meters
- 2 Depth (ft)
- 3 Cone resistance, q_c (tsf or MPa)
- 4 Sleeve friction, f_s (tsf or MPa)
- 5 Penetration pore pressure, u (psi or MPa), measured behind the cone (i.e. u_2)
- 6 Other – any additional data, if collected, e.g. electrical resistivity or UVIF
- 7 Total cone resistance, q_t (tsf or MPa) $q_t = q_c + u(1-a)$

8	Friction Ratio, R_f (%)	$R_f = (f_s/q_t) \times 100\%$
9	Soil Behavior Type (non-normalized), SBT	see note
10	Unit weight, γ (pcf or kN/m ³)	based on SBT, see note
11	Total overburden stress, σ_v (tsf)	$\sigma_{v0} = \gamma z$
12	Insitu pore pressure, u_o (tsf)	$u_o = \gamma_w (z - z_w)$
13	Effective overburden stress, σ'_{v0} (tsf)	$\sigma'_{v0} = \sigma_{v0} - u_o$
14	Normalized cone resistance, Q_{t1}	$Q_{t1} = (q_t - \sigma_{v0}) / \sigma'_{v0}$
15	Normalized friction ratio, F_r (%)	$F_r = f_s / (q_t - \sigma_{v0}) \times 100\%$
16	Normalized Pore Pressure ratio, B_q	$B_q = u - u_o / (q_t - \sigma_{v0})$
17	Soil Behavior Type (normalized), SBT_n	see note
18	SBT_n Index, I_c	see note
19	Normalized Cone resistance, Q_{tn} (n varies with I_c)	see note
20	Estimated permeability, k_{SBT} (cm/sec or ft/sec)	see note
21	Equivalent SPT N_{60} , blows/ft	see note
22	Equivalent SPT $(N_1)_{60}$ blows/ft	see note
23	Estimated Relative Density, D_r , (%)	see note
24	Estimated Friction Angle, ϕ' , (degrees)	see note
25	Estimated Young's modulus, E_s (tsf)	see note
26	Estimated small strain Shear modulus, G_o (tsf)	see note
27	Estimated Undrained shear strength, s_u (tsf)	see note
28	Estimated Undrained strength ratio	s_u/σ'_v
29	Estimated Over Consolidation ratio, OCR	see note

Notes:

- 1 Soil Behavior Type (non-normalized), SBT listed below Lunne et al. (1997)
- 2 Unit weight, γ either constant at 119 pcf or based on Non-normalized SBT (Lunne et al., 1997 and table below)
- 3 Soil Behavior Type (Normalized), SBT_n Lunne et al. (1997)
- 4 SBT_n Index, I_c $I_c = ((3.47 - \log Q_{t1})^2 + (\log F_r + 1.22)^2)^{0.5}$
- 5 Normalized Cone resistance, Q_{tn} (n varies with I_c)

$Q_{tn} = ((q_t - \sigma_{v0})/p_a) (p_a/(\sigma'_{v0})^n$ and recalculate I_c , then iterate:

When $I_c < 1.64$, $n = 0.5$ (clean sand)
 When $I_c > 3.30$, $n = 1.0$ (clays)
 When $1.64 < I_c < 3.30$, $n = (I_c - 1.64)0.3 + 0.5$
 Iterate until the change in n, $\Delta n < 0.01$

- | | | |
|----|--|--|
| 6 | Estimated permeability, k_{SBT} (based on Normalized SBT_n)
(Lunne et al., 1997 and table below) | |
| 7 | Equivalent SPT N_{60} , blows/ft | Lunne et al. (1997) |
| | $\frac{(q_t/p_a)}{N_{60}} = 8.5 \left(1 - \frac{I_c}{4.6} \right)$ | |
| 8 | Equivalent SPT $(N_1)_{60}$ blows/ft
where $C_N = (p_a/\sigma'_{vo})^{0.5}$ | $(N_1)_{60} = N_{60} C_N$ |
| 9 | Relative Density, D_r , (%)
Only SBT_n 5, 6, 7 & 8 | $D_r^2 = Q_{tn} / C_{Dr}$
Show 'N/A' in zones 1, 2, 3, 4 & 9 |
| 10 | Friction Angle, ϕ' , (degrees)
Only SBT_n 5, 6, 7 & 8 | $\tan \phi' = \frac{1}{2.68} \left[\log \left(\frac{q_c}{\sigma'_{vo}} \right) + 0.29 \right]$
Show 'N/A' in zones 1, 2, 3, 4 & 9 |
| 11 | Young's modulus, E_s
Only SBT_n 5, 6, 7 & 8 | $E_s = \alpha q_t$
Show 'N/A' in zones 1, 2, 3, 4 & 9 |
| 12 | Small strain shear modulus, G_o
a. $G_o = S_G (q_t \sigma'_{vo} p_a)^{1/3}$
b. $G_o = C_G q_t$ | For SBT_n 5, 6, 7
For SBT_n 1, 2, 3 & 4
Show 'N/A' in zones 8 & 9 |
| 13 | Undrained shear strength, s_u
Only SBT_n 1, 2, 3, 4 & 9 | $s_u = (q_t - \sigma_{vo}) / N_{kt}$
Show 'N/A' in zones 5, 6, 7 & 8 |
| 14 | Over Consolidation ratio, OCR
Only SBT_n 1, 2, 3, 4 & 9 | $\text{OCR} = k_{ocr} Q_{t1}$
Show 'N/A' in zones 5, 6, 7 & 8 |

SBT Zones

The following updated and simplified SBT descriptions have been used in the software:

- | | |
|----|--------------------------|
| 1 | sensitive fine grained |
| 2 | organic soil |
| 3 | clay |
| 4 | clay & silty clay |
| 5 | clay & silty clay |
| 6 | sandy silt & clayey silt |
| 7 | silty sand & sandy silt |
| 8 | sand & silty sand |
| 9 | sand |
| 10 | sand |

SBT_n Zones

- | | |
|---|-------------------------|
| 1 | sensitive fine grained |
| 2 | organic soil |
| 3 | clay |
| 4 | clay & silty clay |
| 5 | silty sand & sandy silt |
| 6 | sand & silty sand |
| 7 | sand |

11	very dense/stiff soil*	8	very dense/stiff soil*
12	very dense/stiff soil*	9	very dense/stiff soil*

*heavily overconsolidated and/or cemented

Track when soils fall with zones of same description and print that description (i.e. if soils fall only within SBT zones 4 & 5, print 'clays & silty clays')

Estimated Permeability (see Lunne et al., 1997)

SBT _n	Permeability (ft/sec)	(m/sec)
1	3×10^{-8}	1×10^{-8}
2	3×10^{-7}	1×10^{-7}
3	1×10^{-9}	3×10^{-10}
4	3×10^{-8}	1×10^{-8}
5	3×10^{-6}	1×10^{-6}
6	3×10^{-4}	1×10^{-4}
7	3×10^{-2}	1×10^{-2}
8	3×10^{-6}	1×10^{-6}
9	1×10^{-8}	3×10^{-9}

Estimated Unit Weight (see Lunne et al., 1997)

SBT	Approximate Unit Weight (lb/ft ³)	(kN/m ³)
1	111.4	17.5
2	79.6	12.5
3	111.4	17.5
4	114.6	18.0
5	114.6	18.0
6	114.6	18.0
7	117.8	18.5
8	120.9	19.0
9	124.1	19.5
10	127.3	20.0
11	130.5	20.5
12	120.9	19.0



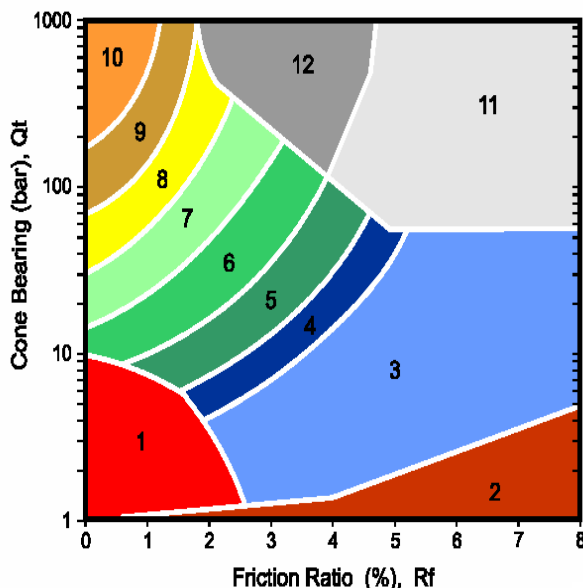
Cone Penetration Test Data & Interpretation

The Cone Penetration Test (CPT) data collected from your site are presented in graphical form in the attached report. The plots include interpreted Soil Behavior Type (SBT) based on the charts described by Robertson (1990). Typical plots display SBT based on the non-normalized charts of Robertson et al (1986). For CPT soundings extending greater than 50 feet, we recommend the use of the normalized charts of Robertson (1990) which can be displayed as SBTn, upon request. The report also includes spreadsheet output of computer calculations of basic interpretation in terms of SBT and SBTn and various geotechnical parameters using current published correlations based on the comprehensive review by Lunne, Robertson and Powell (1997), as well as recent updates by Professor Robertson. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg Drilling & Testing Inc. do not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and do not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

Some interpretation methods require input of the groundwater level to calculate vertical effective stress. An estimate of the in-situ groundwater level has been made based on field observations and/or CPT results, but should be verified by the user.

A summary of locations and depths is available in Table 1. Note that all penetration depths referenced in the data are with respect to the existing ground surface.

Note that it is not always possible to clearly identify a soil type based solely on q_t , f_s , and u_2 . In these situations, experience, judgment, and an assessment of the pore pressure dissipation data should be used to infer the correct soil behavior type.

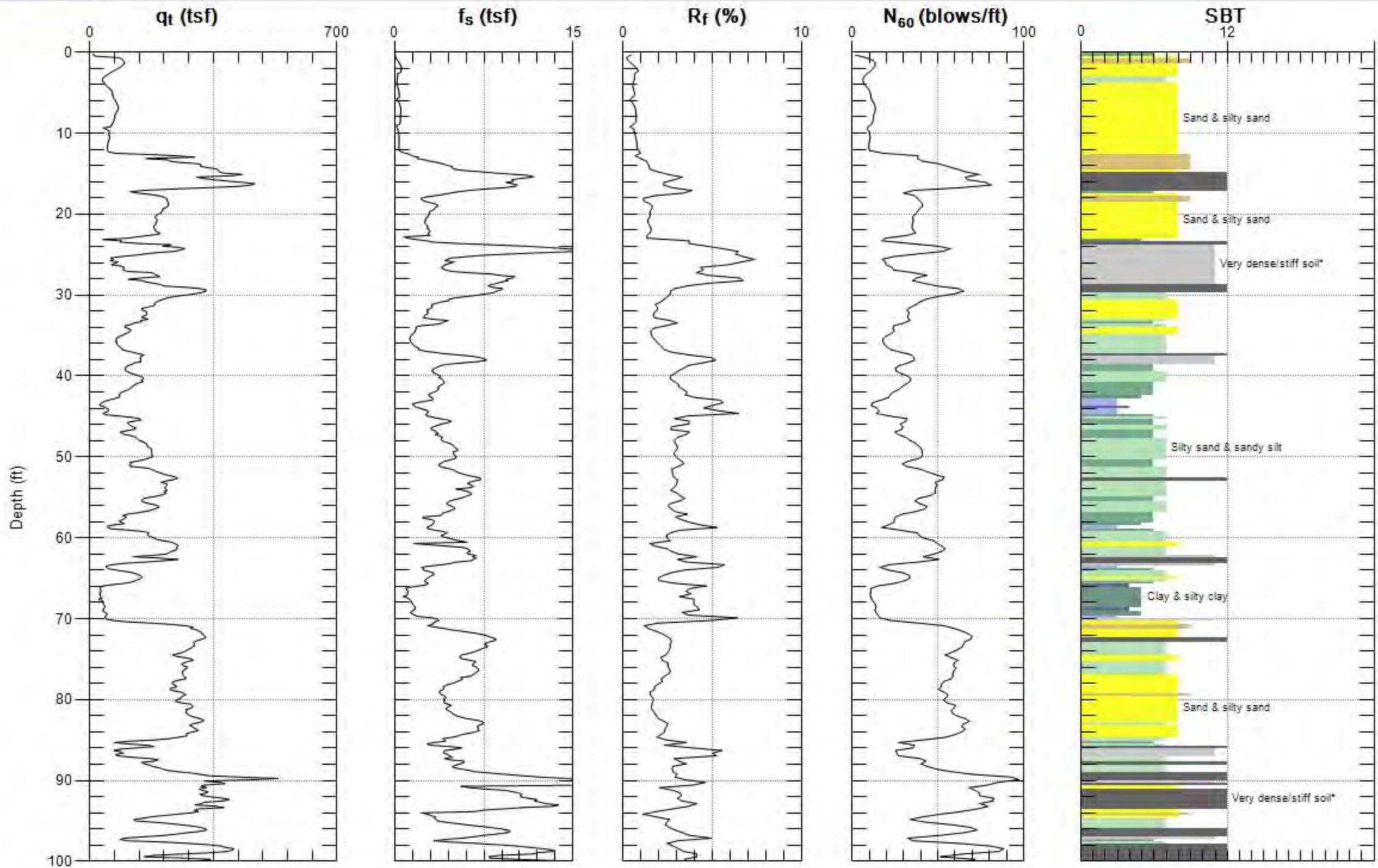


(After Robertson, et al., 1986)

ZONE	SBT
1	Sensitive, fine grained
2	Organic materials
3	Clay
4	Silty clay to clay
5	Clayey silt to silty clay
6	Sandy silt to clayey silt
7	Silty sand to sandy silt
8	Sand to silty sand
9	Sand
10	Gravely sand to sand
11	Very stiff fine grained*
12	Sand to clayey sand*

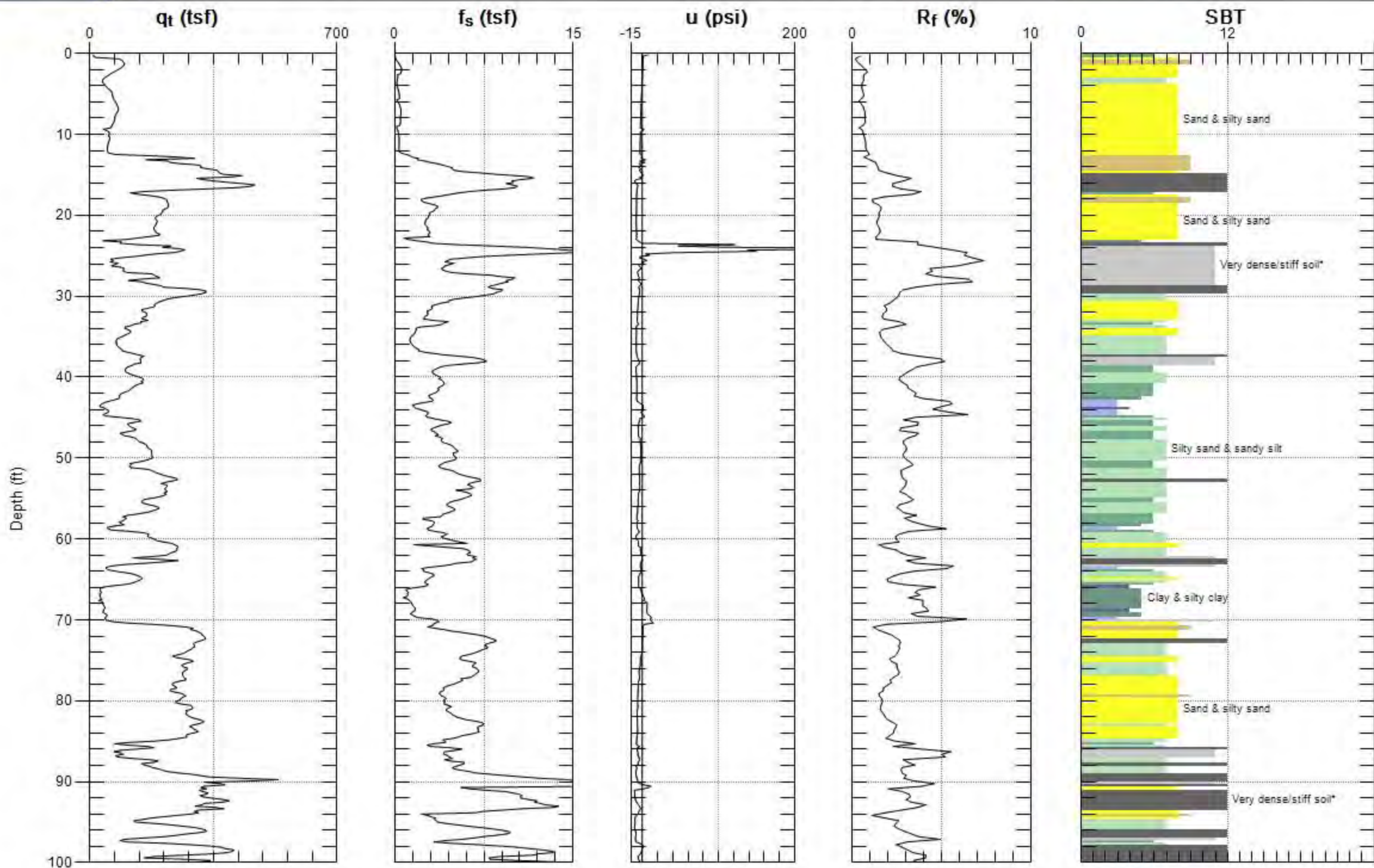
*over consolidated or cemented

Figure SBT



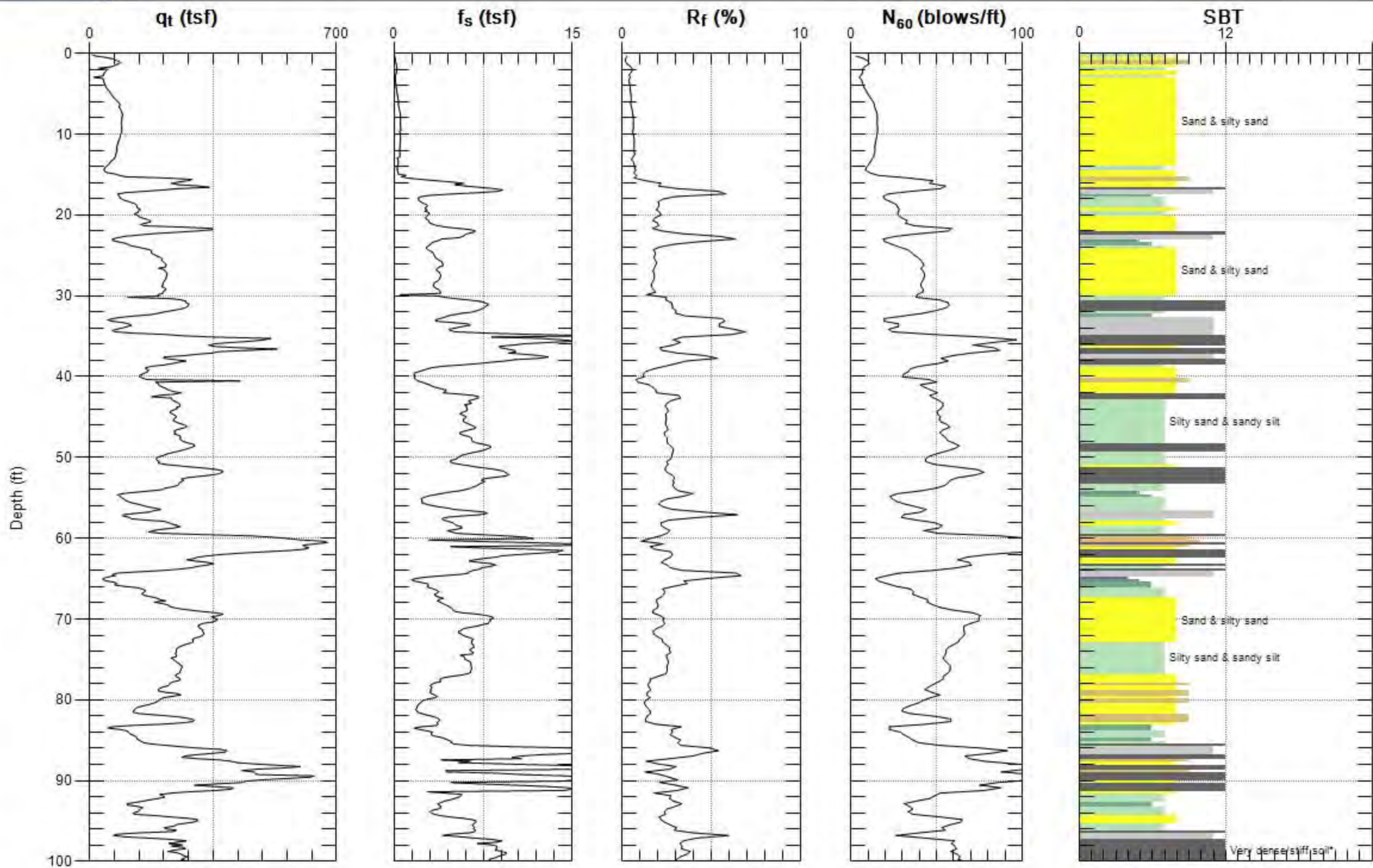
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



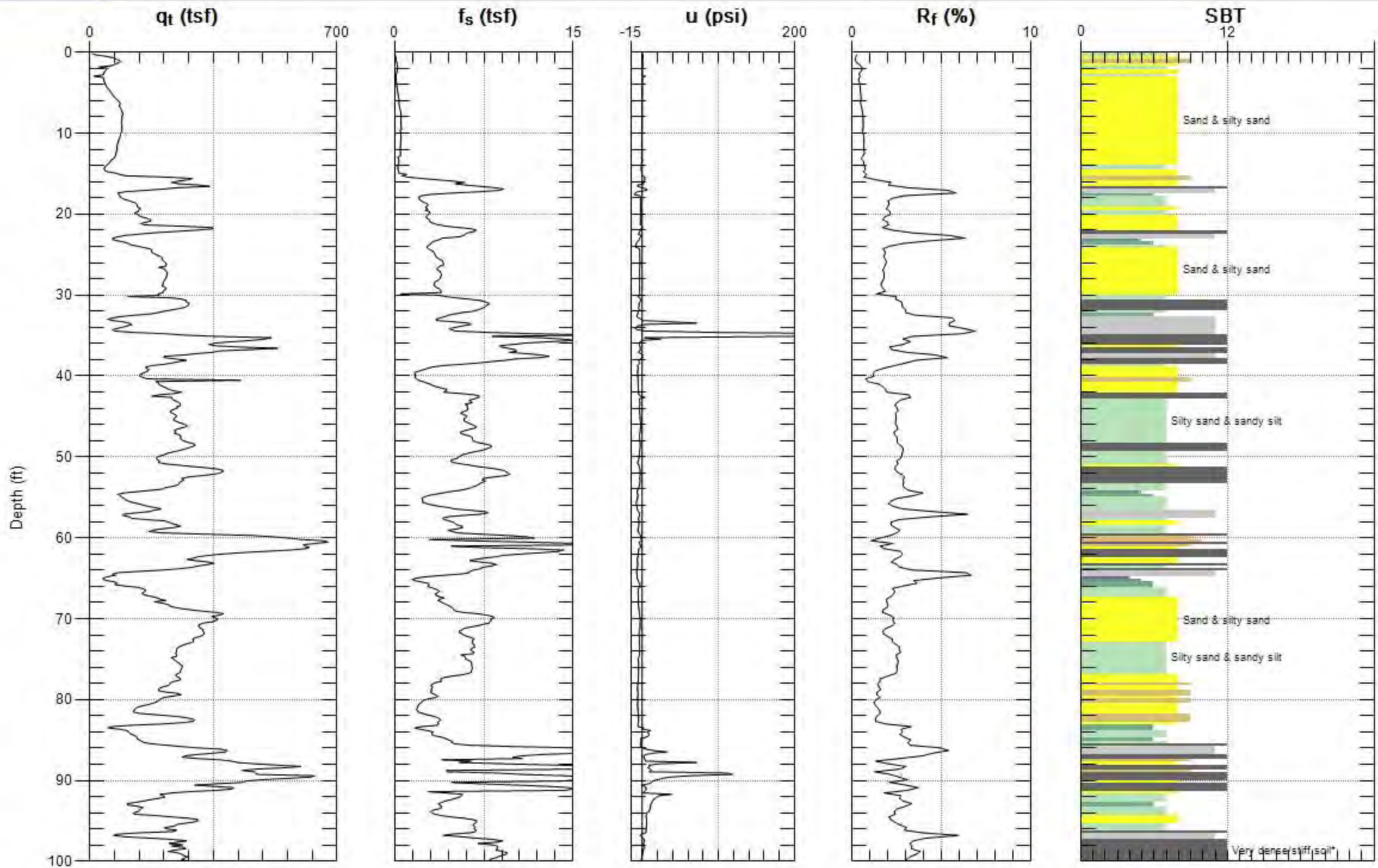
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SBT: Soil Behavior Type (Robertson 1990)



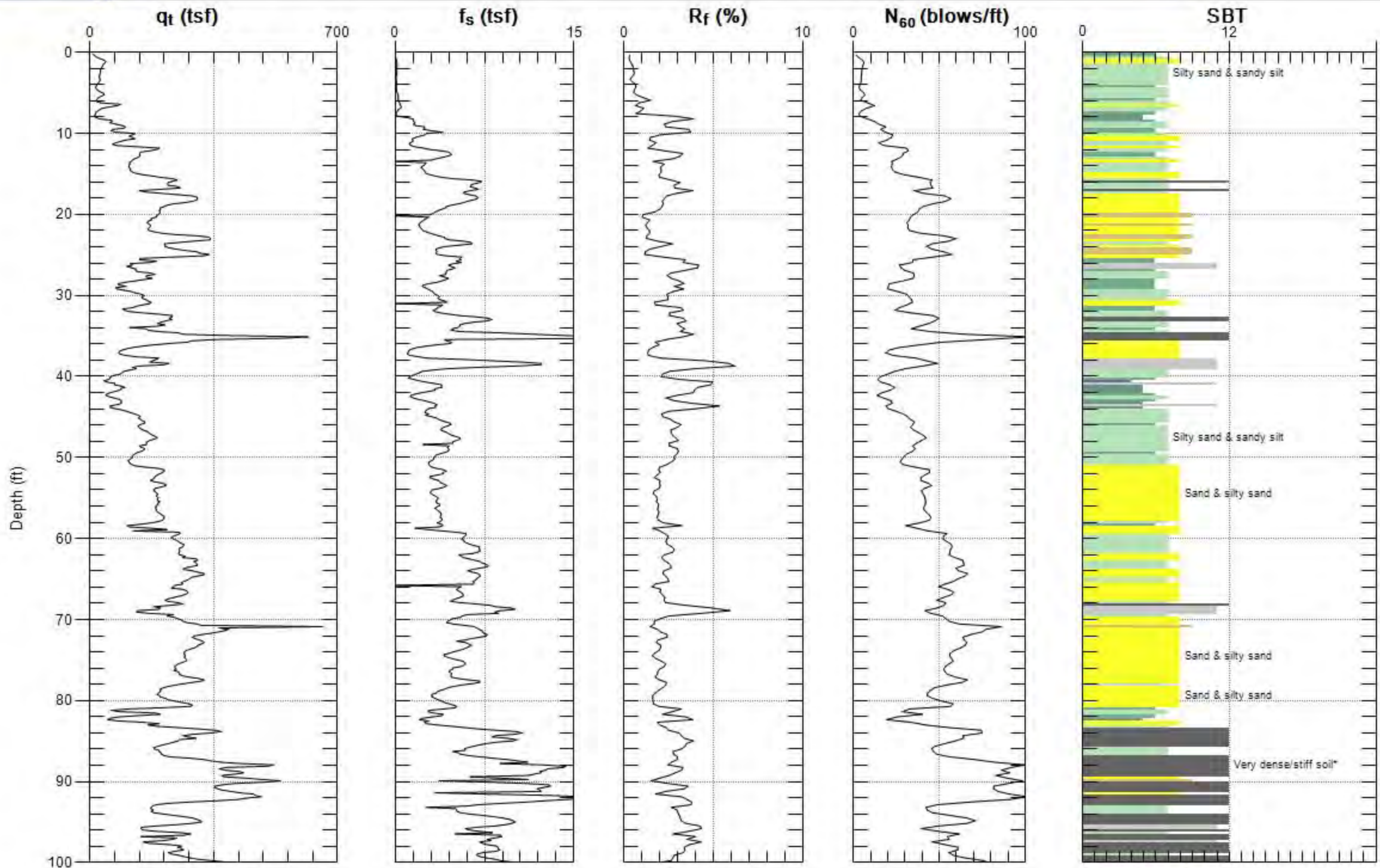
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SBT: Soil Behavior Type (Robertson 1990)



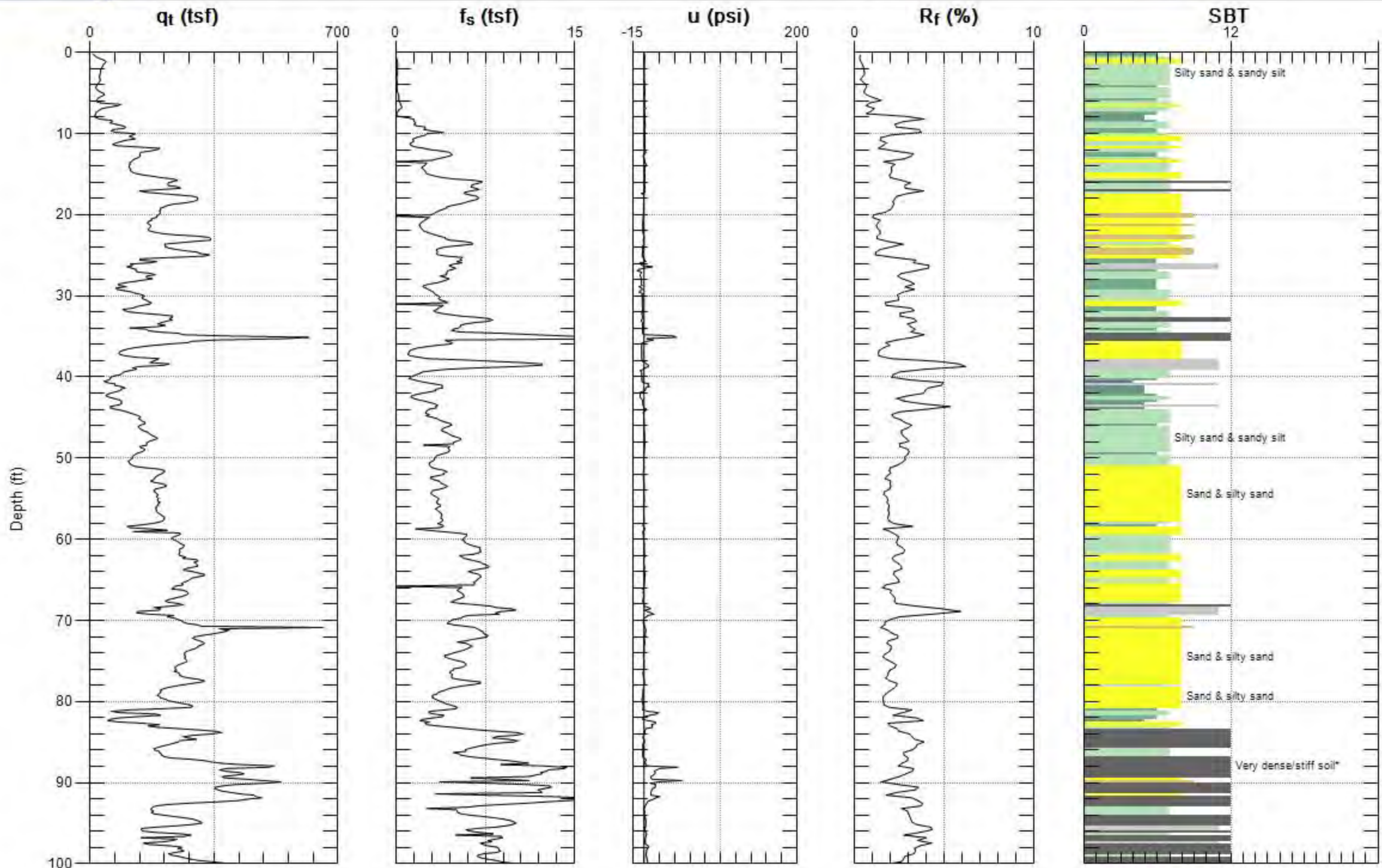
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SBT: Soil Behavior Type (Robertson 1990)



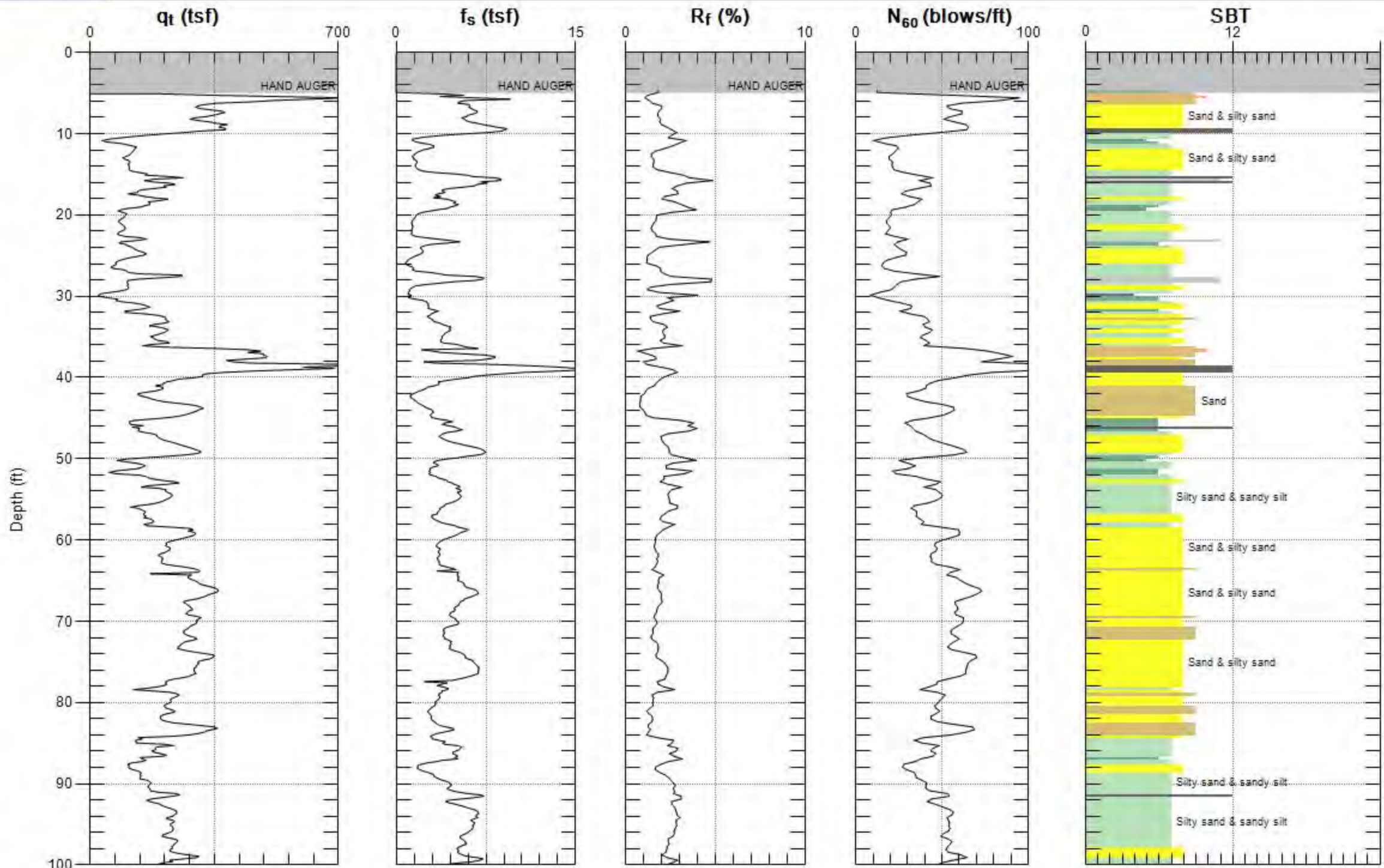
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



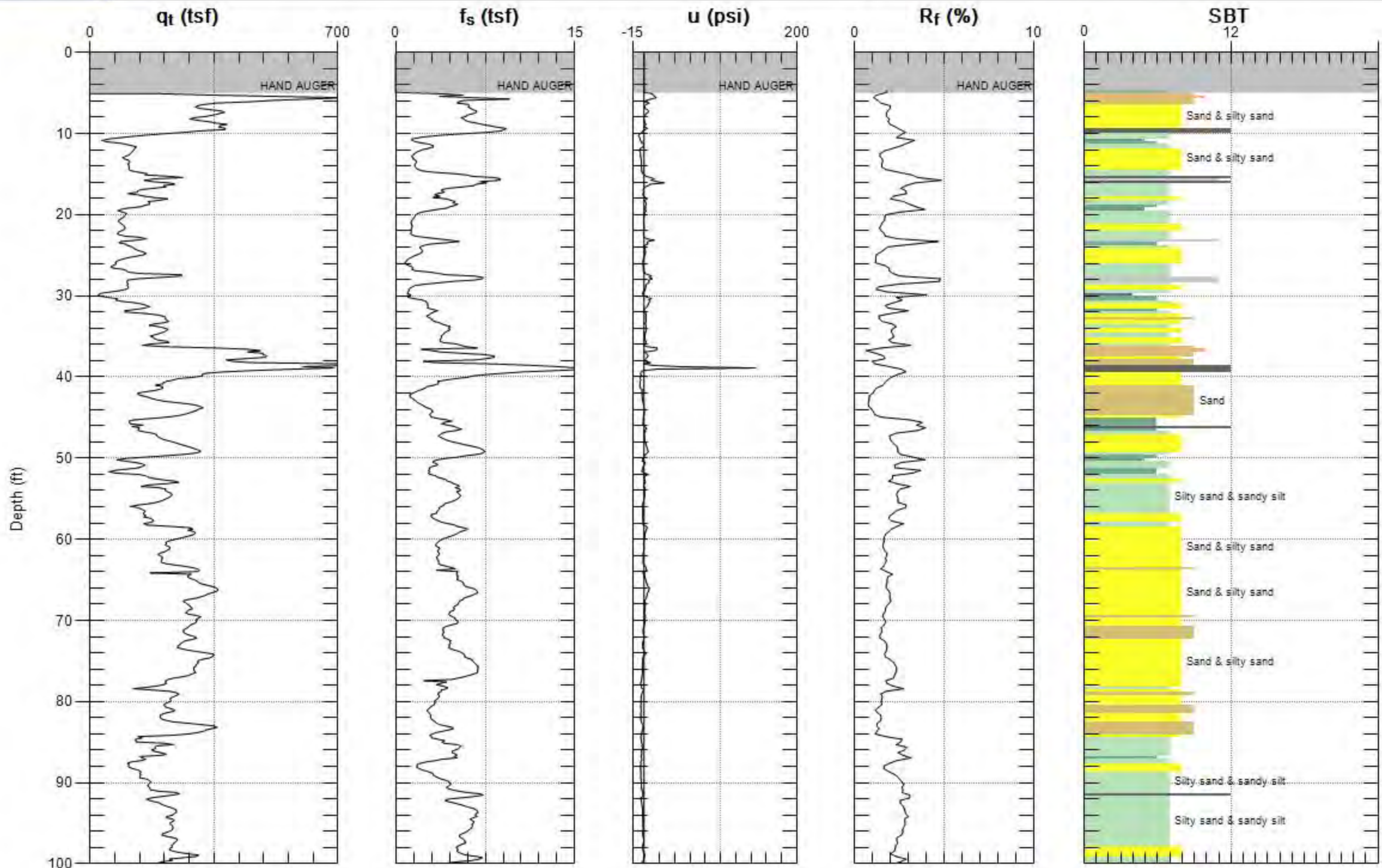
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SBT: Soil Behavior Type (Robertson 1990)



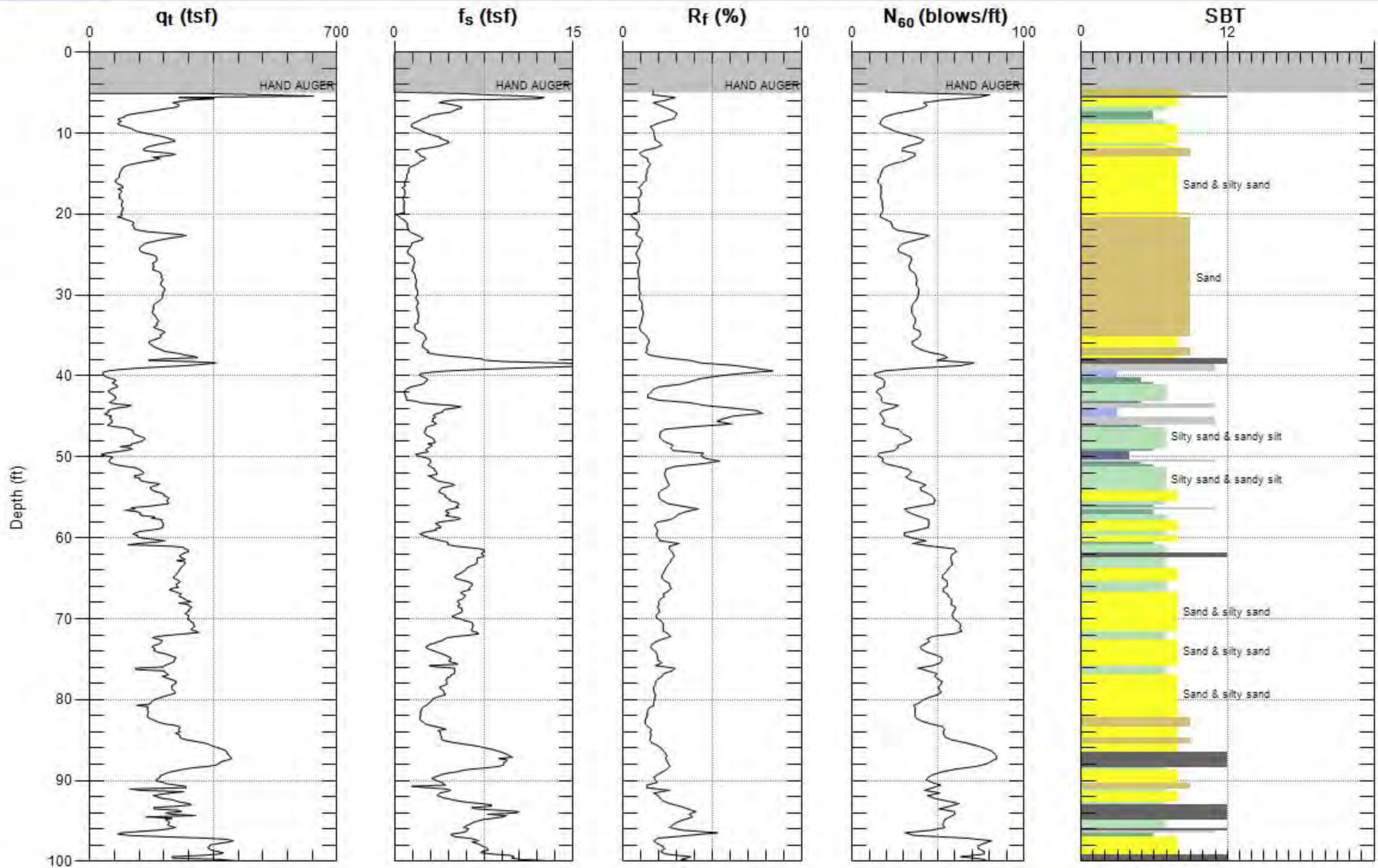
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



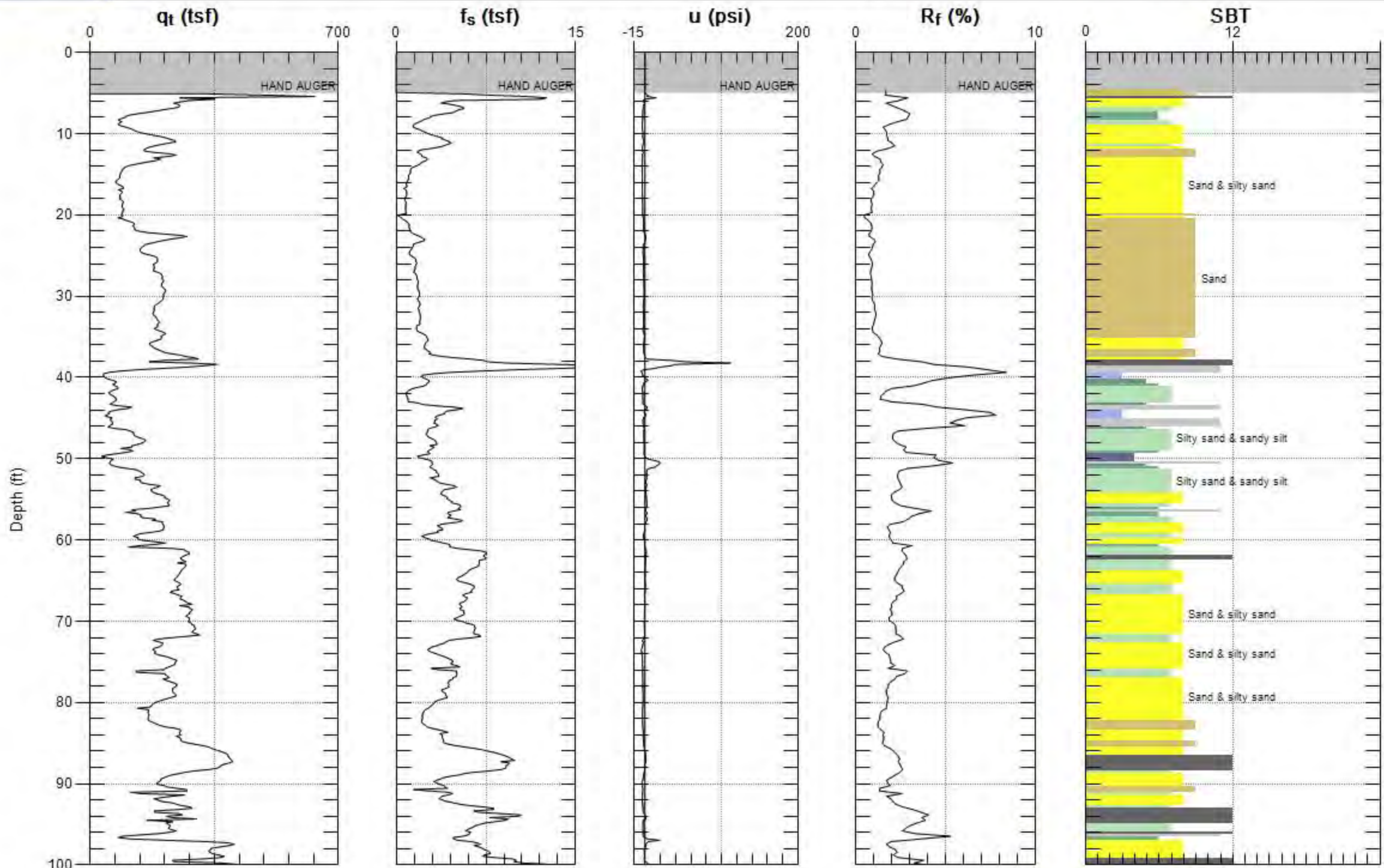
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



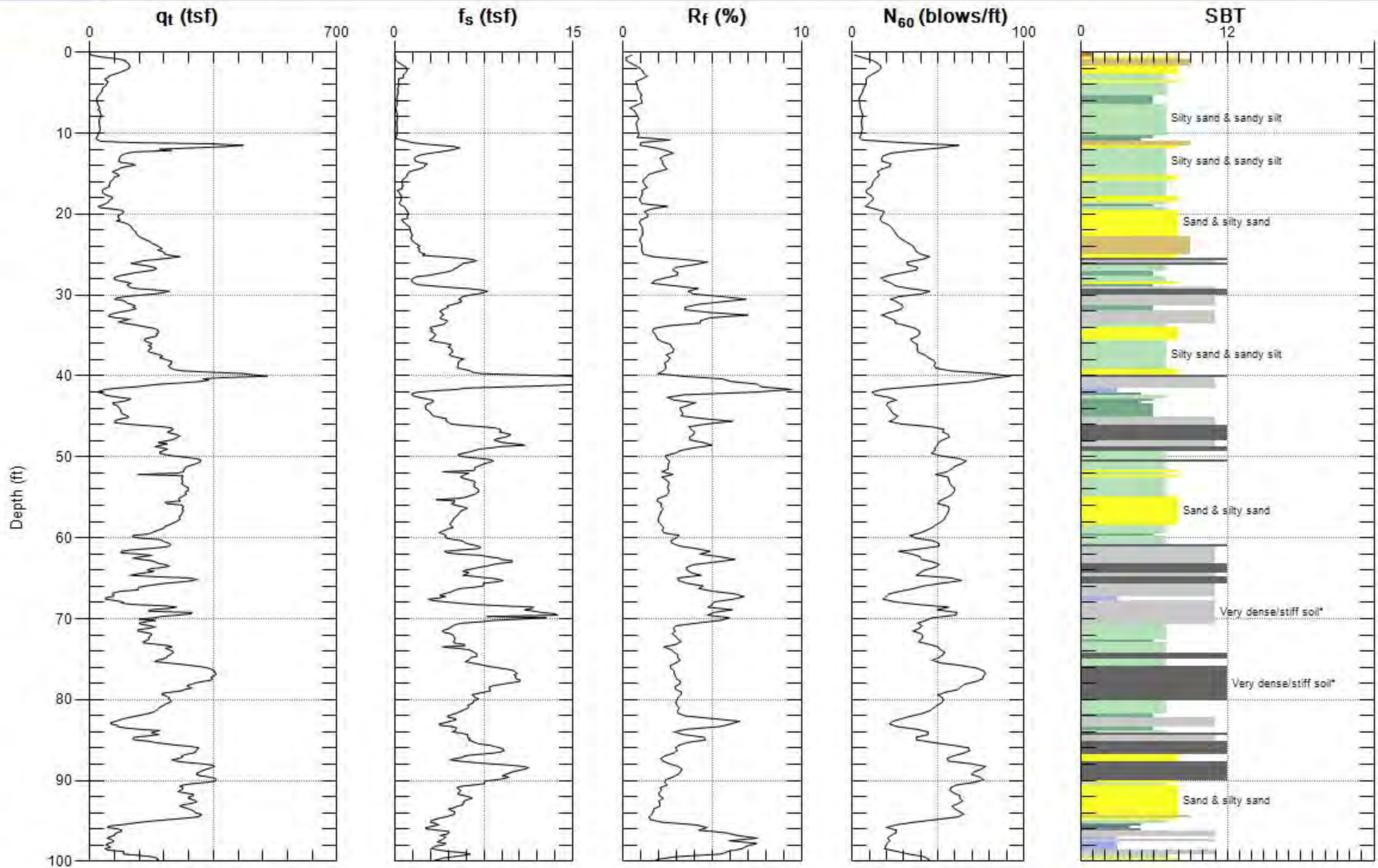
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



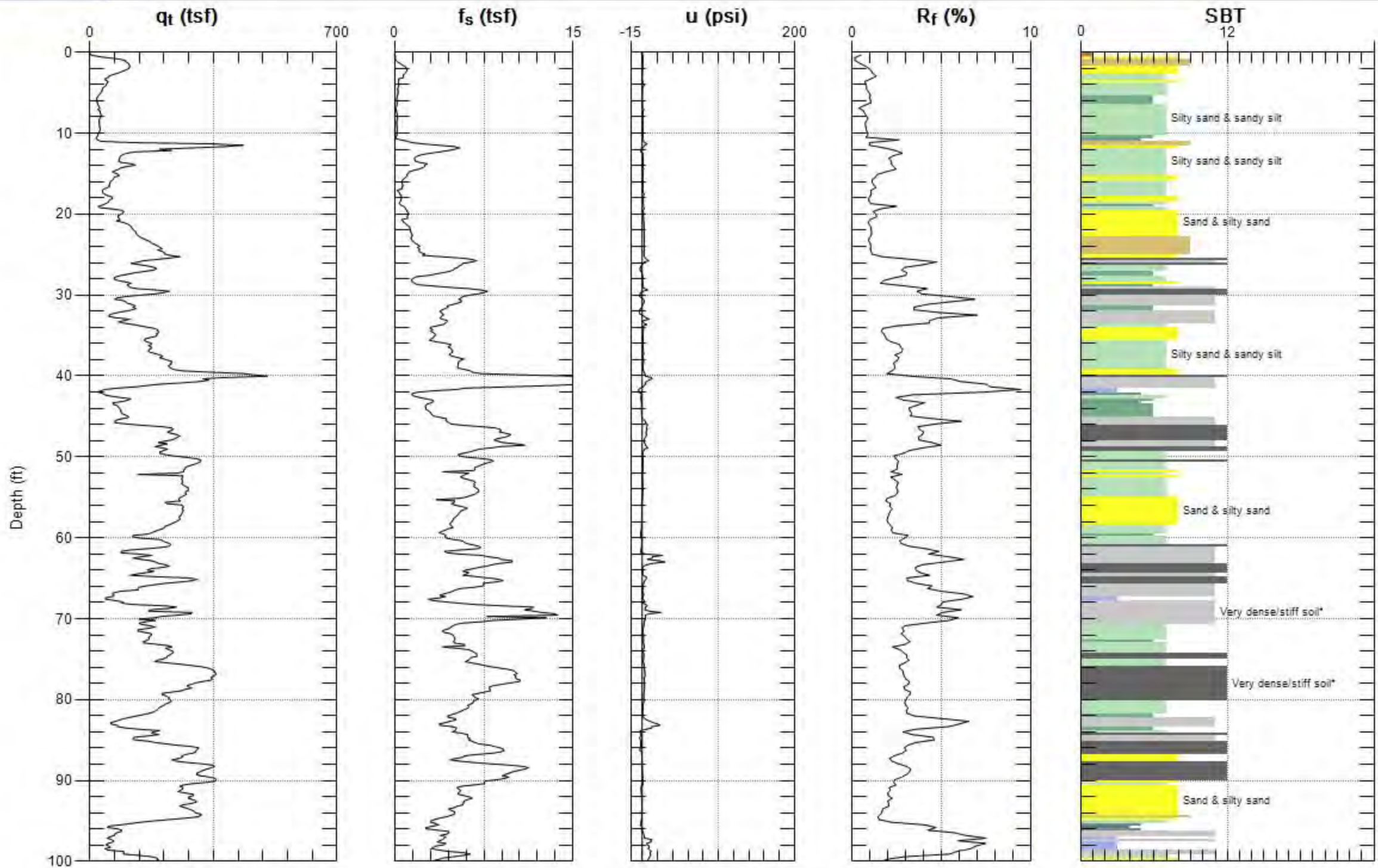
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



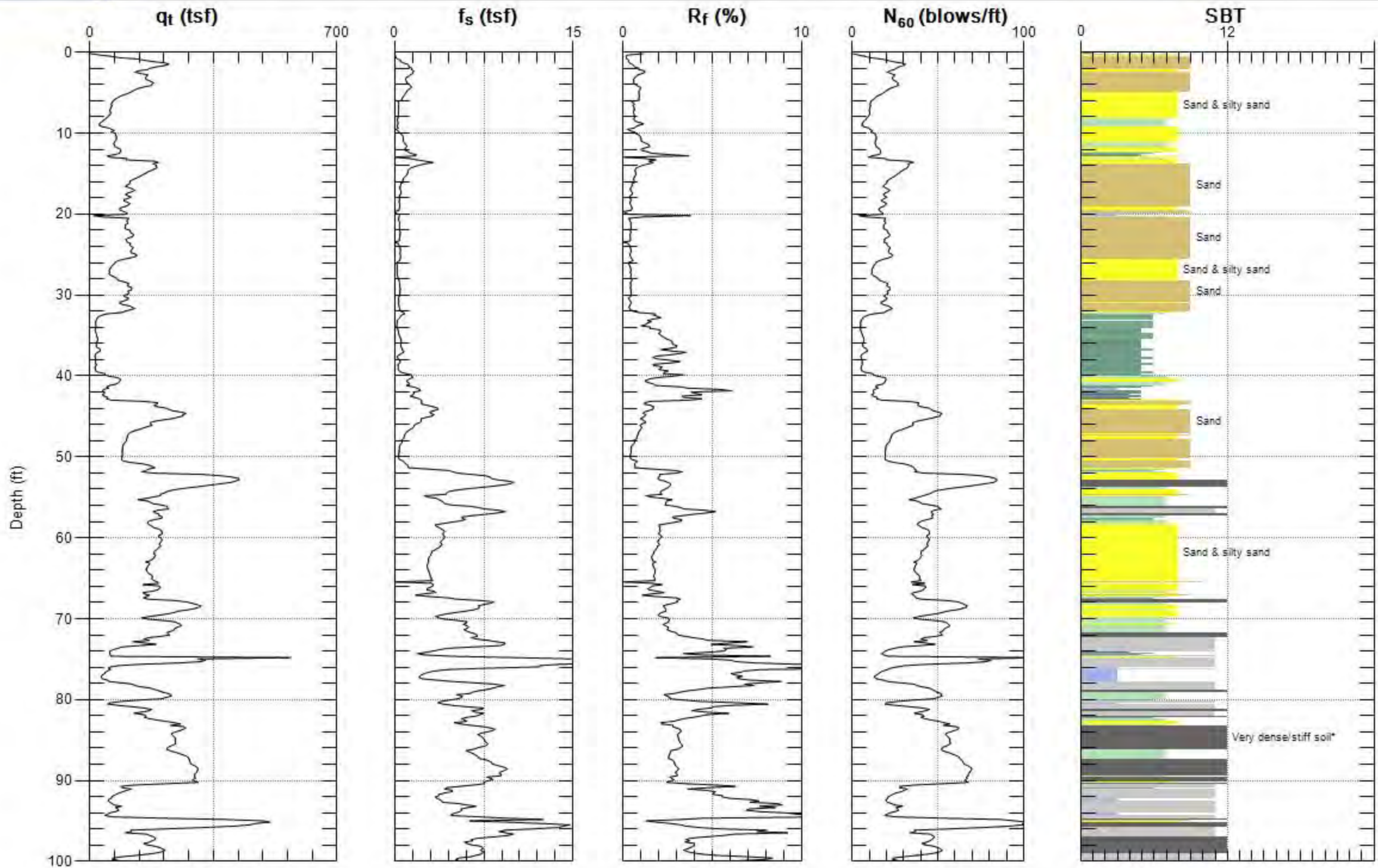
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



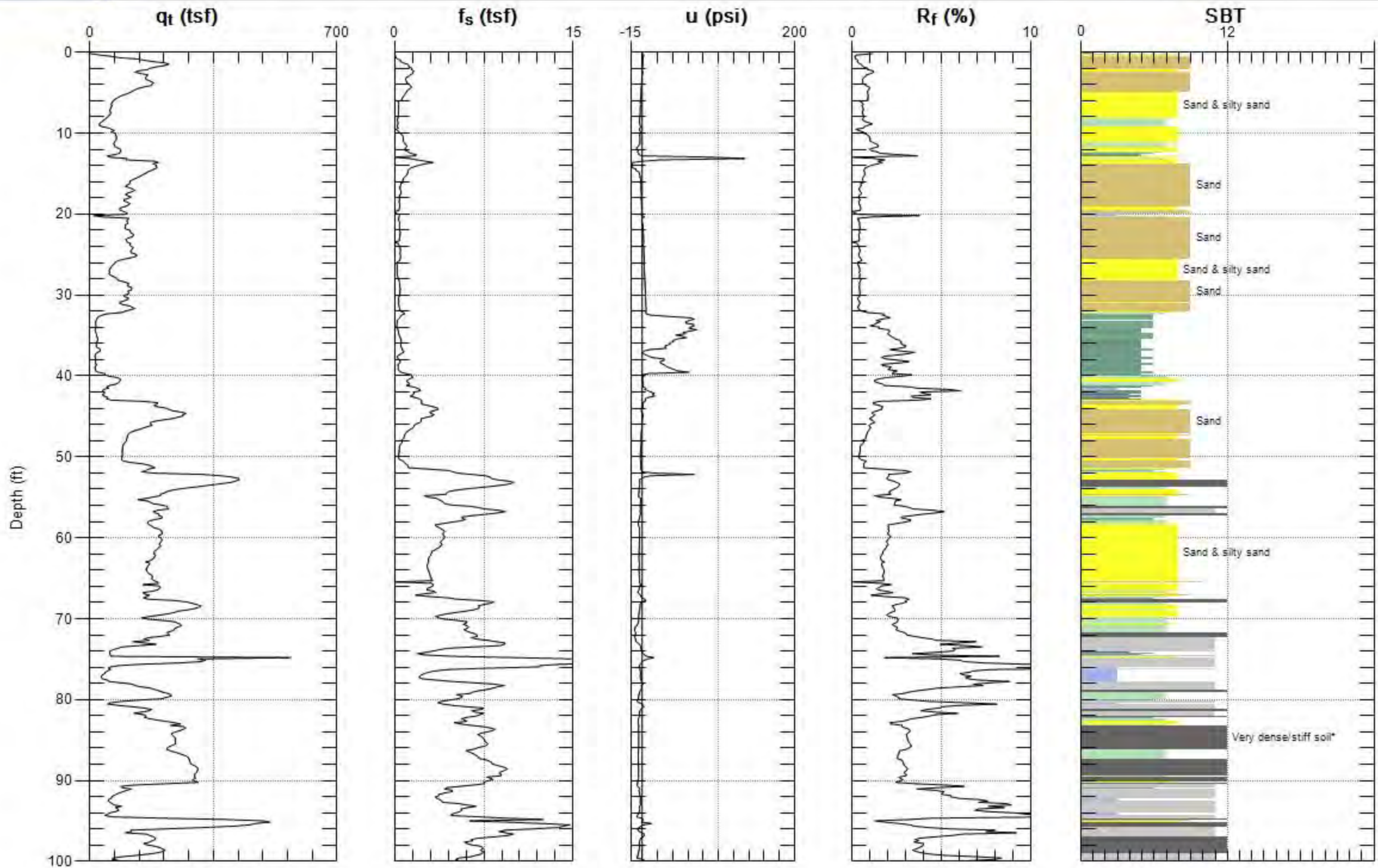
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Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



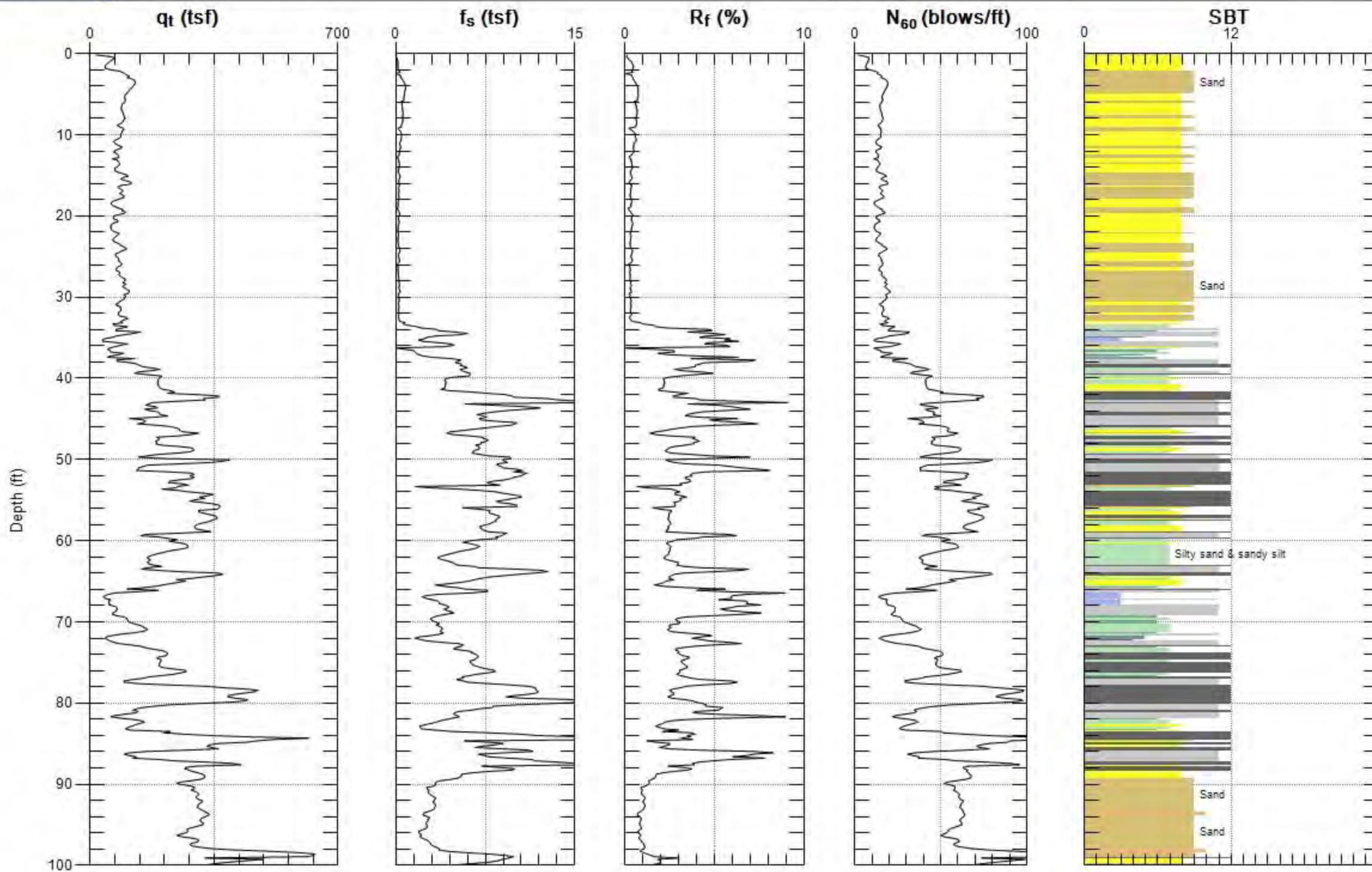
Max. Depth: 100.558 (ft)
Avg. Interval: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 100.558 (ft)
Avg. Interval: 0.164 (ft)

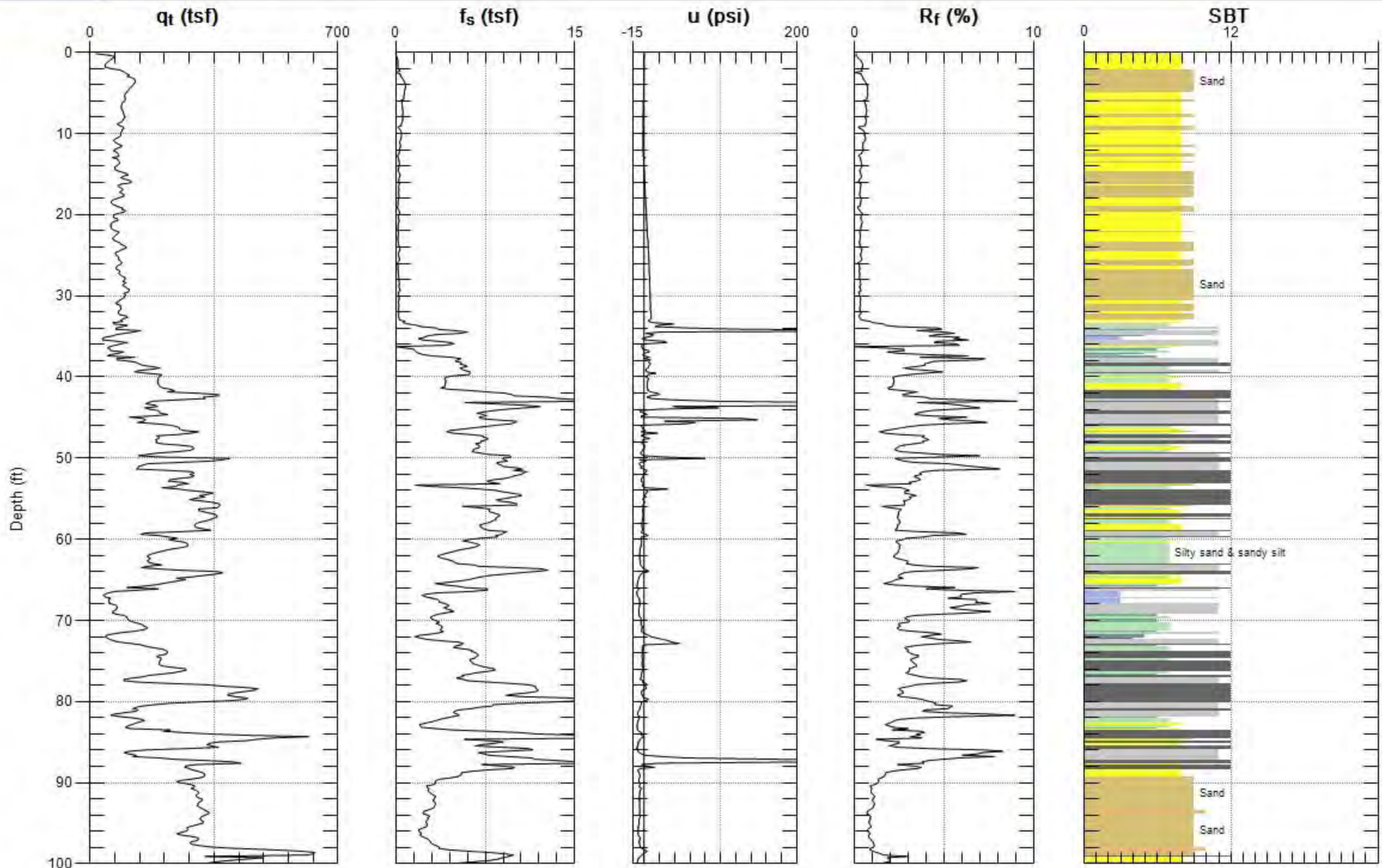
SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 100.394 (ft)

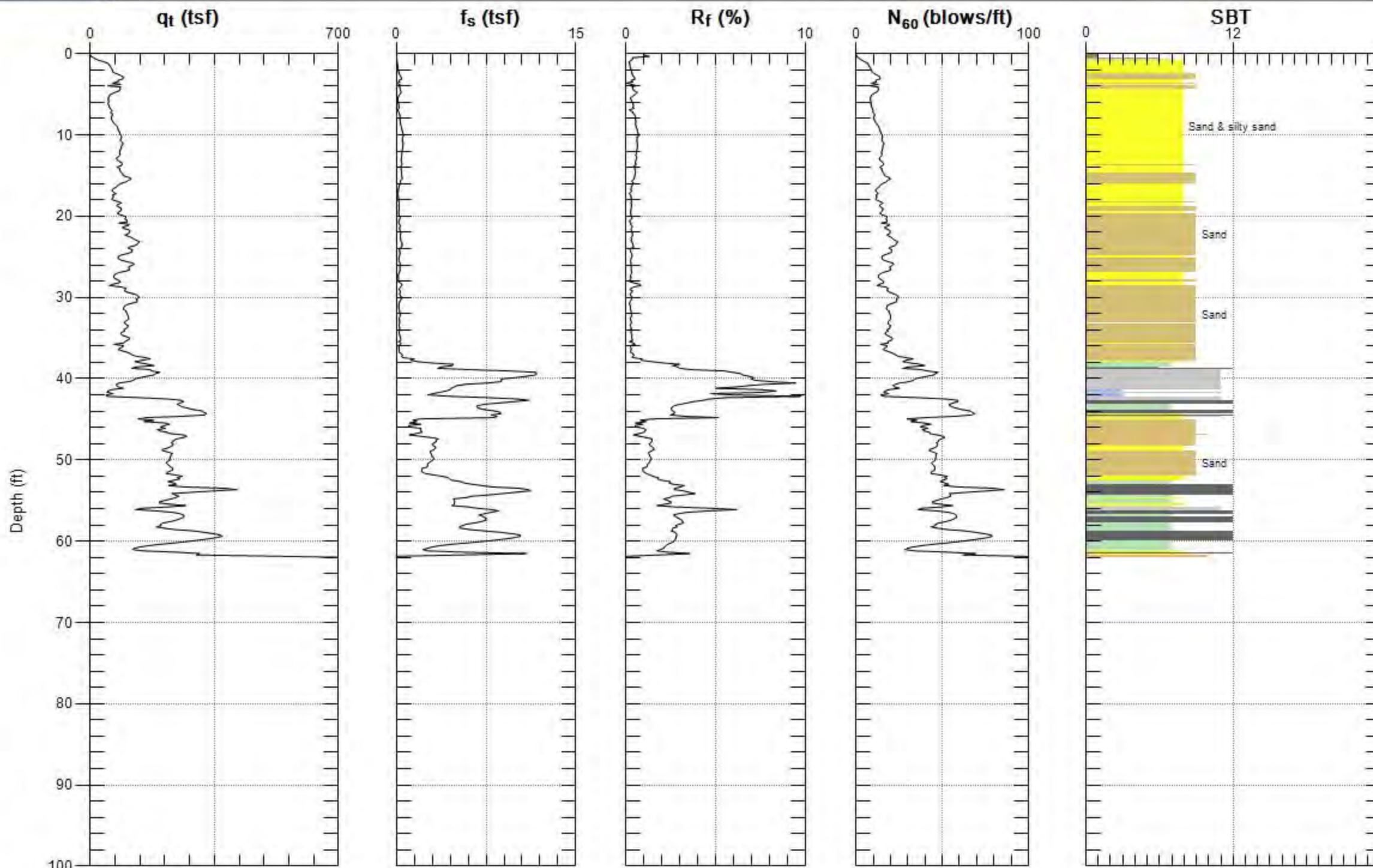
Avg. Interval: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)



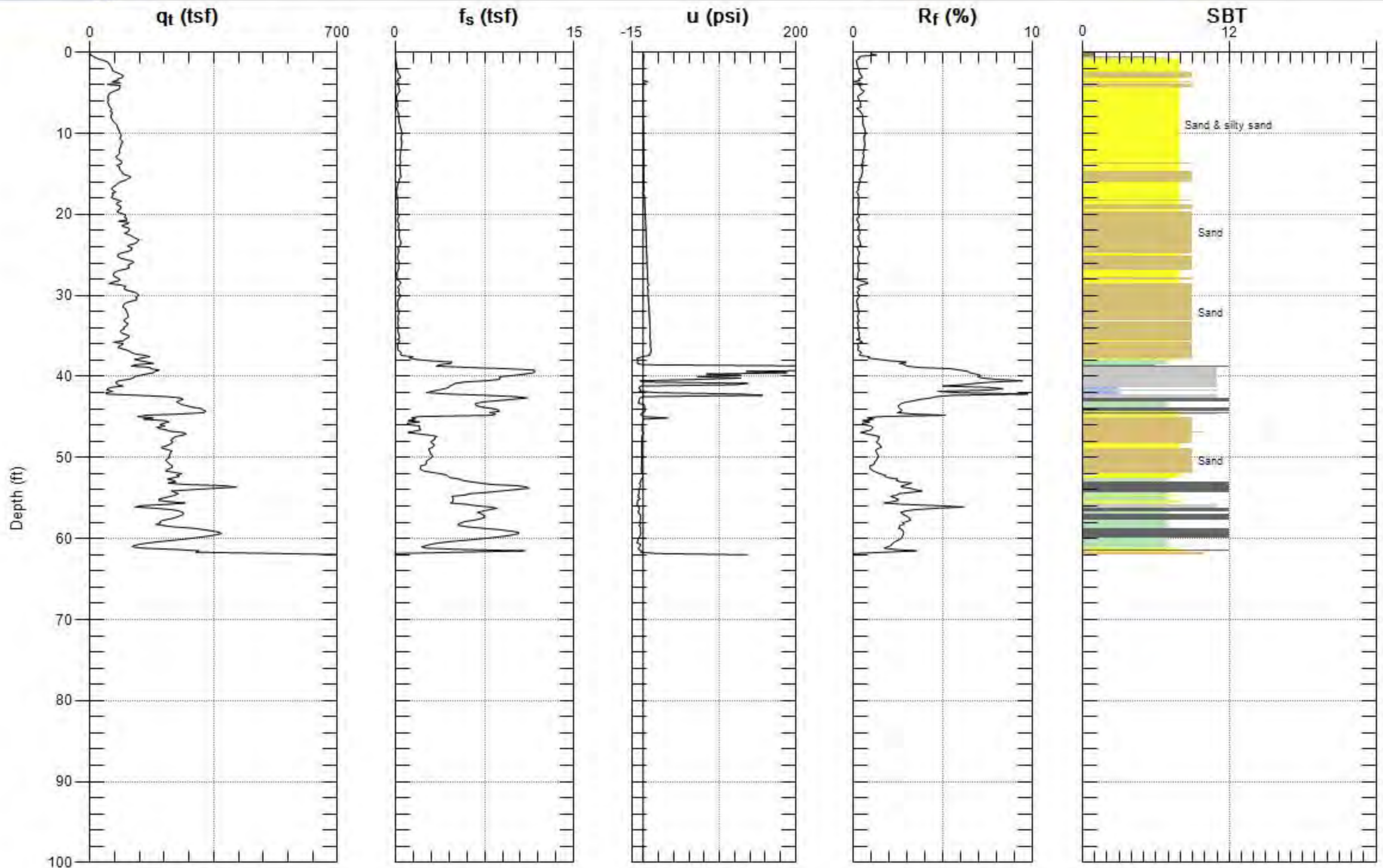
Max. Depth: 100.394 (ft)
Avg. Interval: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)



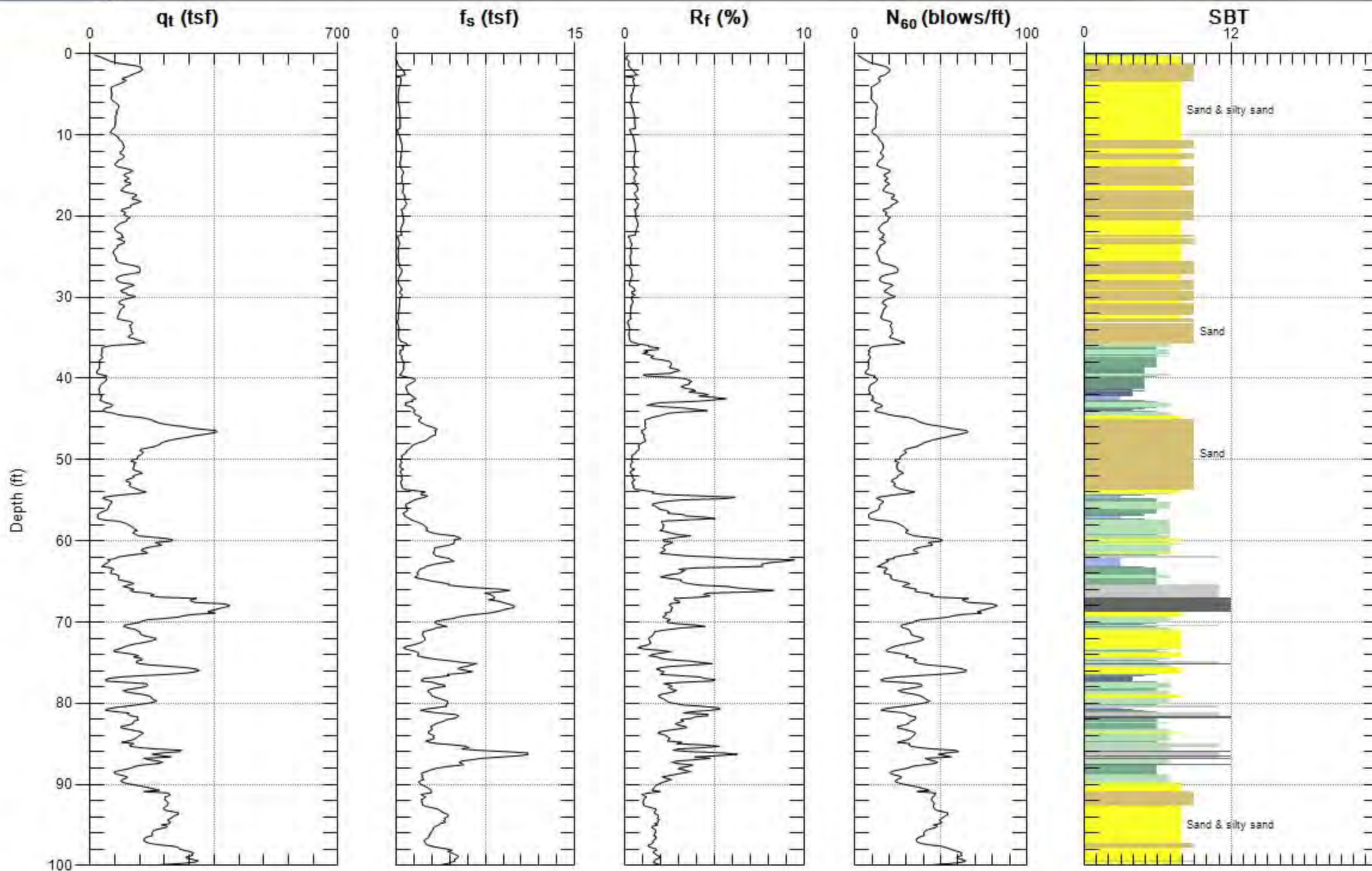
Max. Depth: 62.008 (ft)
Avg. Interval: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 62.008 (ft)
Avg. Interval: 0.164 (ft)

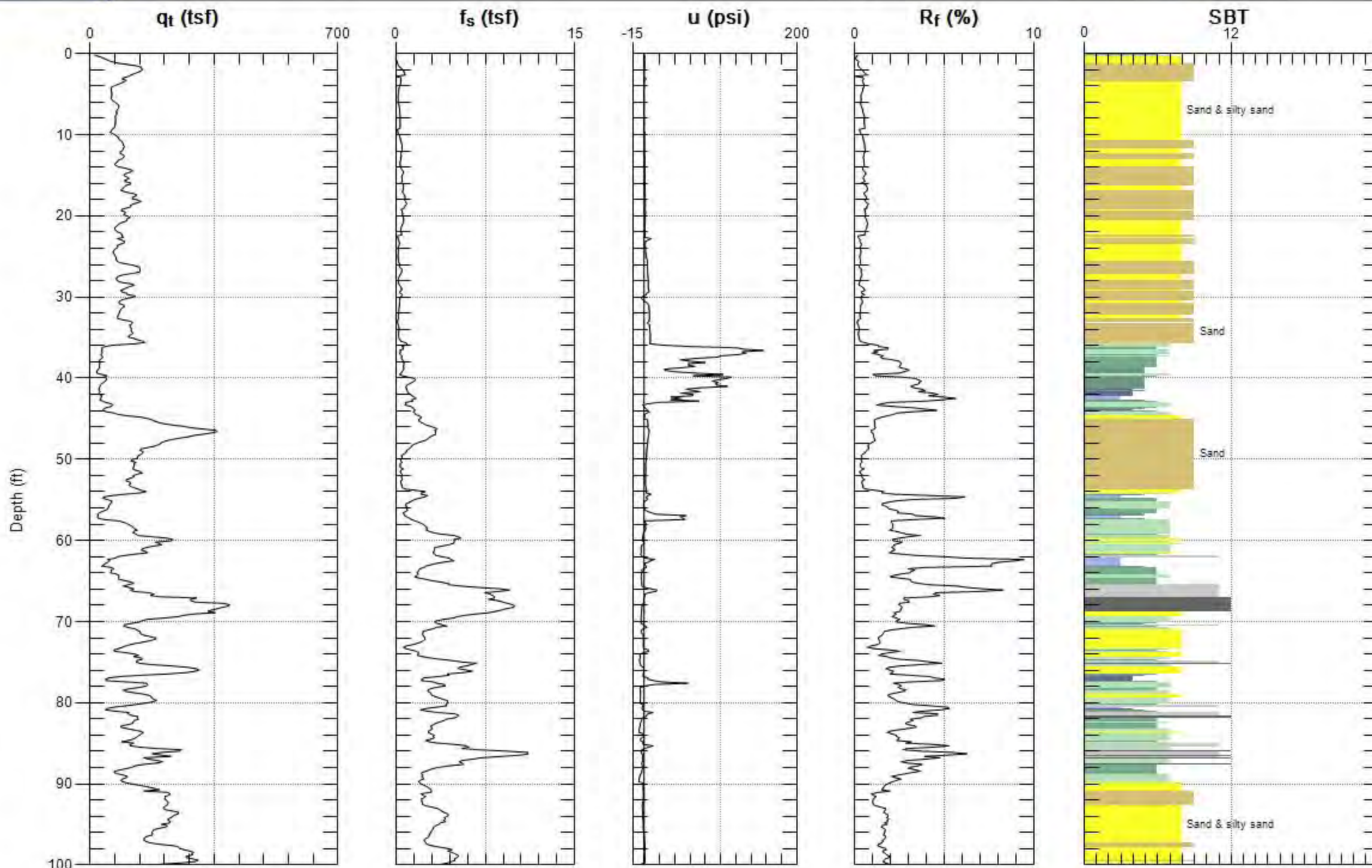
SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 101.050 (ft)

Avg. Interval: 0.164 (ft)

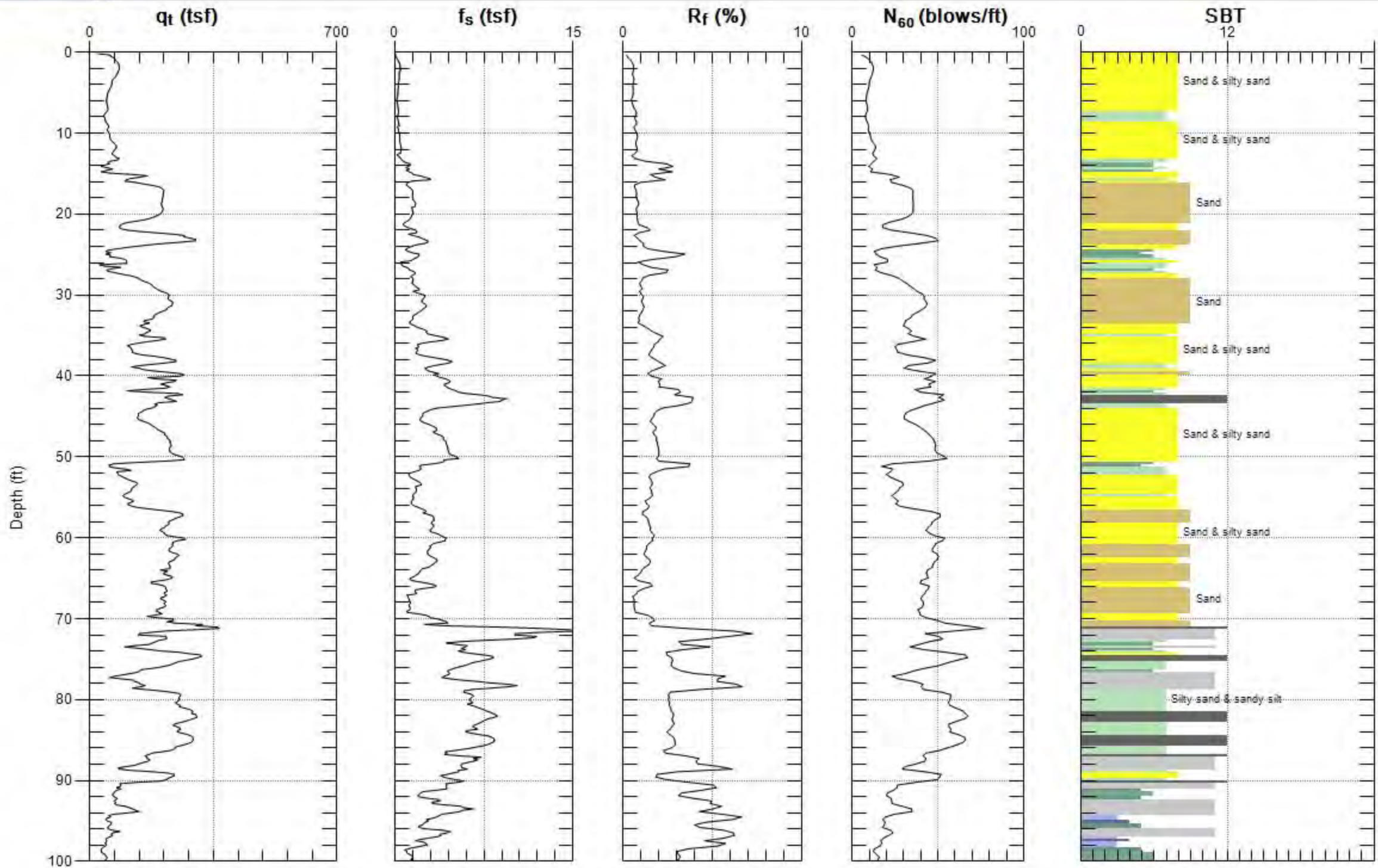
SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 101.050 (ft)

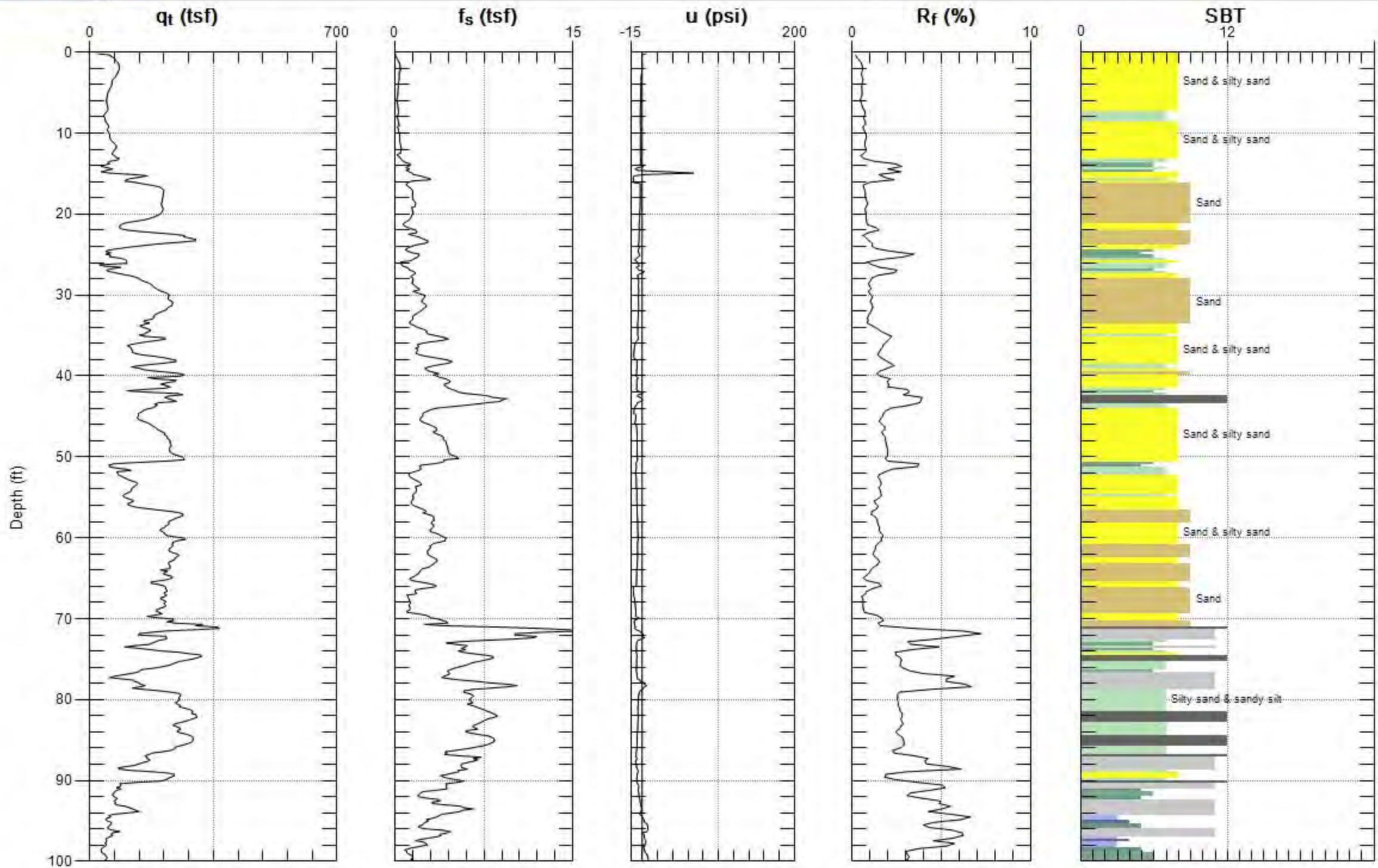
Avg. Interval: 0.164 (ft)

SBT: Soil Behavior Type (Robertson 1990)



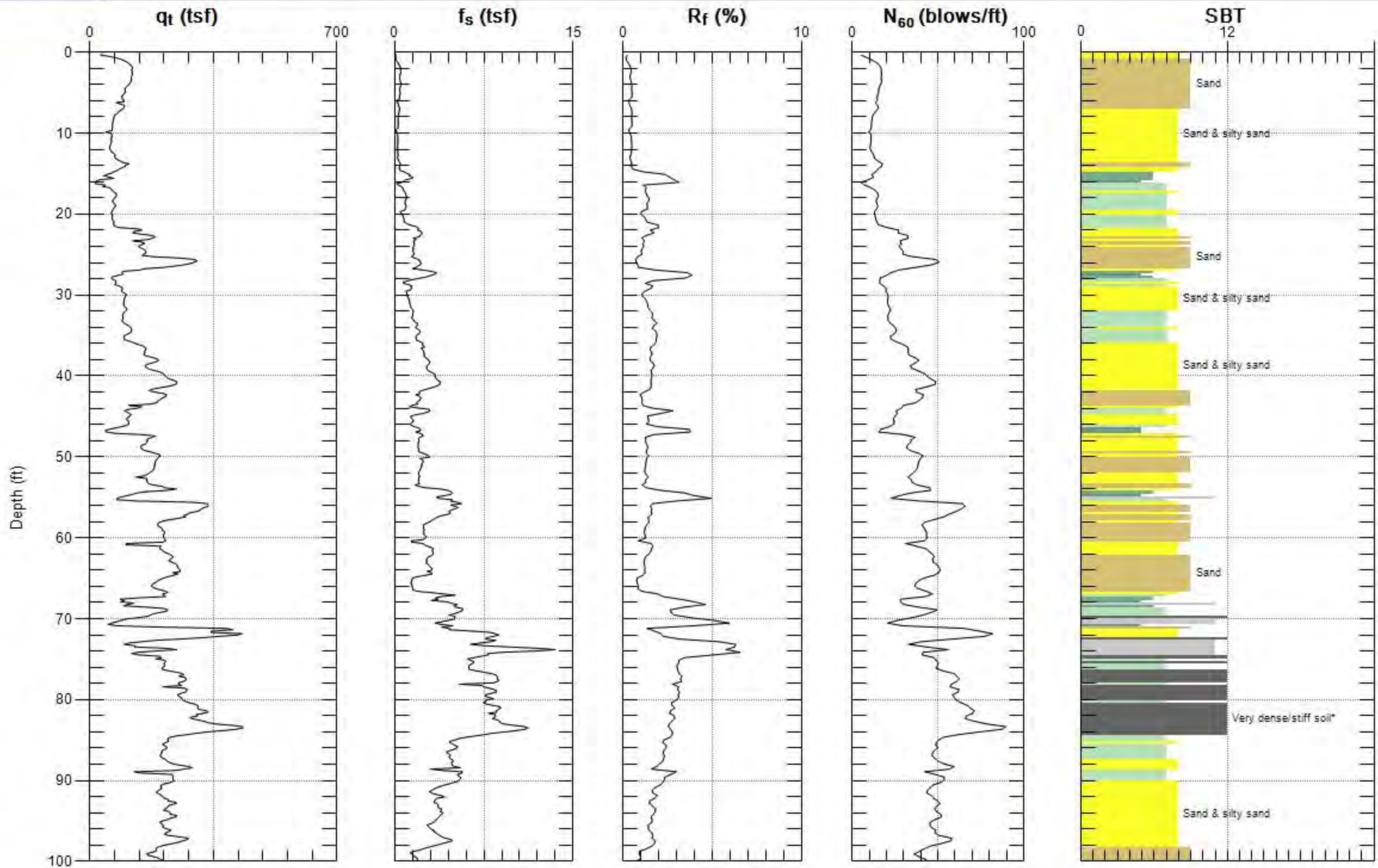
Max. Depth: 100.722 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



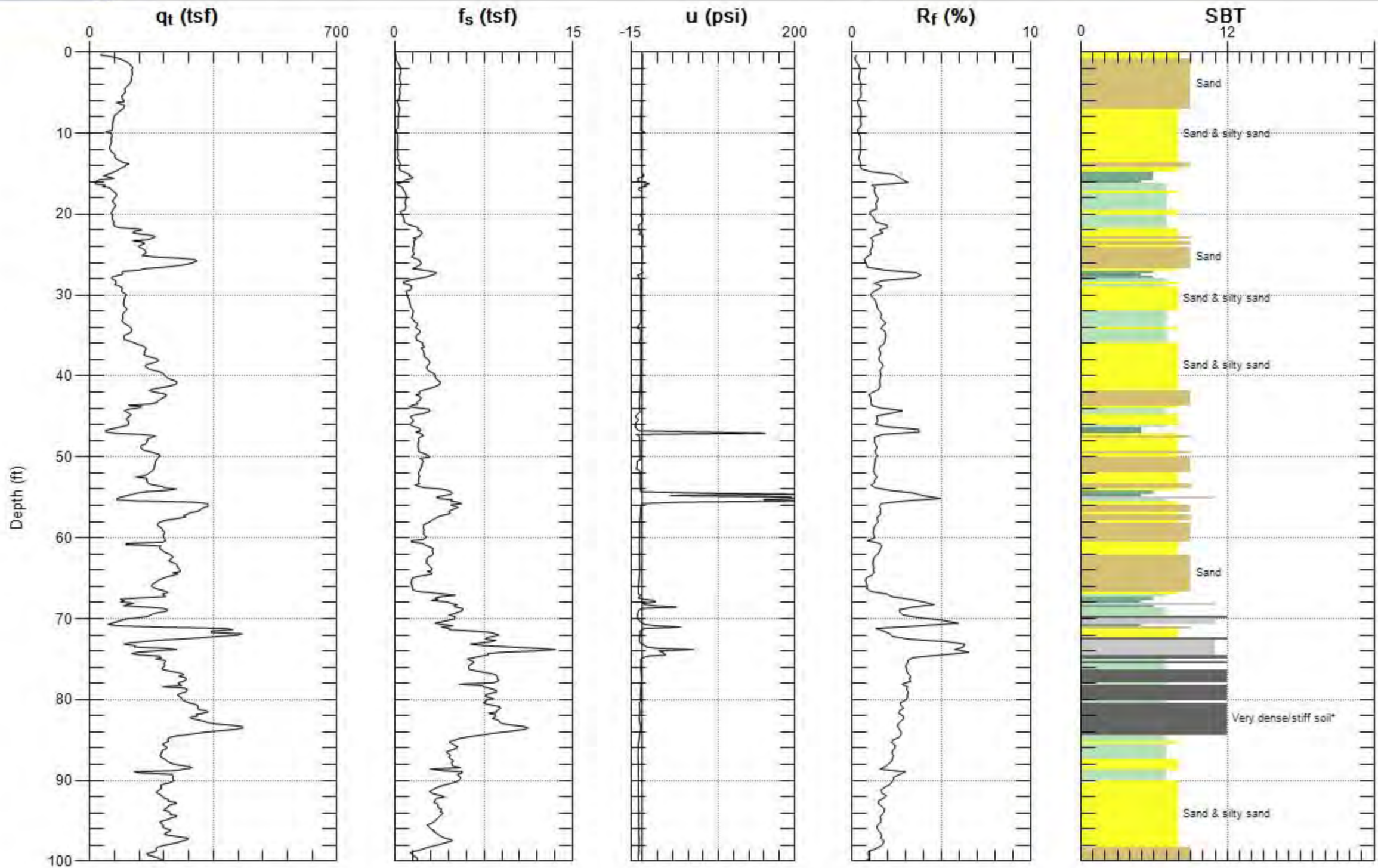
Max. Depth: 100.722 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



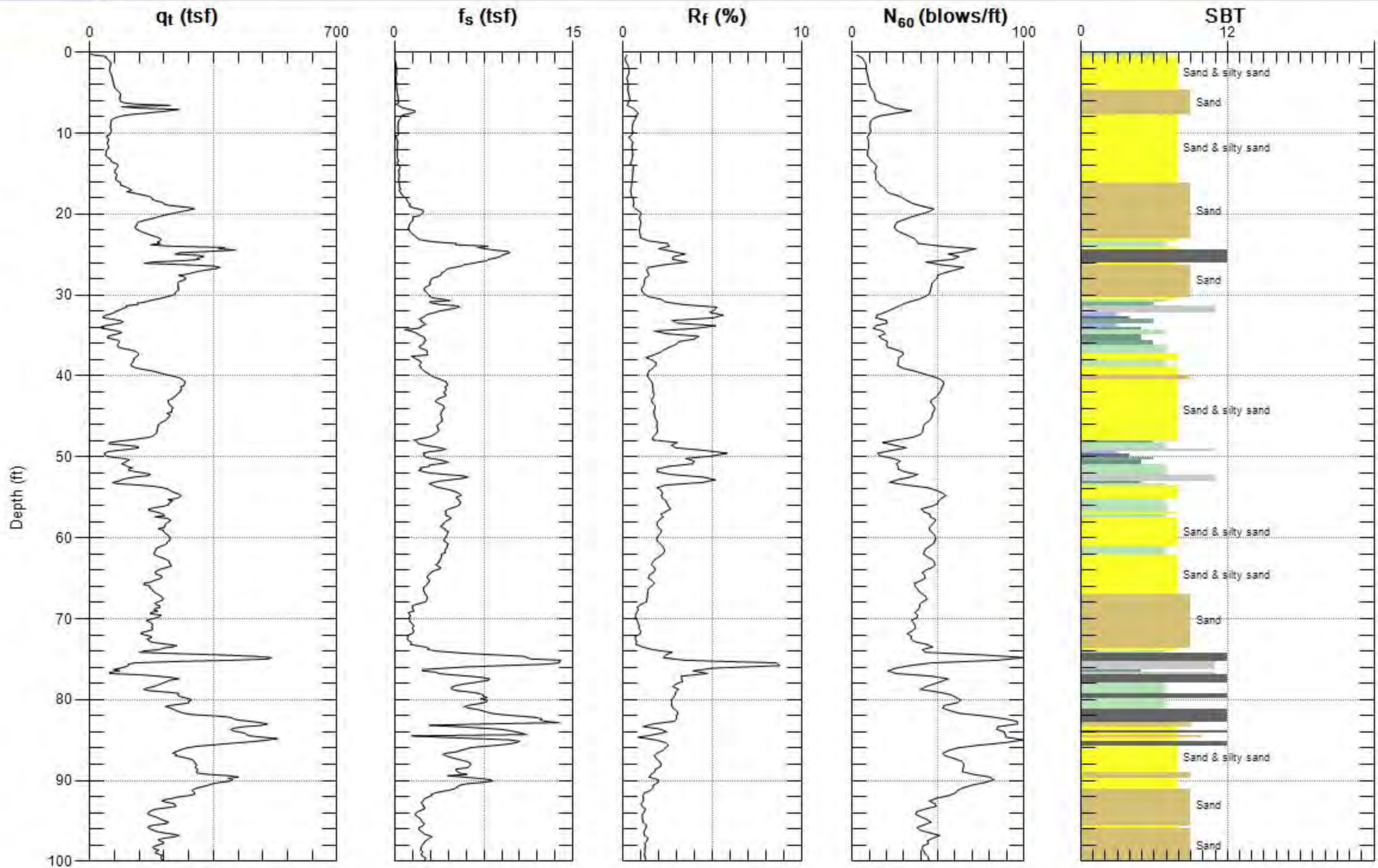
Max. Depth: 100.394 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



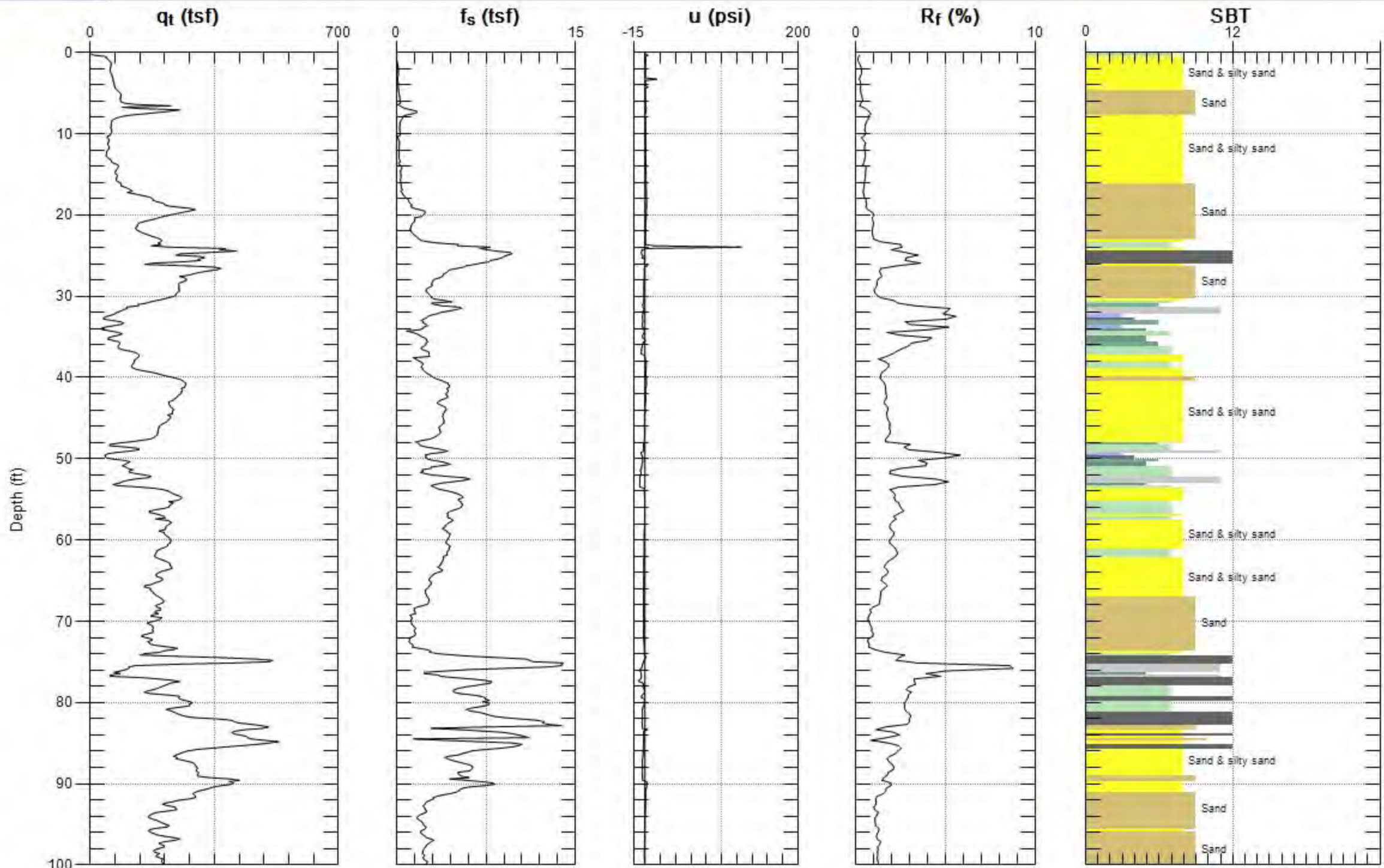
Max. Depth: 100.394 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



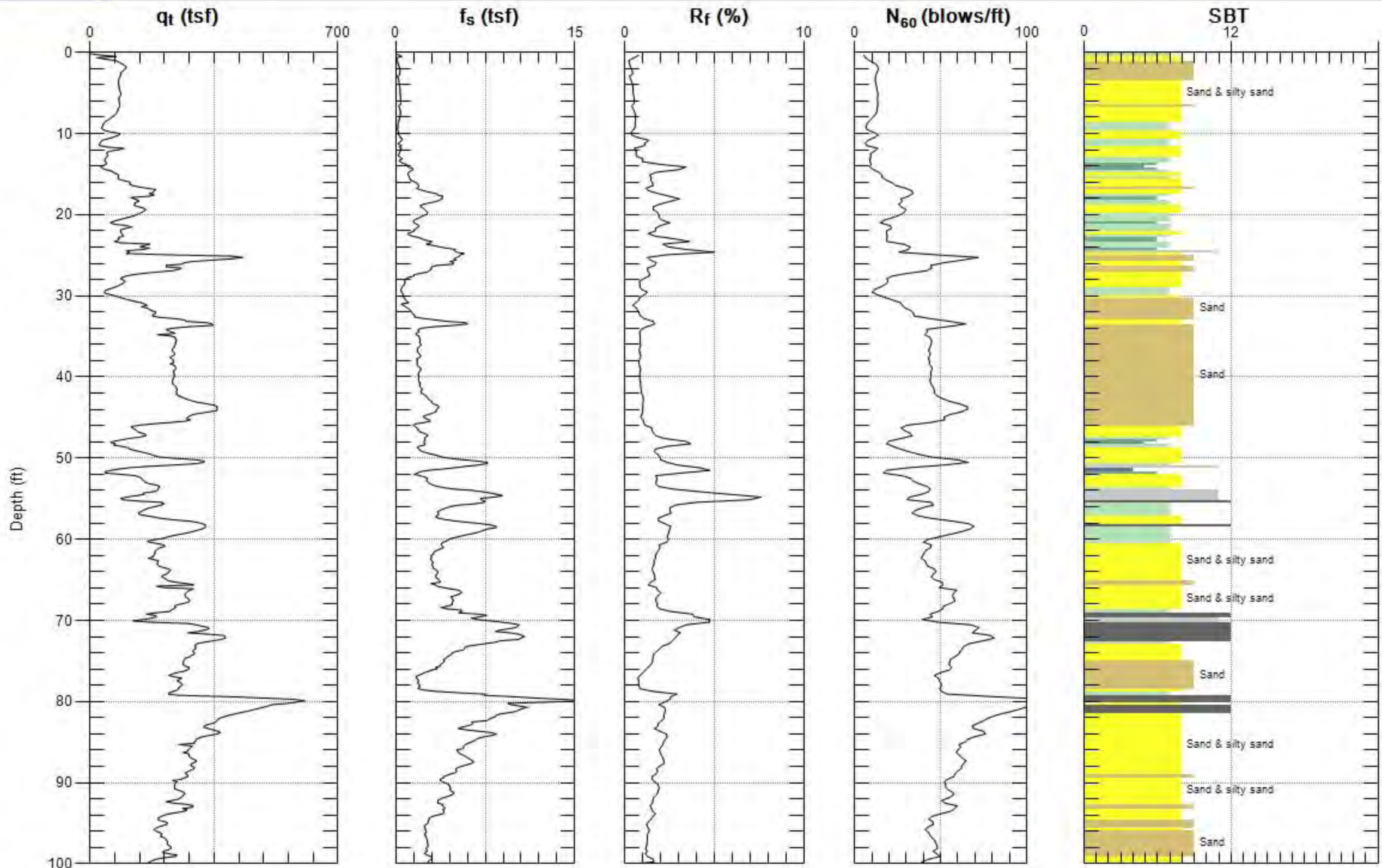
Max. Depth: 100.558 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



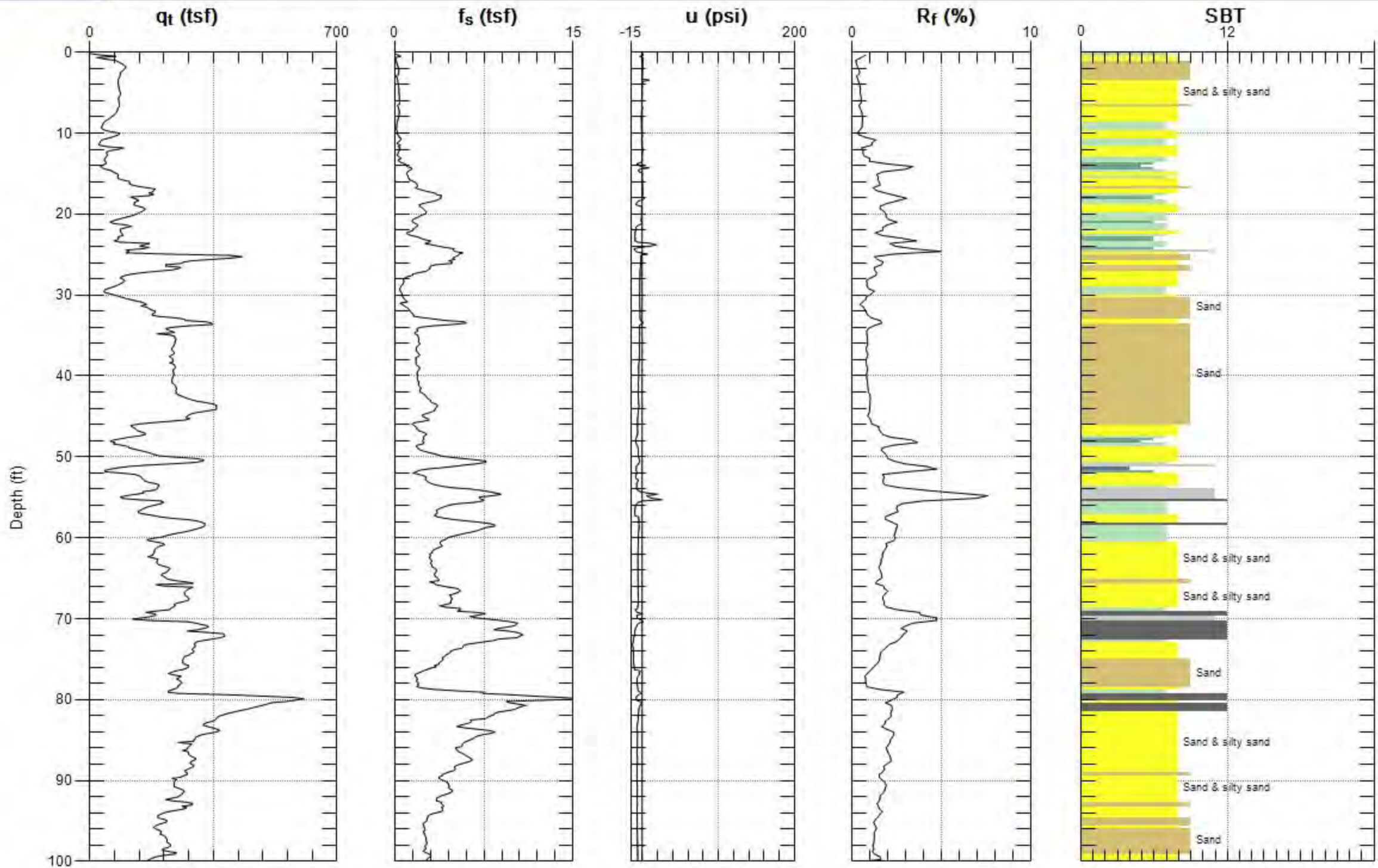
Max. Depth: 100.558 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



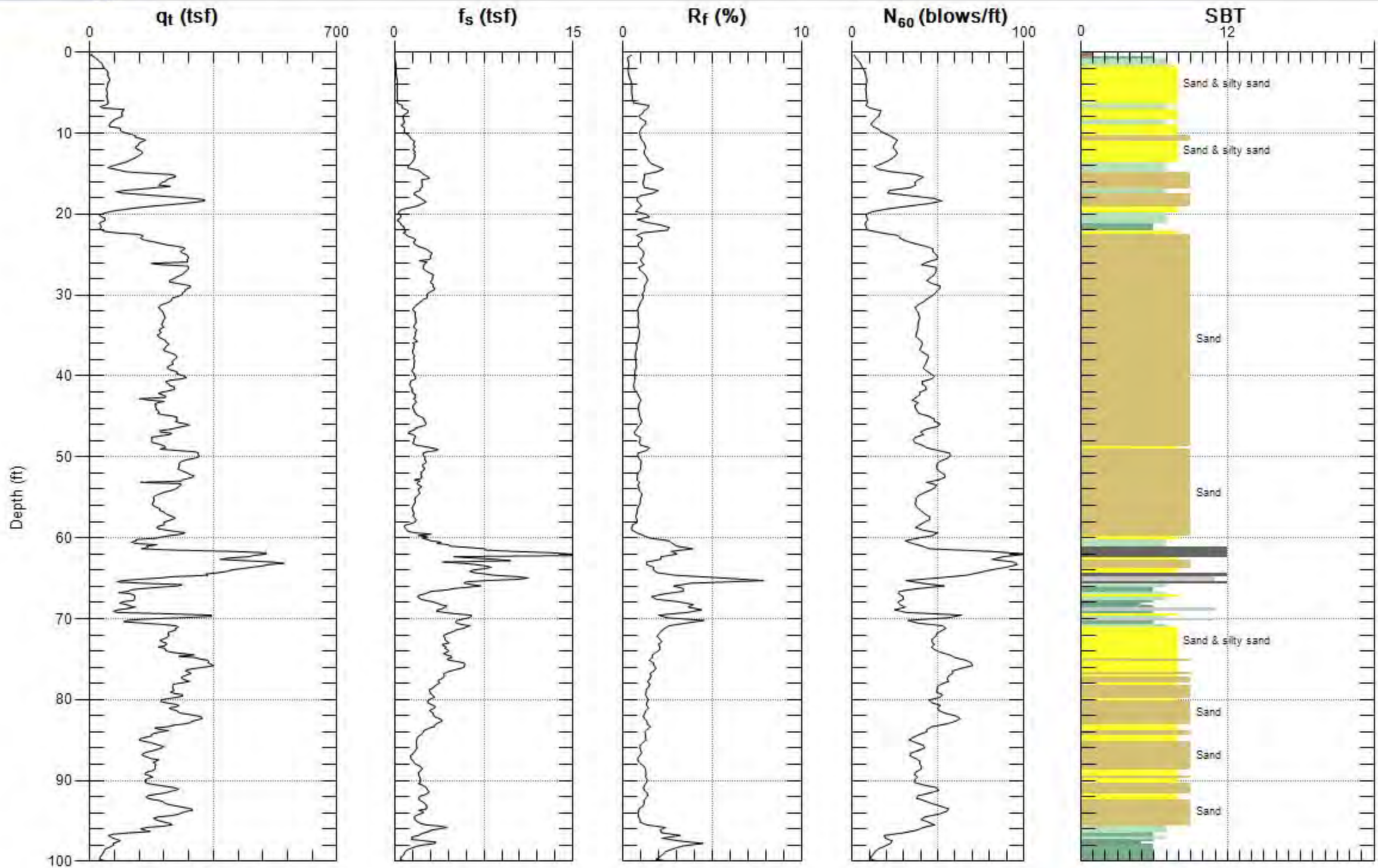
Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)



Max. Depth: 100.558 (ft)
Avg. Interval: 0.328 (ft)

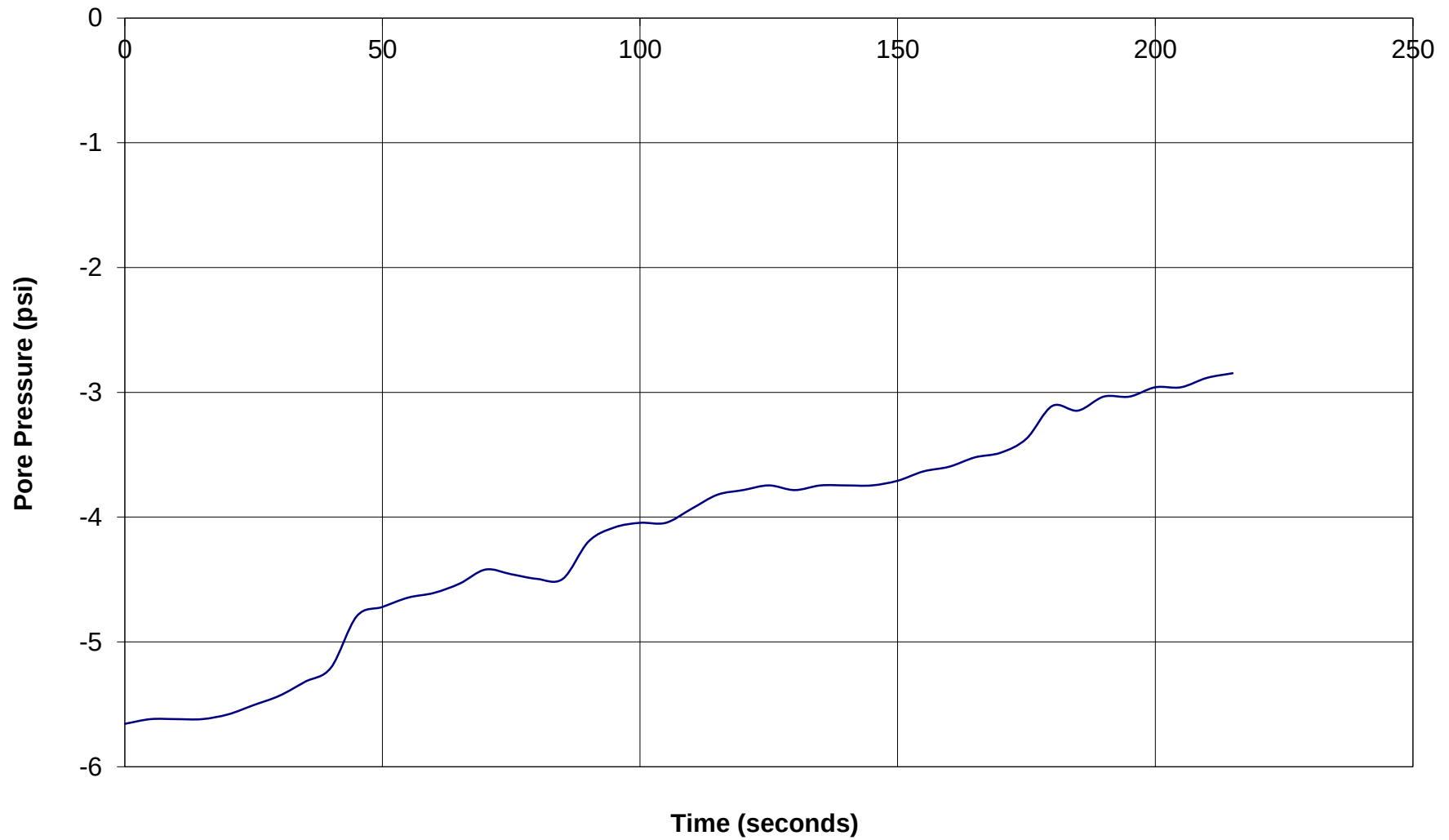
SBT: Soil Behavior Type (Robertson 1990)



GREGG DRILLING & TESTING

Pore Pressure Dissipation Test

Sounding: 2-CPT4
Depth: 41.338458
Site: MARKS POND AREA
Engineer: J.BLANKE

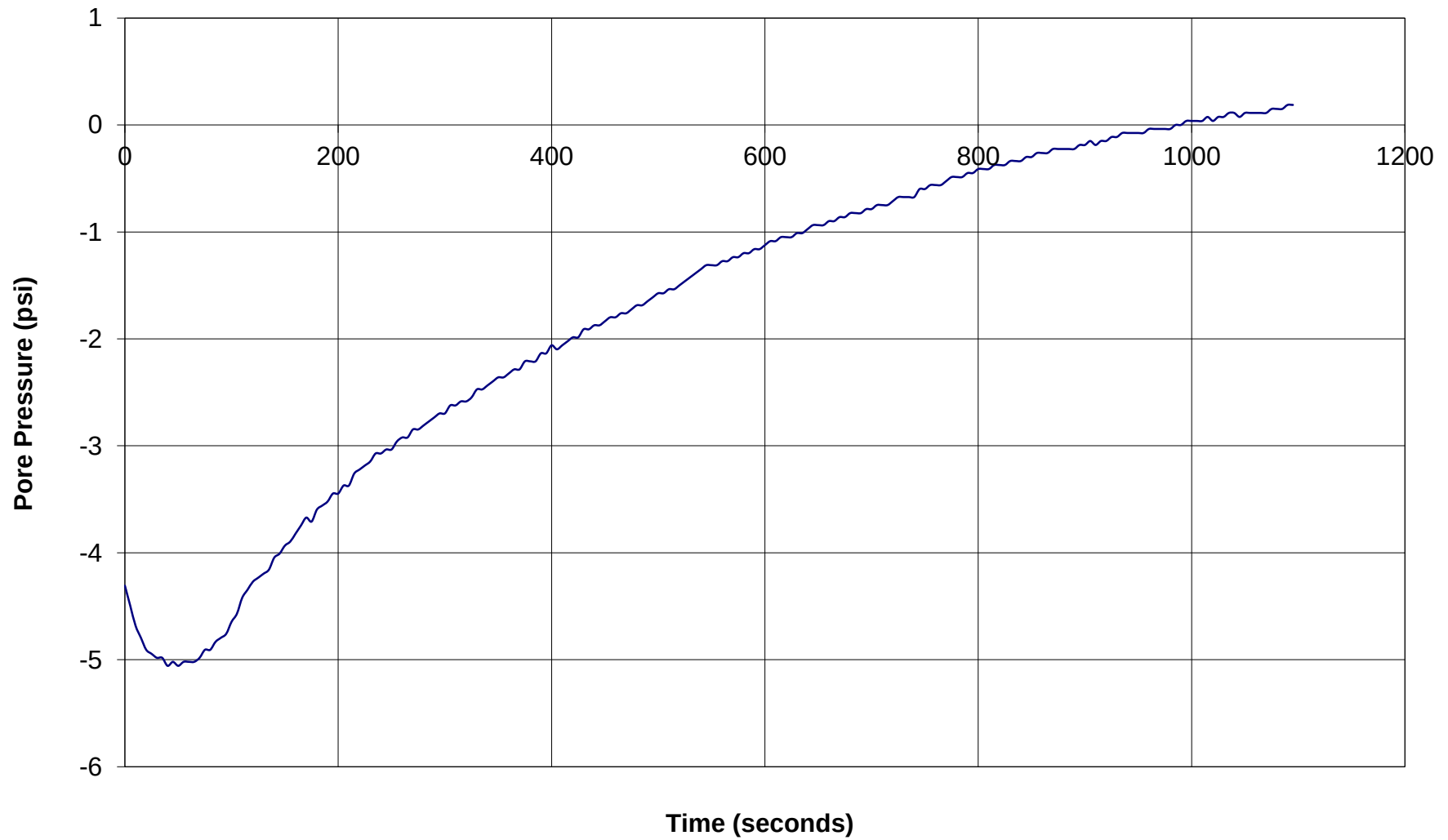




GREGG DRILLING & TESTING

Pore Pressure Dissipation Test

Sounding: 3-CPT1
Depth: 54.9539025
Site: MARKS POND AREA
Engineer: J.BLANKE

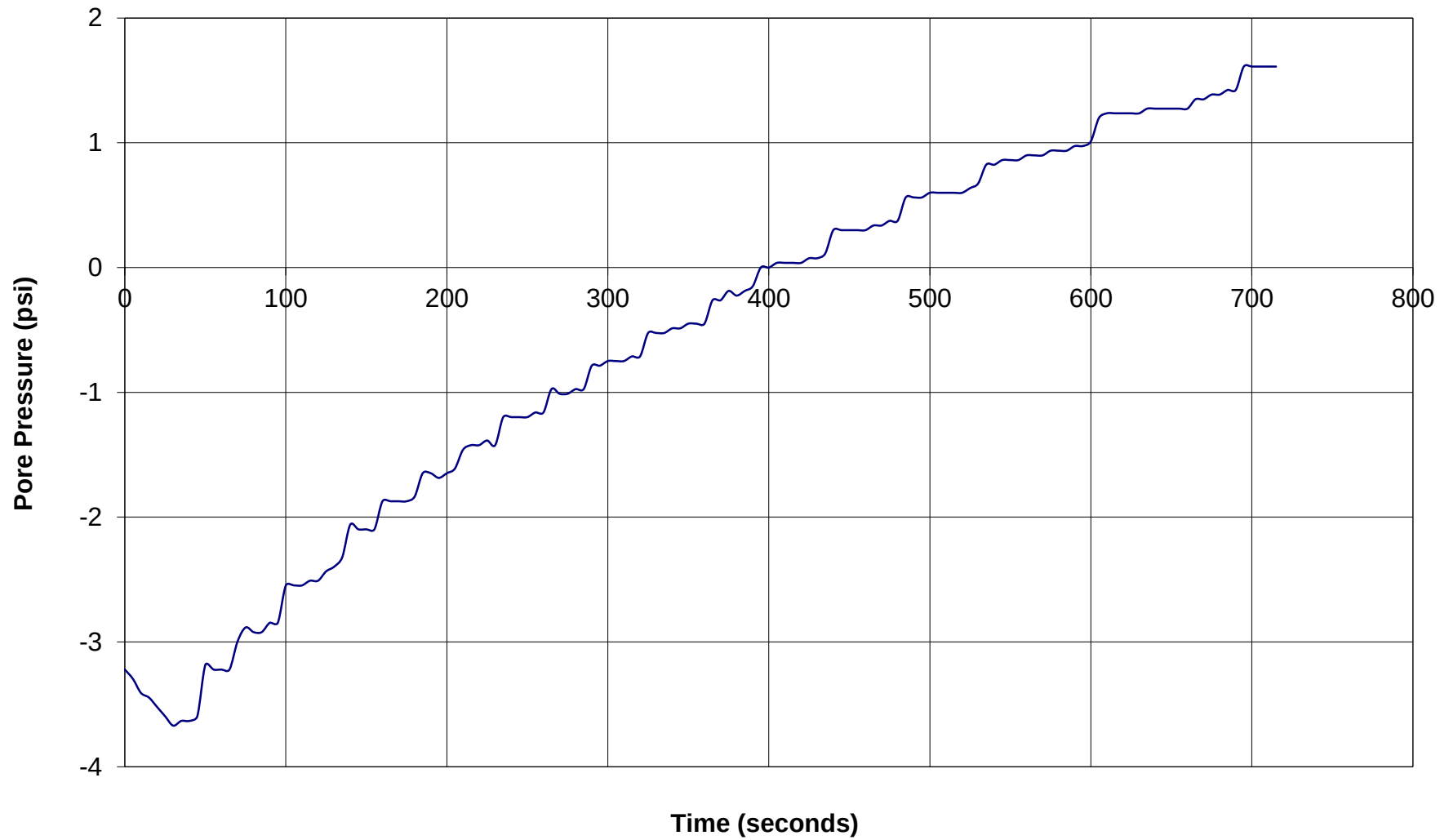




GREGG DRILLING & TESTING

Pore Pressure Dissipation Test

Sounding: 4-CPT3
Depth: 89.566659
Site: MARKS POND AREA
Engineer: J.BLANKE





GREGG DRILLING & TESTING

Pore Pressure Dissipation Test

Sounding: 4-CPT4
Depth: 76.2792975
Site: MARKS POND AREA
Engineer: J.BLANKE

