US Army Corps
of Engineers

Los Angeles District

El Rio Antiguo environmental restoration study, Tucson, AZ
Feasibility F-3 level Geotechnical Appendix *("without project conditions")*

("El Rio Antiguo" refers to drainage known as *el Rillito*, also called Rillito Creek or Rillito River)

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Background and purpose. *El Rillito* (Spanish for "the little river") is a tributary to the Santa Cruz River, Tucson, Arizona's main drainage channel, and has been referred to variously as a "creek" and as a "river" in past reporting. The segment currently under study has been tentatively labeled *el Rio Antiguo* ("the old river"). Because there are only 11 annual inches of rainfall, *el Rillito* is normally dry (USACE, 1986, p. 12). The part of *el Rillito* that is currently under study (figs. 1, 2) is that between the N. Craycroft Road crossing in the east and the N. Campbell Ave. crossing in the west, a distance of about 4 miles. *El Rillito* flows another approximately 8 mi westward from the N. Campbell Ave. crossing to the point where it joins the Santa Cruz River (fig. 1). The purpose of the current study, a joint venture between the Pima County Dept. of Transportation and Flood Control District (*hereafter*, "PDTFCD") and the US Army Corps of Engineers, is environmental restoration along *el Rillito* channel and banks and in certain specific areas away from the banks but contiguous with them (see fig. 2).

The environmental restoration zone includes land between E. River Rd. and the north bank of *el Rillito*, which is the wide alluvial fan terminus of Finger Rock Wash (see fig. 2). This zone may be one of the more technically challenging parts of the study (see Collins/Pina and others, 2000, for some of the concepts being considered here and in the rest of the study area). Ultimately, some flood control elements may be added there or at other places, but for the time being the study focus is on: 1) development of suitable plant communities that will support overall environmental restoration goals (hold water, cool and clean water, encourage wildlife and native plant life) and, 2) the necessary irrigation to establish and maintain those communities. Irrigation will be a key technical issue because *el Rillito* is ephemeral (Hoffman and Ripich, in press) and water for any environmental restoration that ultimately may occur will have to be artificially supplied for the most part. The local water table generally may be too deep for the system to be self-maintaining for many sought-after plant species. Therefore, selection of the water source and assuring both adequate supply and quality of that source will be of major focus. In that regard, this geotechnical appendix, which is intended to support the environmental restoration effort as specific designs evolve, is focused on: 1) near-surface alluvium and its geohydrology; as well as; 2) near surface soil stability conditions and their potential to remain stable or destabilize under irrigation; and 3) potential near-surface contamination and its potential to mobilize under irrigation or impact cultivated plant species. Should structural elements be added to the design as this study progresses, further documentation of deeper geologic conditions may be added to this geotechnical appendix, as needed.

A site characterization follows.

Regional setting. *El Rillito* flows 12.2 river miles, east-to-west (fig. 2) beginning with the junction of flows from Tanque Verde Wash and Pantano Wash, just east of the N. Craycroft Rd. crossing. Sabino Creek, Bear Creek, and Agua Caliente Wash are other significant tributaries to *el Rillito* flow; all join Tanque Verde Wash east of the study area. With the inclusion of Cienega Creek, which combines flow south and east of Tucson with Aqua Verde Creek to form Pantano Wash, *el Rillito* watershed is a total of 934 sq mi (USACE, 1986, p. 14) (see fig. 1). Numerous tributaries from the south slope of the Santa Catalina Mountains also contribute flow directly into

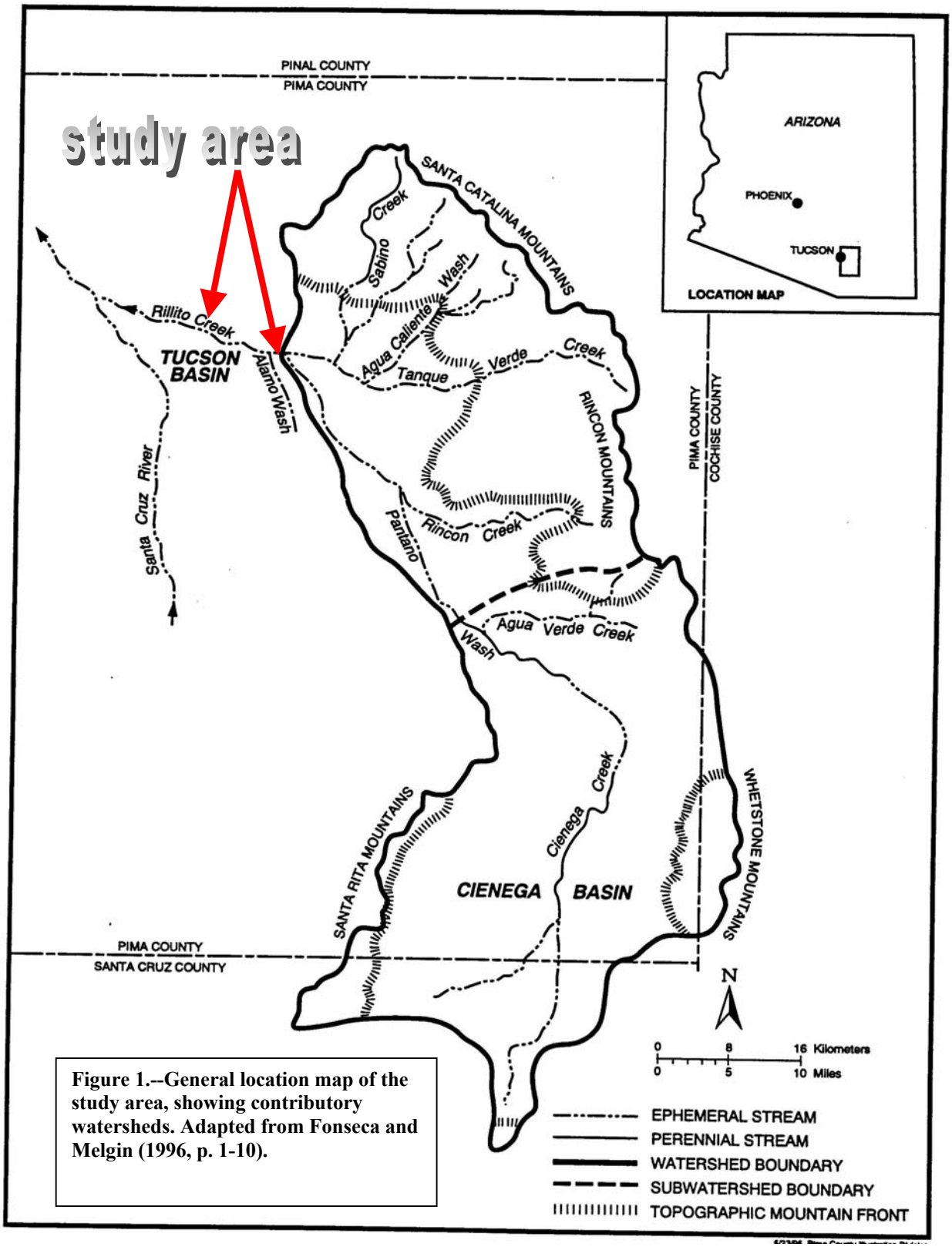

Figure 1.--General location map of the study area, showing contributory watersheds. Adapted from Fonseca and Melgin (1996, p. 1-10).

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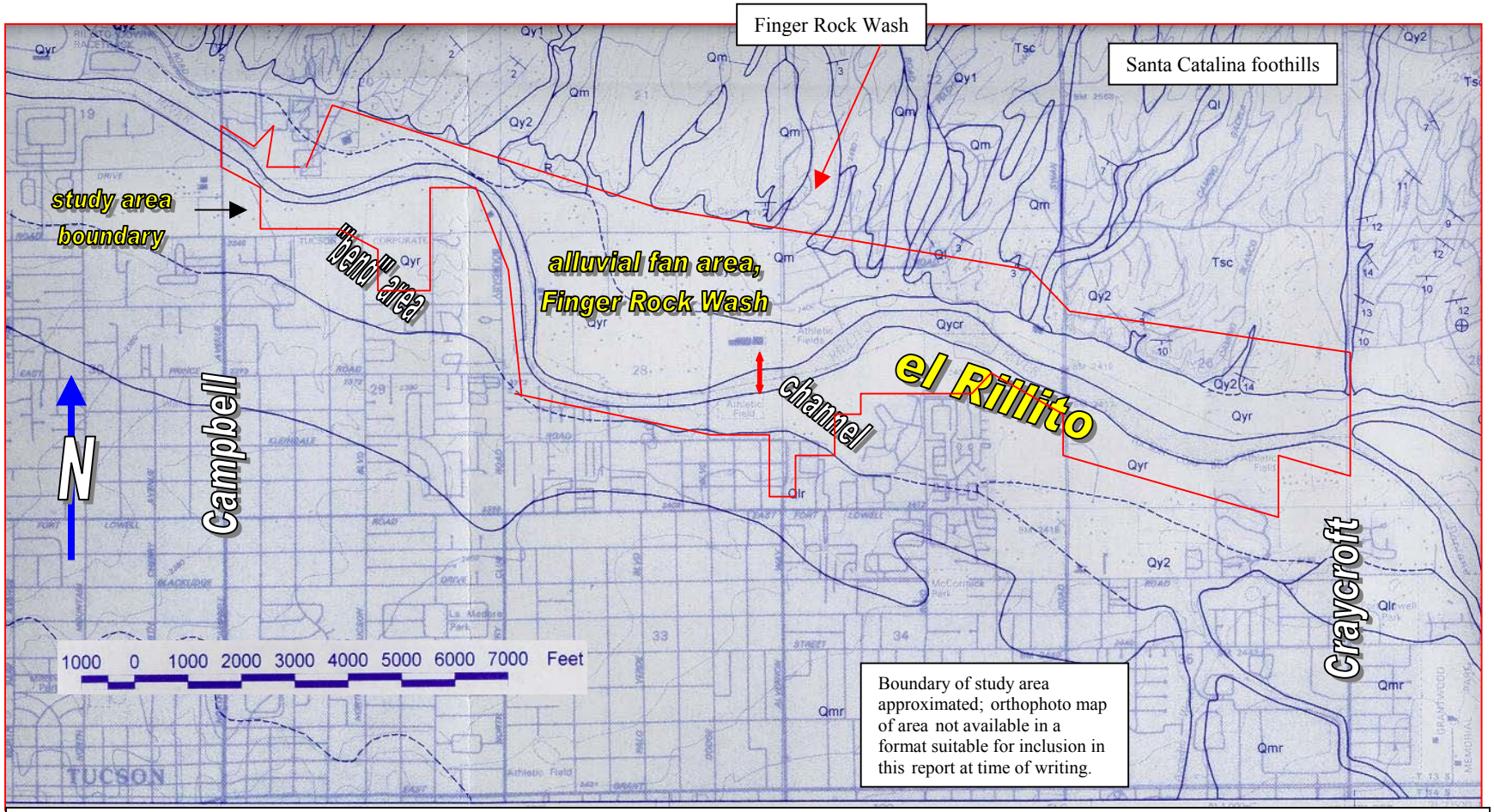

Figure 2.--Detail map of the study area (see red line). Base adapted from Klawon and others (1999, sheet 1). Upstream limit of study area is Craycroft crossing; downstream limit is Campbell crossing. Flow is from right to left. Lettered polygon shapes represent geologic units. See fig. 8 for details concerning geology.

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el Rillito within the study area boundary, including Finger Rock Wash (see fig. 2), which itself has been the subject of a flood-control study (USACE, 1996).

The study area is on a Basin-and-Range valley floor called the Tucson Basin, with surface elevations of about 2,000 to 3,000 ft, and drainage to the northwest. The Tucson Basin, a north-northwest-trending structural depression, is filled with 20,000 ft or more of Cenozoic-era deposits topped by a maximum of about 100 ft of Late Quaternary alluvial deposits, with the maximum thicknesses of alluvium along drainage channels. The alluvium is composed of sands, gravels, cobbles, silts, and clays. Cementation of these alluvial deposits with calcium-carbonate cement (*caliche*) is known to occur in places in the near surface. (*See* PDTFCD, 1991, p. A2-8, and Anderson, 1987.) This type of cementation is a common phenomenon in hot-climate desert environments.

Bounding mountain ranges of Tucson basin are the Santa Catalina's, the Rincon Mountains, and Tanque Verde Mountains (north, northeast, and east), Santa Rita Mountains (south), and the Tucson and Sierrita Mountains (west and northwest) (PDTFCD, 1991, p. A2-7). Those ranges were impacted by crustal extension and subsequent normal faulting between 30 and 6 Ma[1] (Pearthree and Biggs, 1999). Rocks within these mountain ranges are Precambrian-age metamorphic rocks, with a generally granitic composition, Tertiary volcanic rocks, and lesser amounts of Paleozoic-age limestones and sandstones (USACE, 1986, p. 9). These rocks, with few exceptions, are deeply buried in the Tucson Basin, although a few bedrock inselbergs are known (Pearthree and Biggs, 1999, p. 10). But bedrock is not anticipated to be a factor in any way with regard to this study due to general depth of burial beneath unconsolidated to weakly consolidated, younger sediments. The nearest geologic formations classed as bedrock are those of the Pantano Formation, which are north of the study area in the foothills of the Santa Catalina Mountains (Fonseca and Melgin, 1996, p. 1-9).

Geomorphology, historical and current. It has been postulated that the mountain foothills around the Tucson Basin were a planar and un-dissected piedmont landform in late Pliocene[2] to early Quaternary times, gradually sloping downward to the elevation of the ancestral Santa Cruz drainage system, and that over the past 2 million years a general and long-term river downcutting cycle dissected this geomorphic landform to expose Tertiary-age sediments (Pearthree and Biggs, 1999, p. 10). Those sediments had previously accumulated as "valley fill" via erosion of the adjoining mountains (USACE, 1986, p. 9). As existing alluvial fans were cut into by the new cycle of erosion, foothill streams also began to downcut in response to change in base level. This downcutting included flows of *el Rillito* (Pearthree and Biggs, 1999, p. 10).

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[1] "Ma" = "million years before present".

[2] The geologic time scale:

Quaternary Period	Holocene epoch (last 10,000 years)
	Pleistocene epoch (2 Ma to 10,000 years before present)
Tertiary Period	Pliocene epoch (5 Ma to 2 Ma)
	Miocene epoch (23 Ma to 5 Ma)
	Oligocene epoch (38 Ma to 23 Ma)
	Eocene epoch (54 Ma to 38 Ma)
	Paleocene epoch (65 Ma to 54 Ma)

Superimposed on this long-term down cutting trend were periods of aggrading[3] in the drainage systems, again including *el Rillito*. Reasons are not known but the theory for this change to an aggrading environment has been advanced: global climate changes away from glacial periods and into interglacials altered local environments to make them warmer, dryer, and with less water in streams, and with different vegetation. The last cycle of change in this regard has been identified as occurring between the last 8,000 and 15,000 years, and there may be evidence of many such interglacials in the past 2 million years (the period of geomorphic alteration currently under discussion). With these changes, thunderstorm activity would have increased and vegetation would have decreased, making much more sediment available for removal from hillsides (Pearthree and Biggs, 1999, pp. 11-12). It has been suggested that this climate change was the mechanism setting off much of the increased erosion known to have occurred in southern and western Arizona (Bull, 1991).

Channel morphology. The channel of *el Rillito* averages 250 feet in width and 4 to 7 feet in depth, but flooding and simultaneous lateral erosion and downcutting have increased widths to as much as 600 ft in places. In historical times, there has been change in the channel morphology of *el Rillito*, as documented in Pearthree and Baker (1987, p. 9 and pl.): in 1858, *el Rillito* was a continuously vegetated cienega environment with grasses, cottonwood, ash, willow; beaver dams were present. The floodplain supported grasses, mesquite, four-wing salt bush, wolfberry. As early as 1872 environmental damage was being done to this environment via overgrazing (Smith, 1910). By the 1890's anthropogenic change had substantially altered the channel morphology: it was by that time a wide channel with vertical banks (i.e., an *entrenched* channel system (Klawon and others, 1999, p. 7)), formed in response to cattle overgrazing, destruction of flood-plain grasses, concentration of surface flows into rills and channels, and newly enhanced impact of summer flood flows on this newly erosion-susceptible surface.

The changes in more recent times have been documented more thoroughly, as more data sources are available. It is clear that lateral migration of *el Rillito* channel is a major channel morphology element. Pearthree and Baker (1987, p. 44, pl.) discuss a significant role of bank composition in resisting this lateral channel movement via resisting erosion: the contrast is between *el Rillito* banks composed dominantly of sand and banks composed dominantly of silt and clay. Those of silt and clay, with their relatively higher cohesive bonds require higher water velocities to erode them, so, under identical conditions, the silt-clay banks will resist erosion, while the sand banks will give way and go into suspension. The result is lateral migration of the stream channel, and this migration can be serious, opening zones for flood breakout of flows from the channel confines that may otherwise have been protected. The range of lateral migration within the study area was documented by Pearthree and Baker (1987, pl.); see fig. 3.

El Rillito channel has straightened in numerous segments (USACE, 1986, p. 14), a result of flood-induced lateral erosion (Pearthree and Baker, 1987, p. 25). Straighter channels mean higher flow velocities. Higher flow velocities can result in downcutting of stream channels, which can be very serious, setting off wide-ranging cycles of erosion on tributaries and damage to infrastructure and environment, including draining of local aquifers and destruction of ecosystems. Another possible, yet much less well documented impetus to downcutting of *el o*

[3] Sediment *accumulation*, as opposed to *downcutting*, which removes sediments from the drainage system.

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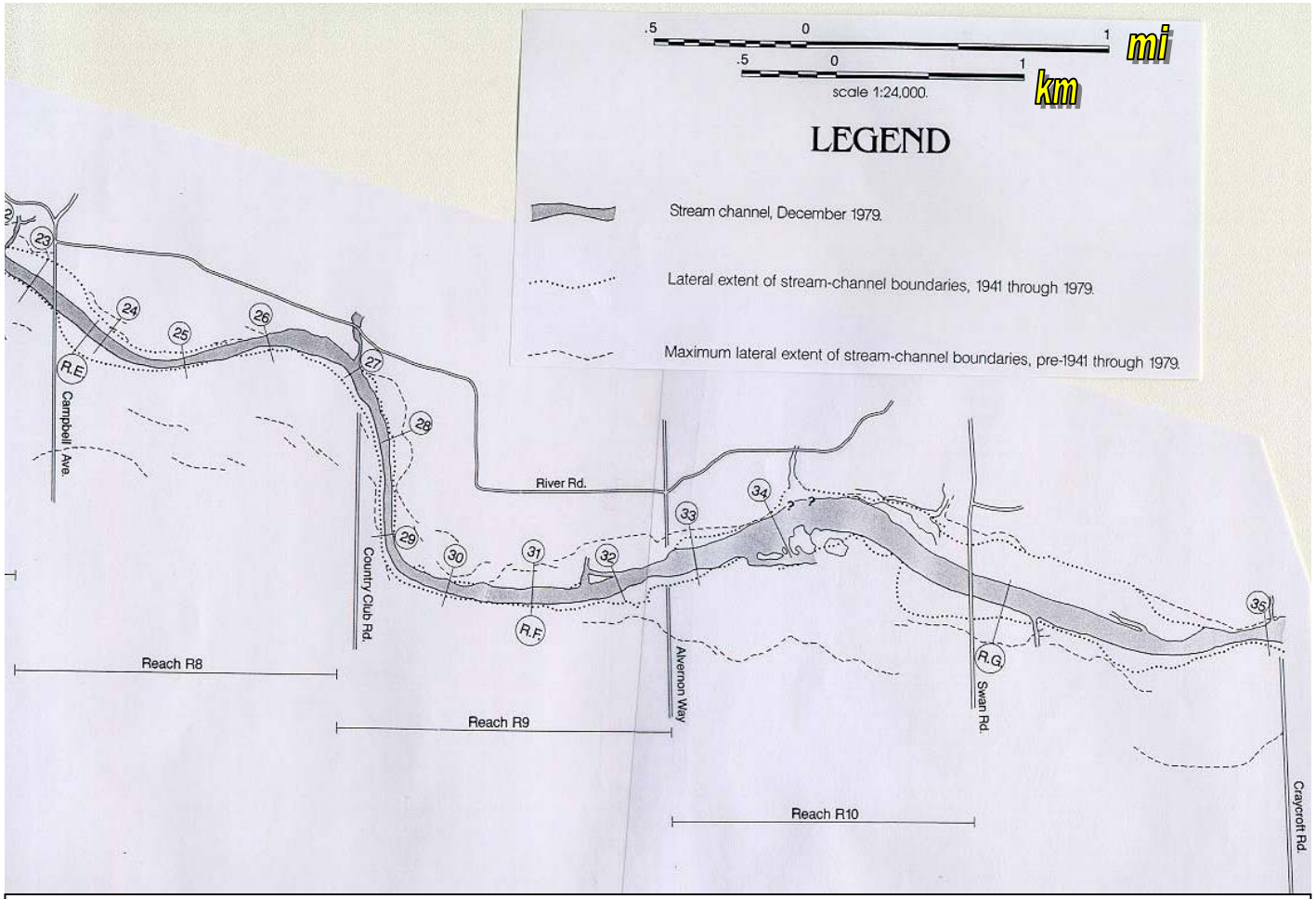

Figure 3.--Lateral migration of *el Rillito* channel, 1941 to 1983. Drawing scanned, with adaptations, from applicable part of Pearthree and Baker (1987, pl.); visible numbers, letters, and reach designations are not applicable to the current report. Study area extends between Craycroft and Campbell. For more detail on the map, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button.

Rillito channel is sand and gravel mining, which formerly took place in the channel, 300 to 800 ft downstream of Campbell Ave., the downstream extent of the current study area. The complete history of the operations was not researched for this paper. A study during the first half of 1973, while mining was in progress, noted degradation of *el Rillito* stream bed elevation on the average of 0.5 ft at the bridge piers at Campbell. Downcutting of a much more severe nature was noted in the vicinity of sand and gravel mining on Pantano Wash and Tanque Verde Creek (Pearthree and Baker, 1987, pp. 44-45), both parts of the *el Rillito* drainage system, but outside of and upstream of the current study area. It is notable that sand and gravel currently are being mined on the banks of *el Rillito*, inside the current study area, but *not* within the stream channel (fig. 4). Details of that operation were not obtained for this paper.

Flood-control improvements. The newest significant impact on channel morphology of *el Rillito* is soil-cement bank stabilization for flood-control purposes. As of 1984, soil-cement protection had been added to selected, discontinuous locations on both banks of *el Rillito*. This protection, designed to contain the 100-year-flood within *el Rillito* banks in all the study area except the "bend" and the "northwest" area, totaled 26,500 linear ft as of 1984 and was primarily the work of PDTFCD. Of that protection, 9,060 linear ft was within the study area, all confined to the "bend" area (USACE, 1986, figs. 5a, 5b). In the early-to-mid 1990's, more soil-cement erosion-control was added to *el Rillito* banks within the study area by PDTFCD and the US Army Corps of Engineers: between the N. Campbell Ave. crossing, eastward to Country Club Rd., a distance of about 1 mile, which was part of an overall 13.2 mi of planned soil-cement stabilization (PFCD, 1991, p. 5). This construction ultimately was designed to protect the incised, steep river banks from erosion, and to restore them to pre-1983 flood condition. The total of soil cement emplacement as of 2002 was not completely tabulated for this paper, but aerial photographs suggest that protection is near-continuous within the study area on both banks of *el Rillito*. A gap in the soil cement is known on the south bank (see fig. 4, which shows the western end of the soil cement protection). The length of that gap was not measured, but it is less than ½ mile long, as soil cement is again present at the Dodge Blvd. bridge. There may be other gaps.

Linear river park. A semi-continuous linear park with a variety of facilities (figs. 5, 6, 7) has been constructed in the study area along *el Rillito* banks. Linear-park improvements have been made for about 2-¾ mi farther to the west of this study area, starting at the N. Campbell Ave. crossing (Gousha, 1990).

Study area geology. The study area surface and near surface is composed Pleistocene- to Holocene-age river channel and floodplain deposits and terraces within *el Rillito* drainage channel and banks and on contiguous lands to the south (table 1 for details). But on *el Rillito's* north bank, only the youngest of the river channel, floodplain and terrace deposits are present. This is because *el Rillito* has been migrating northward, eroding what is north of it and depositing reworked sediment to the south. It is now at a position where it is or nearly is in juxtaposition with piedmont alluvium of the Santa Catalina foothills. Piedmont materials are of Pleistocene-, Pliocene-, and Miocene-ages (see fig. 8, geologic map). (*See* Klawon and others, 1999, sheet.) A geologic cross section reprinted in Fonseca and Melgin (1996, p. 1-18) is useful for visualizing the general subsurface structure within the study area (added to the current report as fig. 9). From the use of table 1 and fig. 8, it should be noted that that vast majority of the study area <u>near-subsurface</u> is underlain by only two geologic units, both of which are riverine

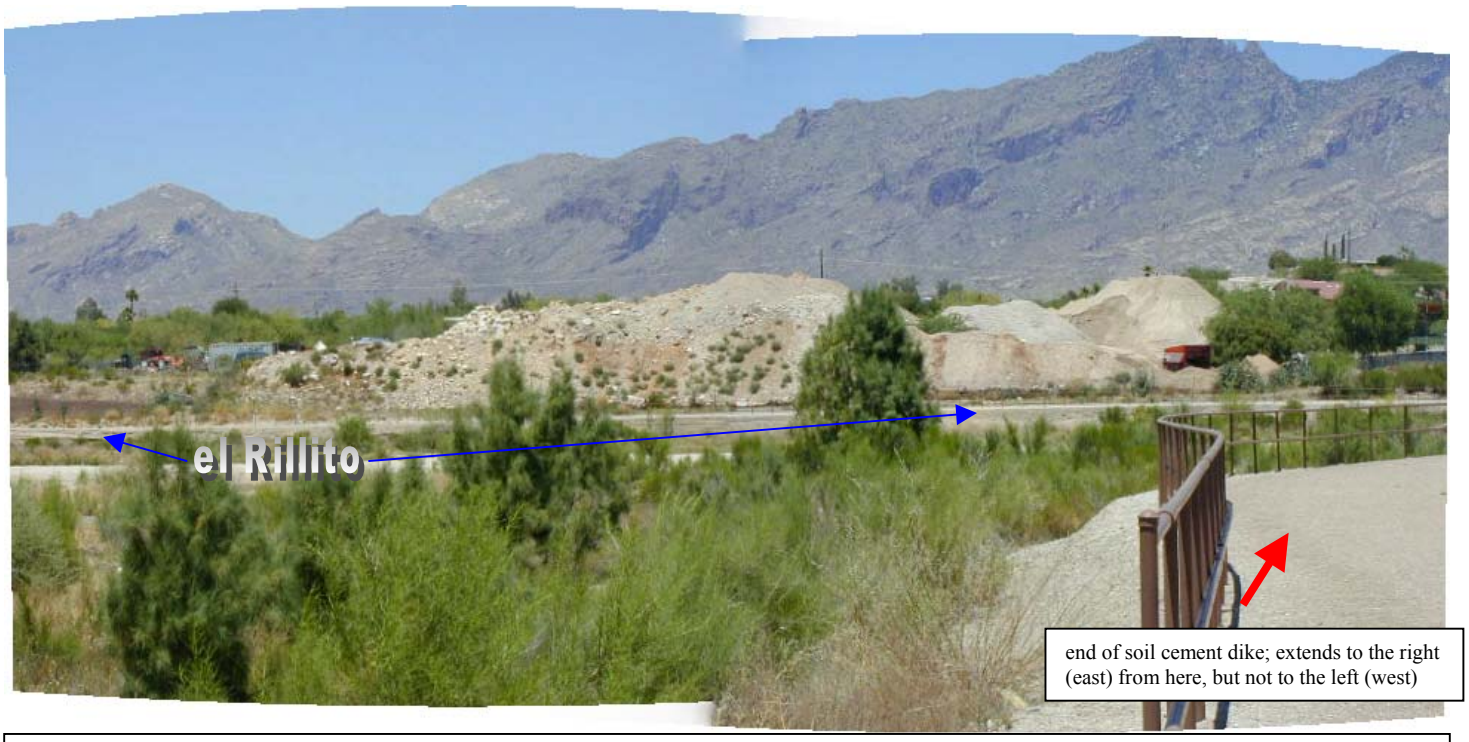

Figure 4.--Active sand and gravel mining operation adjoining the north bank of *el Rillito*. The operation is within the confines of the study area boundary. View is to the north. *El Rillito* flow is from right of frame to left. Photo by US Army Corps of Engineers, 16 May 2001. Details of the sand and gravel mining operation were not researched for this paper.

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Figure 5.--Soil cement protection on both banks of *el Rillito*, reportedly emplaced by US Army Corps of Engineers in 1996 and 1997, on 1:1 slopes and extending 15 ft below grade. Picture taken on the north bank of *el Rillito*, looking upstream. Note Hacienda del Sol pedestrian bridge, another of many improvements along the banks. This is near the northern extent of the "bend" area (see fig. 2), so this in-the-upstream-direction view of *el Rillito* actually is to the south, due to the bend. Photo by US Army Corps of Engineers, 16 May 2001.

Figure 6.---Other improvements along *el Rillito*, north bank, a short distance downstream of Swan Rd. Vehicles normally are not driven here except for maintenance; vehicles in view were on site for a large-group study team site visit. View is to the northwest. *El Rillito* is to the back of the photographer. Photo by US Army Corps of Engineers, 16 May 2001.

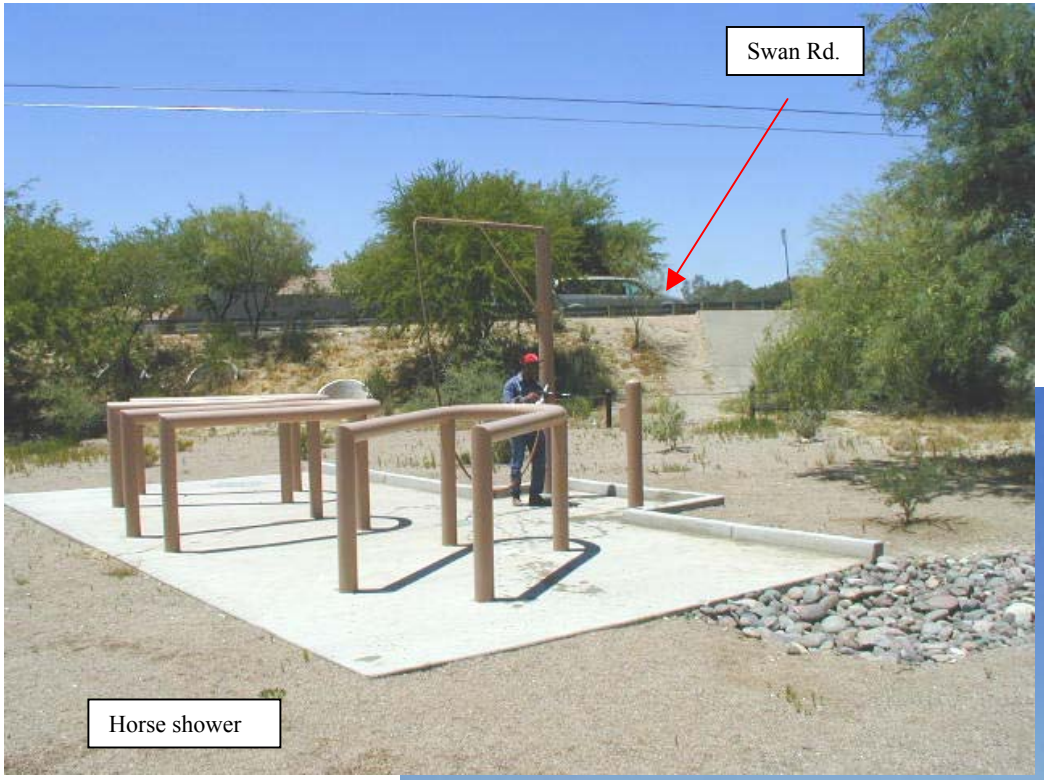

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Figure 7.--Other facilities along *el Rillito* include these on the south bank, immediately downstream of the Swan Rd. bridge: a shelter and picnic site (lower frame) and horse shower (upper frame). View of lower frame is northeast; upper frame is west-northwest. Photos by US Army Corps of Engineers, 16 May 2001.

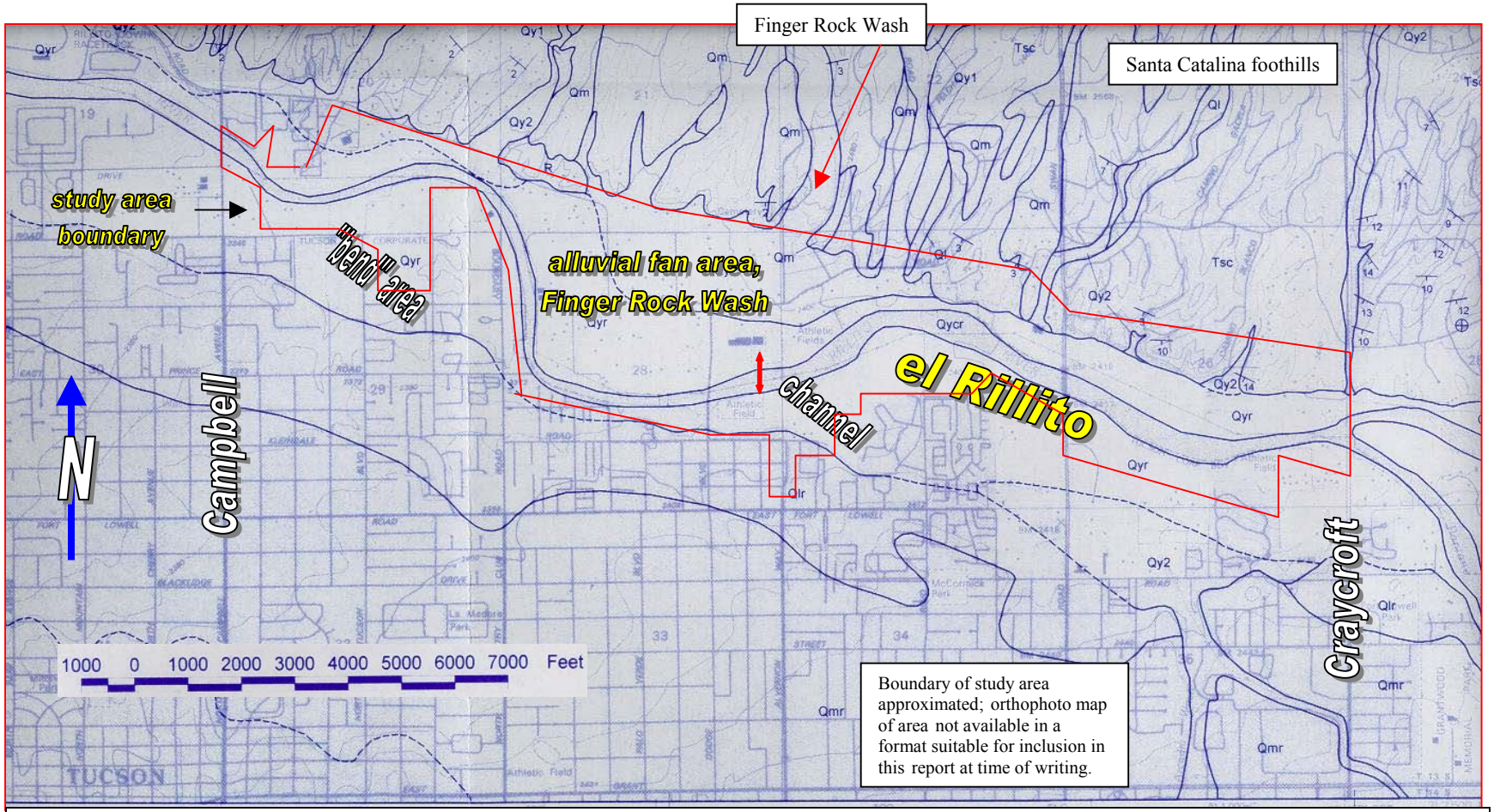

Figure 8.--Geologic map of the study area (red line) and vicinity, adapted from Klawon and others (1999, sheet 1). Lettered polygon shapes represent geologic units. See table1 for definitions of those geologic units. For more detail on the map, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button.

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***Table 1.--Geologic materials in El Rio Antiguo study area*.** **See fig. 8 for map of geologic units described below.**

Data from Klawon and others (1999, sheet, and pp. 4-9) unless noted otherwise. Abbreviations used: "ka" = "thousands of years before present; "Ma" = "millions of years before present"; "<" = "less than" amount specified.

Name (listed youngest on top, to oldest on bottom)	**Age/ Thickness in study area**	**Erosional cycle** *(from Hoffman & Ripich, in press unless noted)*	**Groundwater conditions**	**Materials description**	**Ecosystem characteristics** *(Note: local sponsor undertook soils mapping/sampling to determine these same characteristics in late Feb. 2002; those data not available for this report; info. below is from literature and May 2001 geotech field observations.)*
materials shallow enough to probably or possibly be a factor in this study:					
Qycr (from Klawon and others, 1999) stream channel deposits valley fill	< 100 years; not over 100 feet; PDTFCD staff indicates only 30-ft to Ft. Lowell Fm	active channel	not specified but probably usually dry	dominated by gravel and coarse sand (Davidson, 1973)	See photo, fig. 10; desert broom can dominate; generally sparsely vegetated due to low density and high porosity of materials; salt cedar (tamarisk) can be problematic
Qy2 (from Klawon and others, 1999) riverine or piedmont channel deposits, low terraces, alluvial fans from modern drainages valley fill	< 2 ka; thickness not specified	most recent cycle of erosion and deposition	not specified but probably usually dry	cobbles, sand, silt, and boulders on lower ground; on piedmont near mtns., sand, cobbles, with some boulders; according to (Davidson, 1973), piedmont area dominated by gravel and coarse sand	supports variable-density of vegetation; along larger washes can reportedly incl. mesquite, cottonwood, willow, sycamore, with smaller bushes and grass, which can both be very dense; smaller washed support palo verde, mesquite, large creosote, other bushes
Qyr (from Klawon and others, 1999) floodplain and terrace deposits north and south of the current active channel (apparently subdivided in Hoffman and Ripich (in press) into "floodplain and terrace deposits" and "floodplain terrace deposits") valley fill	< 10 ka; thickness not specified	most recent cycle of erosion and deposition; but some elements of multiple-stage arroyo cut-and-fill over past 5,000 yrs; was floodplain until last 100 yrs of arroyo development (Klawon and others, 1999, p. 7)	not specified but probably usually dry	weakly consolidated to unconsolidated sand, silt, and clay with gravel lenses in former channels; weak soil development	See photos, fig. 11, 12; generally sparsely vegetated due to low density and high porosity of materials; tamarisk can be problematic "highly susceptible to lateral erosion" (Klawon and others, 1999, p. 8)

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Qlr late Pleistocene river terraces, known as Jaynes terrace; cut-and-fill relationship with Cemetery terrace valley fill	10 ka to 130 ka; thickness not specified	deposit of 2nd cycle of erosion and redeposition of basin-fill materials	no information	gravel, sand, silt, clay reddened soils with weak argillic horizons, moderate calcic horizons	no data
Ql late Pleistocene alluvium; dissected terraces and alluvial fans valley fill	10 ka to 130 ka; thickness not specified	probably deposit of 2nd cycle of erosion and redeposition of basin-fill materials	no information	pebbles, cobbles, finer-grained sediment; surfaces have loose, open lags of pebbles, cobbles; soils light orange to slightly reddened moderately developed clay loam argillic horizons; stage II calcium carbonate development	supports dominantly creosote bursage, ocotillo; adjoins study area boundary to north
Qmr middle Pleistocene river terraces, known as Cemetery terrace valley fill	~130 ka to 500 ka; thickness not specified	deposit of 1st cycle of erosion and redeposition of basin-fill materials	no information	sand, silt, clay, gravel; reddened soils w/ clay-rich argillic horizons; variable calcic horizon development (often stage II or IV); can have strong soil development	outside of current study area boundary
Qm middle Pleistocene piedmont alluvium; incl. relict dissected alluvial fans, terraces	~130 ka to 500 ka; thickness not specified	no information	no information	pebble and cobble lags with dark orange to reddened clay argillic horizons and clay skins; stage III carbonate development but strong petrocalcic horizons are rare	support bursage, ocotillo, creoste, cholla, saguaro; adjoins study area boundary to north
Ft. Lowell Formation, 30 ft deep below a cover of unconsolidated of alluvium at Dodge Blvd. crossing (Leo Smith, PDTFCT, pers. commun. 16 May 2001)	Pleistocene age (Fonseca and Melgin, 1996, p. 1-17); 100-350 ft (Hoffman & Ripich, in press)	basin-fill	partly saturated; part of the main Tucson Basin aquifer where saturated (Davidson, 1973)	unconsolidated to poorly consolidated, interbedded gravel, sand, sandy silt, and clayey silt (Hoffman & Ripich, in press)	n/a

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Name (listed youngest on top, to oldest on bottom)	**Age/ Thickness in study area**	**Erosional cycle** *(from Hoffman & Ripich, in press unless noted)*	**Groundwater conditions**	**Materials description**	**Ecosystem characteristics** *(Note: local sponsor undertook soils mapping/sampling to determine these same characteristics in late Feb. 2002; those data not available for this report; info. below is from literature and May 2001 geotech field observations.)*
upper Tinaja beds (informal use as per Anderson, 1987)	Miocene and Pliocene age (Fonseca and Melgin, 1996, p. 1-17); 100-400 + ft (Hoffman & Ripich, in press)	basin-fill	saturated throughout; part of the main Tucson Basin aquifer (Davidson, 1973)	unconsolidated to poorly consolidated, clayey silt, sandy silt, sand and gravel (Hoffman & Ripich, in press)	n/a
QT early Pleistocene to Pliocene piedmont alluvium; relict heavily dissected alluvial fans	1 ka to 5 Ma thickness not specified	no information; probably valley fill(?)	no information	weakly to moderately indurated, but erosion resistant due to large gradation; gravel dominant, range of boulders to pebbles (gneissic clasts, usually), w/ minor lenses of reddish sand and silt; gray-to-white soils with pedogenic carbonate development (stage V) on ridgecrests; carbonate litter common	support mesquite, palo verde, ocotillo, creoste, cholla, saguaro; adjoins study area boundary to north
Tsc Miocene alluvium; dissected and tectonically deformed alluvial fans (deformed via late-phase uplift of Santa Catalinas); cut by minor faults	5 to 20 Ma; thickness not specified	no information; probably valley fill(?)	no information	moderately indurated, cobbly to bouldery gravel with finer sand deposits; clasts of gneiss and schist, usually	no plant data; adjoins study area boundary to north
materials too deep to be a factor in this study:					
middle Tinaja beds (informal use as per Anderson, 1987)	Miocene and Pliocene age (Fonseca and Melgin, 1996, p. 1-17); thickness not determined during research for this paper	basin-fill	not determined during research for this paper; probably saturated throughout	gypsiferous and anhydritic clayey silt and mudstone (Hoffman & Ripich, in press)	n/a
lower Tinaja beds (informal use as per Anderson, 1987)	Miocene and Pliocene age (Fonseca and Melgin, 1996, p. 1-17); thickness not determined during research for this paper	basin-fill	not determined during research for this paper; probably saturated throughout	silty gravel and conglomerate (Hoffman & Ripich, in press)	n/a

***Table 1.--Geologic materials in El Rio Antiguo study area*. See fig. 8 for map of geologic units described below.**

Data from Klawon and others (1999, sheet, and pp. 4-9) unless noted otherwise. Abbreviations used: "ka" = "thousands of years before present; "Ma" = "millions of years before present"; "<" = "less than" amount specified.

Name (listed youngest on top, to oldest on bottom)	**Age/ Thickness in study area**	**Erosional cycle** *(from Hoffman & Ripich, in press unless noted)*	**Groundwater conditions**	**Materials description**	**Ecosystem characteristics** *(Note: local sponsor undertook soils mapping/sampling to determine these same characteristics in late Feb. 2002; those data not available for this report; info. below is from literature and May 2001 geotech field observations.)*
Pantano Formation may be the unspecified bedrock ("R") shown along northern study area boundary, fig. 8	Eocene to Oligocene age (Fonseca and Melgin, 1996, p. 1-17); thickness not determined during research for this paper	basin-fill	not determined during research for this paper; probably saturated throughout except where exposed on the flanks of the Santa Catalina Mtns.	conglomerate, sandstone, mudstone, gypsiferous mudstone (Hoffman & Ripich, in press)	n/a
many older basin fill deposits	not tabulated for this paper	basin-fill	not determined during research for this paper; probably saturated throughout	not determined during research for this paper	n/a
bedrock complex	Precambrian to Paleozoic age	bedrock	n/a	n/a	

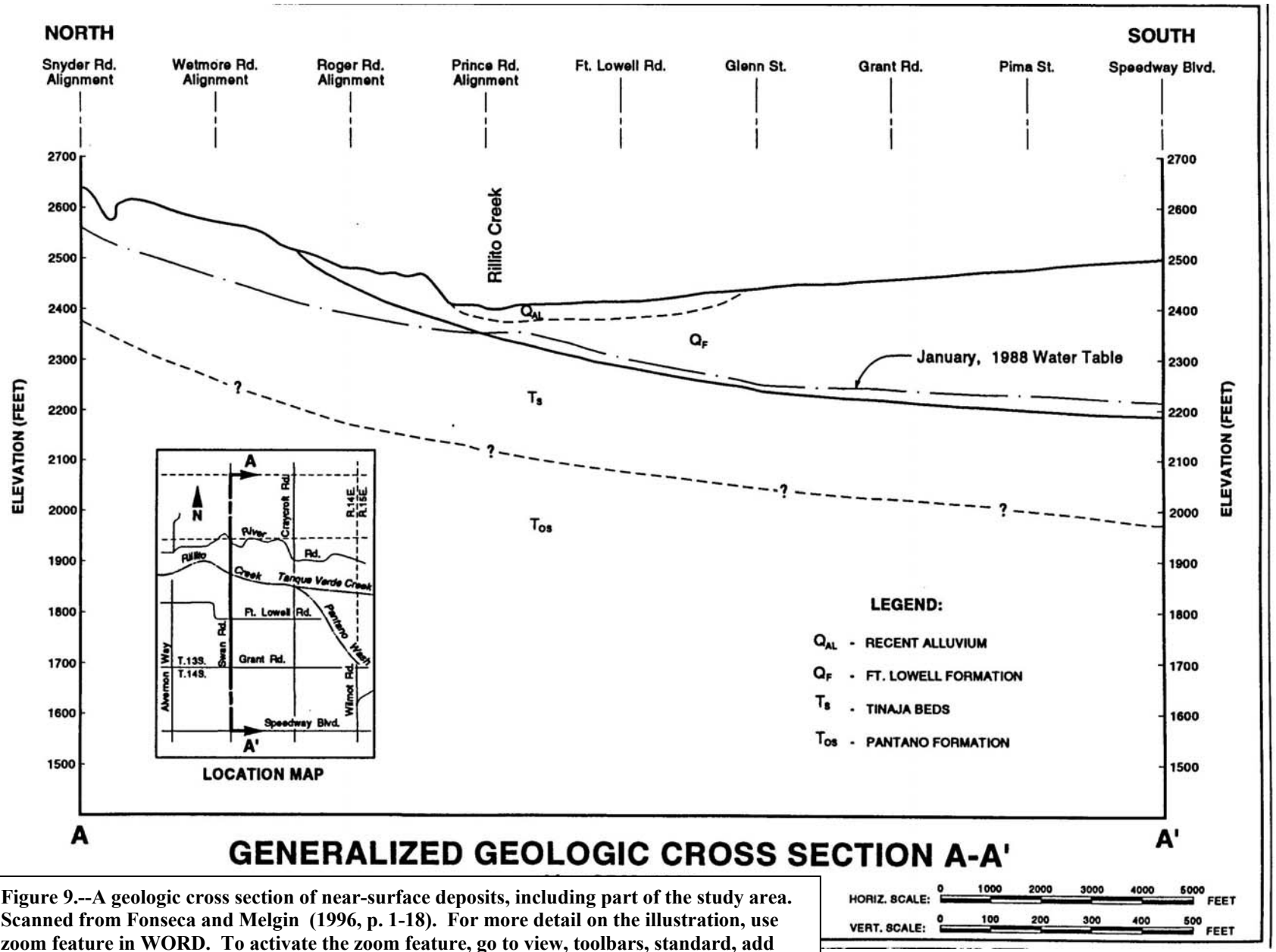

Figure 9.--A geologic cross section of near-surface deposits, including part of the study area. Scanned from Fonseca and Melgin (1996, p. 1-18). For more detail on the illustration, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button.

Figure 10.--Vegetation supported in *el Rillito* on geologic unit Qycr (refer to table 1 for definitions of geologic units). Upper frame is immediately downstream of Swan Rd., from right bank, looking downstream (west); note sparse vegetation. Lower right frame is more densely vegetated invert in the same vicinity, taken from left bank. Note vegetation dominated by desert broom. Photographs by US Army Corps of Engineers, 16 May 2001.

Figure 11.--Vegetation supported on geologic unit Qyr (refer to table 1 for definitions of geologic units). Upper right frame is Columbus landfill, left bank, looking downstream (west); note generally sparse vegetation. Lower left frame is a small mesquite bosque in same area. See also fig. 12, below. Photographs by US Army Corps of Engineers, 16 May 2001.

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Figure 12.--Tamarisk at the Columbus landfill, taken a short distance east of fig. 11, upper frame. View to west. Photograph by US Army Corps of Engineers, 16 May 2001.

alluvium: Qycr and Qyr, which are, the active channel, and Holocene (i.e., "very young") river floodplain and terrace deposits, respectively. Utilizing drill and other subsurface data, a dozen geologic profiles and cross sections of the study area, showing stream-channel cut-and-fill zones and older terraces, have been constructed by Hoffman and Ripich (in press). Those were not included herein as only a draft manuscript of their work, subject to review, was available at the time of this writing.

Immediately beneath the riverine and piedmont materials described in the paragraph above, are older sediments that represent the original filling of the Tucson Basin by erosional debris from the surrounding mountain ranges. These older sediments are termed "basin fill" and most sources indicate their age as Tertiary. Streams in the Tucson Basin are continuously reworking basin fill materials through erosion and redeposition; three different cycles of this reworking have been interpreted (Hoffman and Ripich, in press). After reworking and redeposition, these sediments are referred to as "valley-fill" materials. Considering the depths of materials and the current concepts and objectives for this study, it is only the "valley-fill" materials that would be dealt with in terms of study-related irrigation, support of constructed plant communities, physical movement of soils, or perhaps construction; none of the basin fill will be impacted. Nevertheless, the basin-fill is important as it is Tucson Basin's aquifer.

Engineering parameters of el Rillito channel and banks. For this F-3 phase of the feasibility study, no geotechnical explorations were undertaken. Future, evolving design elements may warrant new explorations to define engineering parameters of study area materials. If so, explorations would be done as an in-kind service by PDTFCD and documented in a Feasibility *F-4* level geotechnical appendix, or a subsequent generation geotechnical appendix. Substantial amounts of sampling and testing in this regard have been completed previously, including the following, as listed below.

<u>Corps of Engineers work</u>. In preparation for soil-cement bank stabilization, the Corps of Engineers in 1988 completed 6 borings and 32 trenches between the Campbell and Craycroft crossings of el Rillito. The logs reveal sands with and without gravels, and a few clay layers (see attachment 1 for logs and lab test results). Laboratory tests, at an unspecified location, included *gradation* tests (i.e., particle size analysis) and soil classification, Atterberg tests, and moisture content. Most excavations were 15 to 17 feet deep; the deepest was 30 ft and the shallowest 7 ft. Hole locations are shown on fig. 13.

<u>Pima County contracted work</u>. For the same soil-cement bank stabilization effort, Pima County Flood Control District contracted Desert Earth Engineering in 1988 to complete a dozen more borings, with sampling for engineering parameters (PDTFCD, 1991, p. A2-14, and appendix A). The drilling and lab work was done by Desert Earth Engineering under contract to PDTFCD in Sept. and Oct. 1988, using a 6-5/8 in. O.D. HSA (hollow-stem auger) rill rig, with a split-spoon penetrometer. Most holes were 20-25 ft deep, but a few were 12 ft deep. Most materials were logged as sands and silty sands; fewer horizons were logged as gravels (see attachment 2 for reproduced logs and lab test results). At the lab, tests included gradations, plasticity index, moisture, density, and consolidation characteristics. Hole locations are shown on fig. 13.

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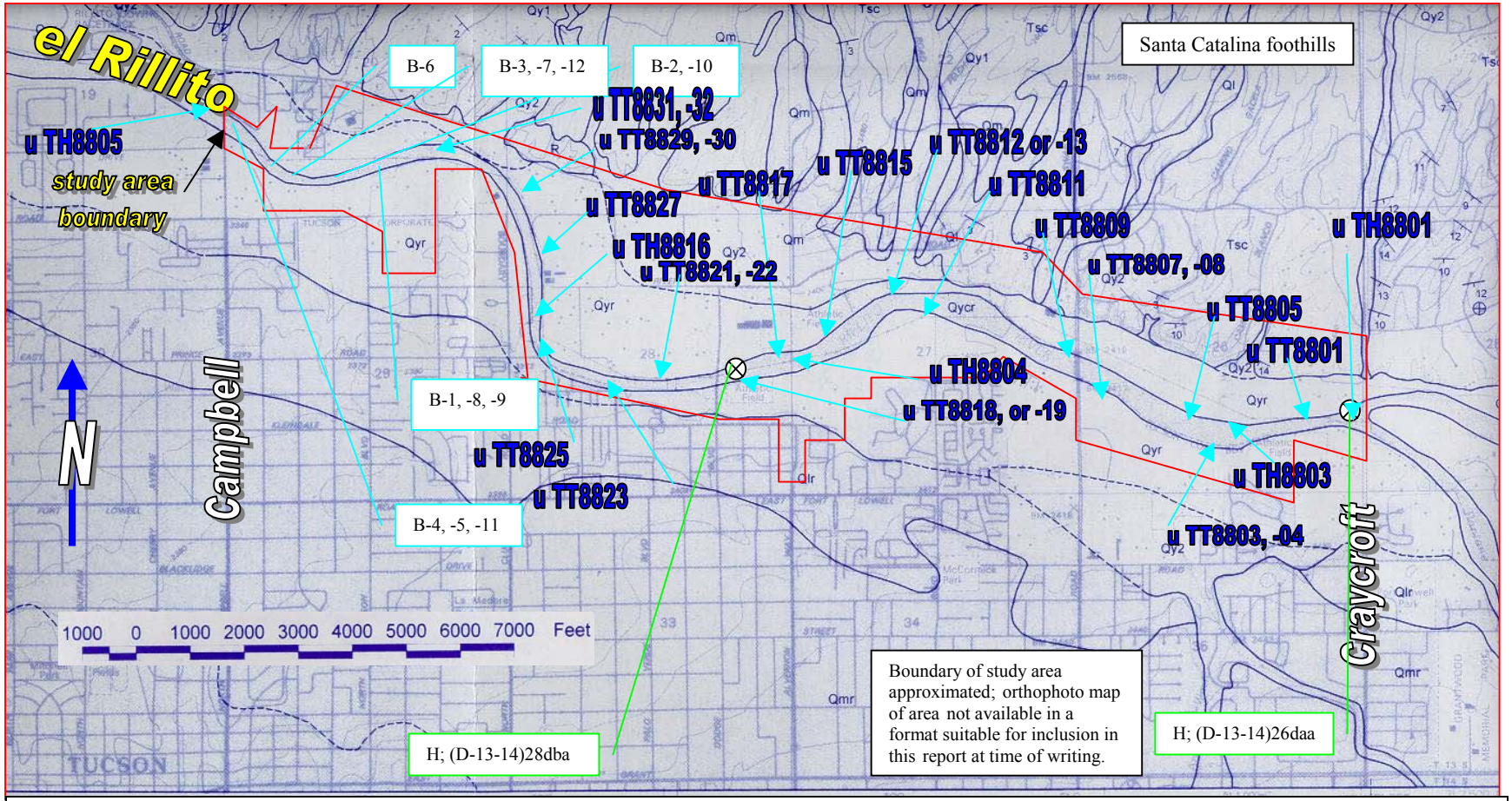

Figure 13.--Location of previous engineering-parameter exploration borings, trenches. "u" + number = USACE, attchmt 1; "B" = PDTFCD, attchmt 2; "H" = USGS (attchmt 4); other sample sites (Pearthree, 1982), not shown here, are on attchmt 3 map. Geologic base from Klawon and others (1999, sheet 1)). Lettered polygon shapes are for geology (see table 1 for explanation).

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Camp Dresser and McKee work. In studying the area for groundwater recharge potential sometime prior to mid-1989, the upper 18 inches of sediment was sampled in the study area on *el Rillito* banks and on the invert between Swan Rd. and Craycroft Rd., as reported in Camp Dresser and McKee (1989A). See attachment 3 of this current report for sample location map and test results.

U.S. Geological Survey work. In a water-resources related study of shallow sediments beneath *el Rillito*, U.S. Geological Survey drilling included two spring-of-1999 ODEX air-hammer borings on *el Rillito* invert within the current study area confines: a 7.5-inch-diameter, 158-ft-deep boring near the Columbus landfill, and a 9-inch-diameter, 56-ft-deep boring at the upstream boundary (Hoffman and Ripich, in press) (see boring locations, fig. 12, this report). Results of the particles-size analysis of samples from those borings are tentatively included herein in attachment 4 (tentatively because the Hoffman and Ripich work is a draft manuscript, subject to review and permission has yet to be obtained to release any of the data in a form such as this Corps of Engineers geotechnical appendix).

Work on Columbus landfill. An abandoned landfill within the study area was probed via 9 trenches by Terracon (2000); their logs, including soil classifications are reproduced as attachment 5 (see attachment 5 map for precise sample locations). Previous landfill characterizations at the site included 38 other trenches, logs for which were not available for this study.

Other work. Pearthree (1982), in a study of *el Rillito* channel geomorphology, reported several surface sample gradation test results, which are included in this current report as table 2, below, as the data are pertinent to discussions below of geohydrology.

Soils. The utility of local soils for accomplishing this study's environmental restoration goals are tied to groundwater levels and the high permeability of the uppermost soils (see groundwater section in this text, below, for details, and see also table 1, above). See also the text section "Engineering parameters of *el Rillito* channel and banks", above, for more information.

The soil groupings shown on fig. 14 are discussed below.

- ***River wash (Rv)*** consists of loose sandy, gravelly, and stony material. It is so coarse, loose, and leachy that it does not support plant growth.
- ***Rough (R)*** consists of steep, rough, and badly eroded areas. They consist of very gravelly or stony material and have developed little or no soil profile and does not support plant growth.
- ***Gila (Gs, Gv, Gm, Gl, Gf, Gd, and Gc)*** soils. The Gm and Gc designations of this soil are finer and better suited to retaining moisture. The Gs, Gv, Gl, Gf, and Gd designations could require irrigation. These soils support native plant species.
- ***Pinal (Py)*** soils. These soils retain moisture and support native plant species.
- ***Mohave (Mo)*** soils. These soils retain moisture and support native plant species.
- ***Laveen (Li and Ls)*** soils. These soils retain moisture and support native plant species.
- ***Anthony (Al)*** soils. These soils retain moisture and support native plant species. Though these soils are variable in their moisture retaining ability.o

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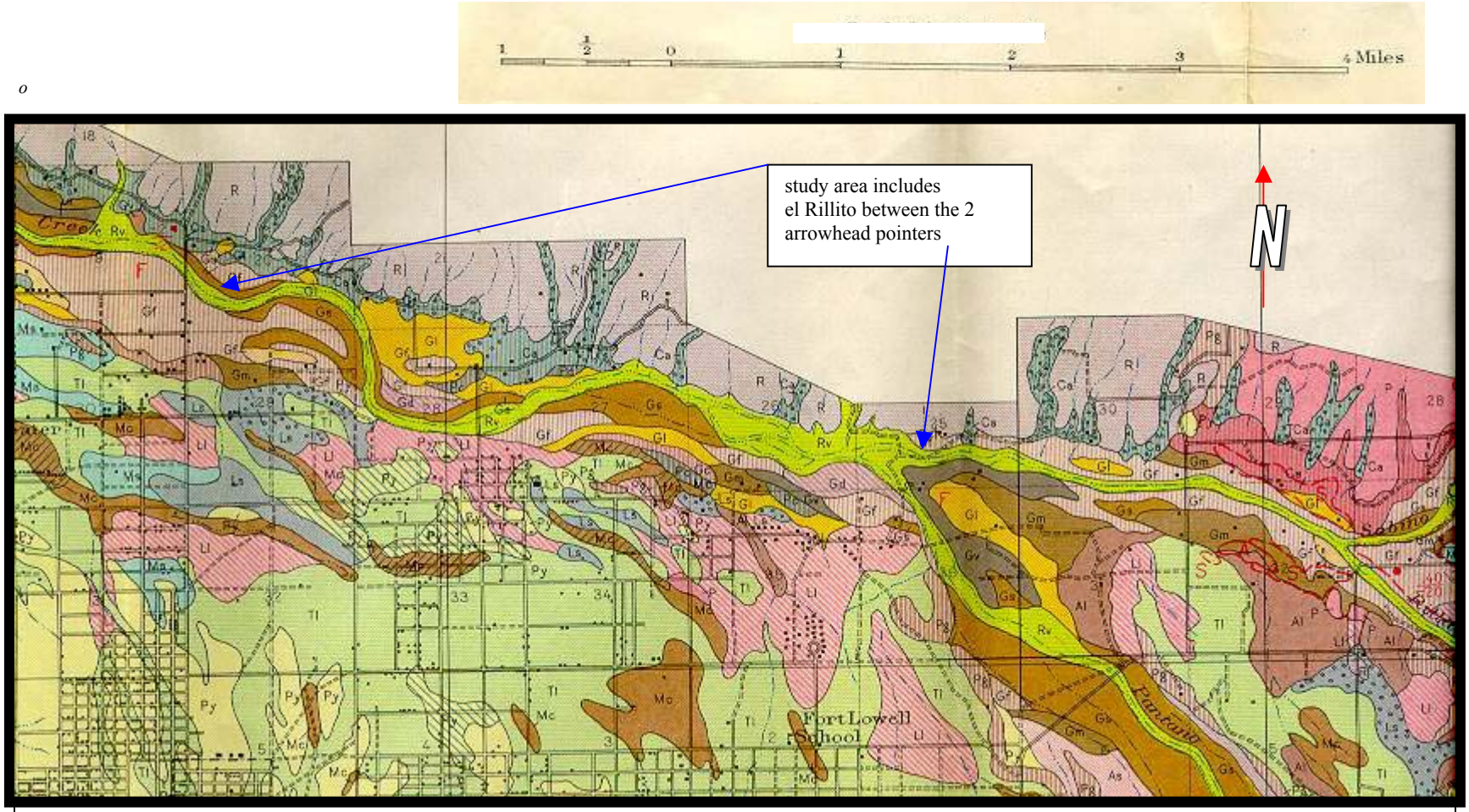

Figure 14-Soils map of the El Rio Antiguo study area, el Rillito, Tucson AZ, scanned part of Youngs and others, 1931 (Soil Survey of the Tucson Area, Arizona, US Dep. Agriculture, Bureau of Chemistry and Soils, and University of Arizona Agricultural Experiment Station, soils map). Use zoom feature in WORD program for more detail (if your "zoom" feature is not activated, in WORD, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button). Soils (as per cited source): 1) Those soils in the river are "Rv" = River wash; "Gs" = Gila fine sand; "Gv" = Gila very fine sandy loam; "Gm" = Gila silt loam; "Gl" = Gila loam; " Gf" = Gila fine sandy loam; "Gd" = "Gila loamy fine sand"; 2) those soils south of the river are "Gc" = Gila silty clay loam; "Py" = Pinal silty loam (hachured is deep phase); "Mc" = Mohave loam (hachured is dark-colored phase); "Ll" = Laveen loam, "Ls" = Laveen sandy loam; Al = Anthony loam; Tl = Tucson loam; 3) those soils north of the river are "Ca" = Cajon sand; "Cs" = Comoro sandy loam (gravelly-subsoil phase); "Pc" = Pima silty clay loam; "R" = rough, broken and stony land Red lines = areas moderately affected by alkali; red dots = soils borings sites with % conc. alkali in surface foot listed on top and avg. % alkali in top 6 ft listed on bottom.

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- ***Tucson (Tl)*** soils. These soils retain moisture and support native plant species.
- ***Cajon (Ca)*** soils. These soils do not retain moisture.
- ***Comoro (Cs)*** soils. These soils retain a low amount of moisture though they do support native plant species
- ***Pima (Pc)*** soils. These soils retain moisture and support native plant species.

Two other factors impact a soils ability to support plant growth. Both of these factors vary between soil classifications and can vary within each soil classification. The first factor is the amount of organic material in the soil. The second factor is whether or not calcium carbonate cementation is present in the soil and the degree of calcium carbonate cementation which exists in the soil. Soils in which the calcium carbonate cementation is continuous do not allow for root growth and do not retain water.

Potentially problematic soils. Soils with the potential to be *collapsible* have been identified in the study area; others, with the potential to be *expansive* also have been identified. The potential problems are related to the type and amount of clay within the soils and how that clay originated (Pearthree and Biggs, 1999, p. 13). *Cemented* soils also are discussed below.

Collapsible soils. Soil-collapse problems have been identified in buildings on *el Rillito* floodplain and terraces (Murphy, 1975, p. 9). Collapsible soils are a problem when they compact and subside in response to initial loading, as in the case of building a new home or other building on formerly pristine desert land. The collapse phenomenon usually occurs when a soil that typically has been dry is wetted or saturated when under a load, as in the case of watering the new lawn or other plantings surrounding a new home that has been built on formerly pristine desert land. Leaking swimming pools and tennis-court runoff also have been known to set off the phenomenon.

The phenomenon is related to the soil structure, particularly with regard to clay particles. A soil is a randomly oriented collection of particles of different sizes, including clay particles. Those clay particles loose their cohesive strength when wetted; adjoining, non-clay soil particles are displaced, and the soil *compacts*, thereby leading to the descriptive term "collapsible soil" (Pearthree and Biggs, 1999, p. 13). As the soil "collapses", the ground compacts and subsides. If this is an area where weight of a building is bearing, damage, even severe damage, can occur. Mapped geologic unit *Qyr*, which occupies the bulk of the study area surface (see fig. 8) has been identified, within *el Rillito's* system, to be potentially collapsible (Anderson, 1968). Collapsible soils problems also have been identified by several authors[4] for mapped geologic unit *Qmr* (see fig. 8), which is an older terrace deposit, called the Cemetery terrace, which is not exposed at the surface of the study area, but is nearby, to the south (fig. 8). It could be encountered at depth near some of the southerly extended parts of the study area boundary. Consolidation tests results for samples of the Jaynes terrace and the Cemetery terrace in Tucson (geologic map units Qlr and Qmr, respectively, on fig. 8) have identified them as the two most soil-collapse-prone geologic units in the Tucson area (Murphy, 1975, p. 9). The Jaynes terrace is within the study area surface (fig. 8).

[4] Platt (1963); Abdullatf (1969); Crossley (1969).

To evaluate Qyr and Qmr soils in the study area for collapsible soils characteristics, some parameters have been supplied. Collapsible soils are generally know to be:

- low in moisture content (<15%)
- high in porosity (>40%) (i.e., high in *void space*)
- low in bulk density with loosely packed particles, never previously subject to loading (above list from Pearthree and Biggs, 1999, p. 13).
- geologically recent in age (Murphy, 1975, p. 9).

It is noteworthy that the streambed materials of *el Rillito*, within the study area confines, have been described as loose and "exceptionally well-drained" (Fonseca and Melgin, 1996, p. 1-11). In general, low density/high void space in Tucson soils is thought be due to original deposition in a water-deficient environment (Murphy, 1975, p. 9).

Ways exist to mitigate identified collapsible soils: add a substantial amount of water to the soils and allow it to settle for weeks or months prior to construction. Pre-loading also may be beneficial (Pearthree and Biggs, 1999, pp. 13, 14). For the study area concepts currently under consideration, the collapsible soils problem may ultimately be just a maintenance problem in areas where surface depressions may develop.

<u>Expansive soils</u>. *Expansive* soils demonstrate shrink and swell characteristics that can cause damage such as displaced walls. As an general example, concrete-block basement walls have been caved inward under the forces. Overall clay *content* and specific clay *mineralogy* are thought to be factors useful in identifying expansive soils characteristic. It is the clay-rich soils that can have this troublesome characteristic (Pearthree and Biggs, 1999, p. 14). A relationship between some Tucson-area expansive soils and high concentration of smectite clays in those soils was reported in the uppermost 10 ft below the surface (Brooks, 1989, p. 118).

Mapped geologic units *Qm* and *Qmo*, which occur in small areas along the northern boundary of the study area (see fig. 8) are piedmont materials rather than riverine, and they have been identified, in general, in the Tucson area, as potentially expansive. But it has been suggested that this problematic characteristic may be minimized by the *in-situ* gravel content of these same materials (Pearthree and Biggs, 1999, p. 14).

<u>Cemented soils</u>. In arid environments, sands and gravels in the near-surface can become cemented to widely-varying degrees of hardness with calcium carbonate. The significance is with regard to excavation and groundwater movement. Excavation can become extremely difficult in places, and groundwater movement can be impaired. The *availability* and the *evaporation* of water are thought to be important elements to the formation of the cemented layers. Cementation always diminishes at some depth in other sands and gravels beneath the cemented layer. A type of problem may exist wherein cemented layers can be concealed in the following manner. There have been several alternating downcutting and aggrading episodes in the study area over the past 5,000 years. Arroyos formed in the downcutting stages and refilled with new sediment in an aggrading stage, after which a wider and flatter floodplain is again a dominant feature (Pearthree and Biggs, 1999, pp. 7, 8, 14). If a layer of cemented soils exists, the downcutting phase may stop where it is first intersected. That cemented layer may subsequently become mantled by younger, unconsolidated sediment. If any substantial excavation is added to the concepts of this study, at least some exploration for cemented

materials should be considered. Unexpectedly finding such cemented layers after construction begins can lead to substantial, unanticipated project costs.

Of the geologic units present in the vicinity of the study area (note fig. 8, the geologic map), five have been identified as having some degree of calcium carbonate cementation (according to Pearthree and Biggs (1999, pp 5, 6, 8, 14):

- Qyr (floodplain and terrace material of a geologically young age) with $CaCO_3$ "filaments and fine masses " in the near surface;
- Qm (piedmont material at the northern edge of the study area) with *type III* [5]and as much as *type IV*[5] calcium-carbonate cementation;
- Qmr (Cemetery terrace, as close as a few hundred feet south of the study area), with as much as *type IV* calcium-carbonate cementation (the petrocalcic horizon has formed but with little or no laminar cap);
- Qo (older piedmont materials, possibly equivalent to Qmo materials of Klawon and others (1999), which adjoins the study area to the north), reportedly have cemented materials;
- QT (oldest piedmont materials) which adjoin the study area to the north, reportedly have cemented materials. These are basin-fill (Klawon and others, 1999, p. 11)

Geohydrology and groundwater. Hoffman and Ripich (in press) define the aquifer of the Tucson Basin as being that part of the Ft. Lowell Formation that is saturated, plus the underlying, and presumably saturated upper Tinaja beds. PDTFCD verifies that both the groundwater surface and top of the Ft. Lowell are expected to be at about -30 ft depth below the invert of *el Rillito*, at least in the central part of the study area in mid-year 2001. The overlying materials above the Ft. Lowell and groundwater table represent a vadose zone, which is important and discussed further, later in this section of text. Basic characteristics of the aquifer beneath *el Rillito* are (SLI, Inc, 1984, p. 8):

- high-yield;
- flowing to the northwest;
- generally paralleling surface drainages in both direction and slope (a characteristic informatively displayed in graphics within Hoffman and Ripich (in press));

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[5] "Types" or "stages" of carbonate morphology (Machette, 1985, pp. 4 -5):

I--thin discontinuous coatings of calcium carbonate, sparse to common; trace to 4% overall $CaCO_3$ depending on gravel content; a calcic soil.

II--continuous, thin-to-thick calcic coatings on pebbles; nodule formations begins; some carbonate in matrix but matrix remains generally noncalcareous to slightly calcareous; 2 to 20% overall $CaCO_3$ depending on gravel content; a calcic soil.

III--massive calcic accumulations between clasts, firmly to moderately cemented; continuous calcic dispersion in matrix; 10 to 60% overall $CaCO_3$ depending on gravel content; a calcic soil.

IV--indurated, with laminae in upper horizon (<0.2 to 1 cm) that may drape over fractured surfaces; cemented platy to weak tabular structure; >25 to >60% overall $CaCO_3$ depending on gravel content; horizon is 0.5 to 1-m thick; a pathogenic calcrete or indurated calcic soil (some classifications schemes consider stage IV as the maximum degree of cementation).

V--indurated, with case hardened surfaces; pisoloites, laminae (>1 cm thick) coat vertical surfaces; dense, strong platy to tabular structure; >50 to >75% overall $CaCO_3$ depending on gravel content; horizon is 1-2 m thick; a pedogenic calcrete or indurated calcic soil.

VI--indurated, case hardened, with multi-generation laminae, pisoloites, breccia; recemented surfaces; dense, thick, strong tabular structure; >75% overall $CaCO_3$; horizon is >2 m thick; a pedogenic calcrete or indurated calcic soil.

- a "sole-source aquifer" a per EPA definitions[6];
- overlain by surficial, in-stream geologic materials with a high infiltration rate; percolation is historically the major source of groundwater recharge in the study area (Camp Dresser & McKee, 1989B, p. 4-1) and about half the 100,000 ac-ft/yr of annual recharge is attributed to infiltration of storm runoff in el Rillito's *invert* (i.e., *stream bottom*) (PDTFCD, 1986, pp. 7-8). See results of infiltration tests in and near the study area, table 2.

Groundwater level decline. Historical decrease in study-area groundwater levels is due to groundwater *overdraft* in the overall Tucson Basin (pumping more groundwater each year than can be naturally replaced), as graphically displayed in Fonseca and Melgin (1996, p. 1-16) [reproduced here as fig. 15], but it should be noted that upstream-most parts of the study area showed much less decrease, and even some recovery (fig. 15). Recovery is further demonstrated in records of well 26cbb3[7] between 1988 through 1992, as shown in Fonseca and Melgin (1996, fig. 9), a phenomenon for which this author has no explanation.

The vadose zone. For the purposes of this study, the most important aspects of groundwater are its depth and its interaction with the vadose zone. The vadose zone is described as "dynamic" due to the following characteristics:

- high permeability;
- shallow depth to groundwater;
- variability in flow events;
- groundwater pumping (the above list Fonseca and Melgin, 1996, p. 1-19)
- essentially all recharge is through sandy channel bottom with very little recharge in overbank areas[8].

Collectively, from these characteristics, we learn that groundwater pumping and seasonal dry periods can cause substantial decrease in groundwater levels in *el Rillito*, while both groundwater recharge and storm events can cause rapid rise in levels. Snowmelt from the Santa Catalinas also is known to cause groundwater elevations to rise to the invert in *el Rillito* (Fonseca and Melgin, 1996, p. 1-19). Determining precisely the allowable range for such fluctuation and maintaining water levels in that range will be crucial to the success of environmental restoration of plant communities along this part of *el Rillito*. For survival in the widest range of fluctuation of groundwater levels, targeted native plant species likely will be limited to only those with the deepest root systems, or else impermeably lined, off-channel basins will have to be constructed for supporting "pockets' of plant communities and elevated subsurface water supplies. The alternatives are monitoring and artificial maintenance of an acceptable level of groundwater, or manufacture of suitable soils. Materials of the channel in the study area, as they are understood at this point in the study, appear to be less than ideal for sustaining high groundwater levels without regular recharge. Other characteristics of the vadose zone deposits and underlying aquifer have been compiled from literature in tables 2 and 3, below; some may prove useful in assessing conceptual designs for environmental restoration for this study. Samples from the o

[6] Supplies greater than 50% of the drinking water for an area (PDTFCD, 1986, p. 5).
[7] Near the southern edge of the study area and east of Swan Rd.
[8] Due to impermeable nature of silt-clay areas in overbank plus very little inundation of those overbanks (SLI, 1984, p. 8).

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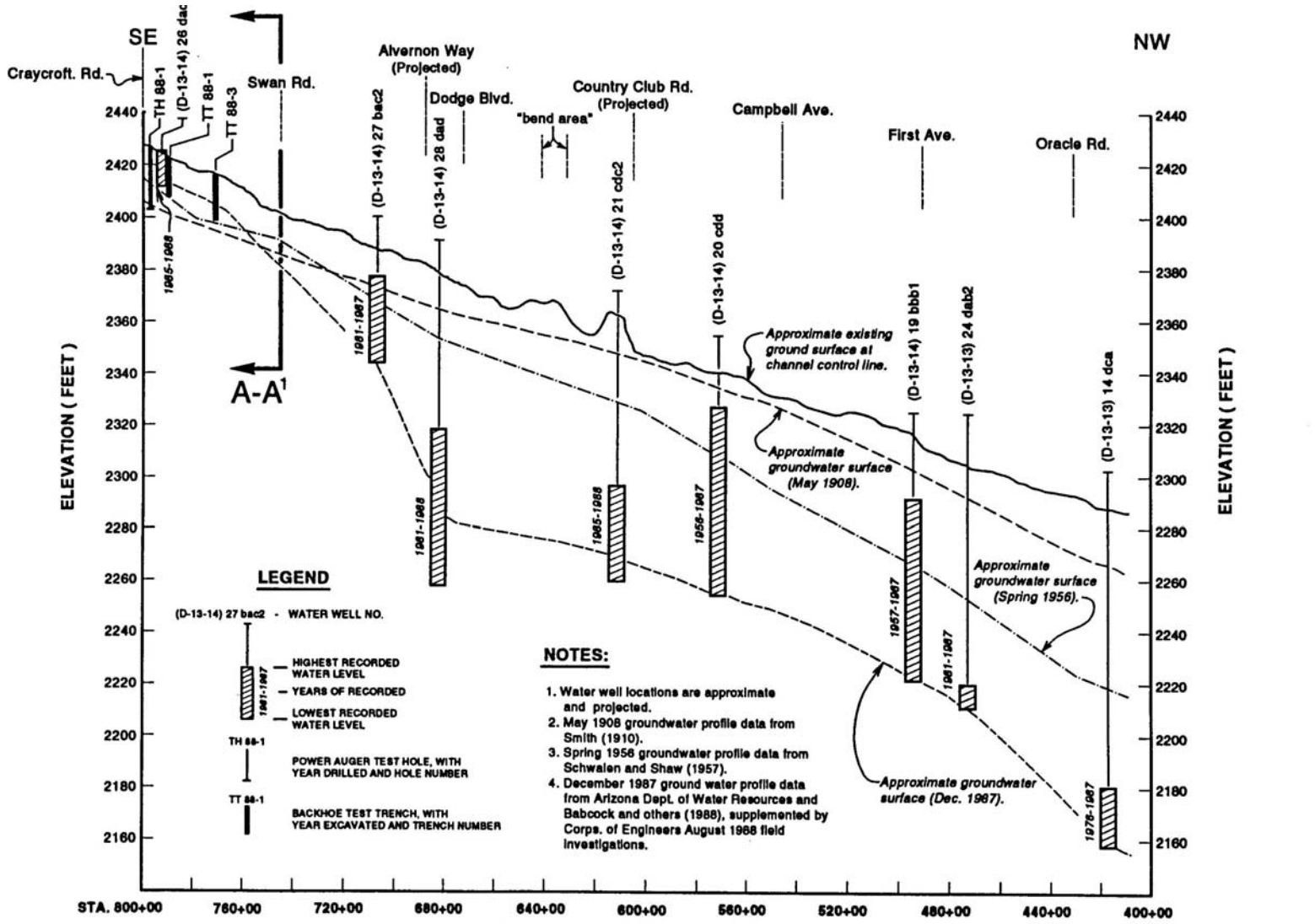

Figure 15--Profile showing groundwater fluctuations over time along *el Rillito*, including the study area (note Craycroft and Campbell). Scanned from Fonseca and Melgin (1996, p. 1-16). For more detail on the illustration, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button.

Table 2.--Gradations of surface samples from banks and streambed, as reported in the literature, el Rillito												
location	**streambed**				**right bank**				**left bank**			
--	**% gravel**	**% sand**	**% silt & clay**	**D_{50} mm**	**% gravel**	**% sand**	**% silt & clay**	**D_{50} mm**	**% gravel**	**% sand**	**% silt & clay**	**D_{50} mm**
el Rillito 500 ft upstream of Campbell, where ch. is 220 ft wide, 8 ft deep (Pearthree, 1982, p. 31)	18.0	81.5	0.5	1.75	33.6	57.6	8.8	1.00	--	--	--	--
el Rillito 910 ft downstream of Dodge, where ch. is 135 ft wide, 14.7 ft deep (Pearthree, 1982, p. 31)	12.6	81.2	6.3	1.32	13.4	70.1	16.5	0.25	17.0	65.9	17.1	0.35
el Rillito 200 ft upstream of Swan, where ch. is 420 ft wide, 6 ft deep (Pearthree, 1982, p. 31)	4.6	88.7	6.7	0.85	28.7	67.6	3.6	1.65	34.1	59.5	6.4	1.70

Table 3.--Vadose-zone geohydrologic parameters, as reported in literature, el Rillito.						
Geologic unit	depth, thickness, and description	porosity	permeability	specific yield	transmissivity	Source
Generalized vadose zone, modern and Holocene	at surface; 40 to 80 ft thick in study area; unconsol. sands, gravels silts (see gradation in table 2), incr. in avg. grain size to the north (towards the mts) to coarse sand with gravels, boulders	0.30 (avg.)	not reported	0.27	n/a	Camp Dresser McKee, 1989B, p. 3-16
Vadose zone specific test 1.1 ([1]) at surface	at surface	--	1587 gpd/ft^2 212 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 1.1 ([1]) 18 in. deep	18 in. deep	--	sample lost	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 1.2 ([1]) at surface	at surface	--	93 gpd/ft^2 12 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 1.2 ([1]) 18 in. deep	18 in. deep	--	147 gpd/ft^2 20 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 1.3 ([1]) at surface	at surface	--	1587 gpd/ft^2 212 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 1.3 ([1]) 18 in. deep	18 in. deep	--	sample lost	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 2.1 ([1]) at surface	at surface	--	221 gpd/ft^2 30 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 2.1 ([1]) 18 in. deep	18 in. deep	--	8453 gpd/ft^2 1130 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 2.2 ([1]) at surface	at surface	--	587 gpd/ft^2 78 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 2.2 ([1]) 18 in. deep	18 in. deep	--	1239 gpd/ft^2 166 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13

Table 3.--Vadose-zone geohydrologic parameters, as reported in literature, el Rillito.

Geologic unit	depth, thickness, and description	porosity	permeability	specific yield	transmissivity	Source
Vadose zone specific test 2.3 ([1]) at surface	at surface	--	269 gpd/ft^2 36 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 2.3 ([1]) 18 in. deep	18 in. deep	--	483 gpd/ft^2 65 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 2.4 ([1]) at surface	at surface	--	269 gpd/ft^2 36 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 2.4 ([1]) 18 in. deep	18 in. deep	--	3533 gpd/ft^2 472 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 2A ([1]) at surface	at surface	--	1258 gpd/ft^2 168 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 2A ([1]) 18 in. deep	18 in. deep	--	2973 gpd/ft^2 397 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 3.1 ([1]) at surface	at surface	--	2165 gpd/ft^2 289 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 3.1 ([1]) 18 in. deep	18 in. deep	--	3102 gpd/ft^2 415 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 3.2 ([1]) at surface	at surface	--	no sample	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 3.2 ([1]) 18 in. deep	18 in. deep	--	no sample	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 3.4 ([1]) at surface	at surface	--	2668 gpd/ft^2 357 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 3.4 ([1]) 18 in. deep	18 in. deep	--	2283 gpd/ft^2 305 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 3.5 ([1]) at surface	at surface	--	1258 gpd/ft^2 168 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 3.5 ([1]) 18 in. deep	18 in. deep	--	2077 gpd/ft^2 278 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 3.6 ([1]) at surface	at surface	--	93 gpd/ft^2 12 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 3.6 ([1]) 18 in. deep	18 in. deep	--	85 gpd/ft^2 11 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 4.1 ([1]) at surface	at surface	--	3385 gpd/ft^2 452 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 4.1 ([1]) 18 in. deep	18 in. deep	--	4154 gpd/ft^2 555 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Vadose zone specific test 5.1 ([1]) at surface	at surface	--	3903 gpd/ft^2 522 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 5.1 ([1]) 18 in. deep	18 in. deep	--	2765 gpd/ft^2 370 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13

Table 3.--Vadose-zone geohydrologic parameters, as reported in literature, el Rillito.

Geologic unit	depth, thickness, and description	porosity	permeability	specific yield	transmissivity	Source
Vadose zone specific test 6.1 ([1]) at surface	at surface	--	1731 gpd/ft^2 231 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-8
Vadose zone specific test 6.1 ([1]) 18 in. deep	18 in. deep	--	4002 gpd/ft^2 535 ft/d	--	--	Camp Dresser McKee, 1989A, p. 3-13
Ft. Lowell Pleistocene-age; unconformable upper and lower contacts	30 to 100 ft deep; probably most likely in the range of 40-80 ft deep; 300 - 400 ft thick, thinning towards the Santa Catalinas -f gravels to clayey silt -f crops out in Santa Catalina foothills - f	0.30 (avg.) f	150 - >700 gpd/ft^2 -c 20 - 94 ft/day -f avg vertical perm.: 1.5 - 70 gpd/ ft^2 -c	--	20,000 - 1,000,000 gpd/ft c	"c" = from Camp Dresser McKee, 1989B, p. 3-16; "f" = from Fonseca and Melgin, 1996, p. 1-17.
upper Tinaja Miocene and Pliocene age	probably 400 - 500 ft deep; thickness not reported in literature; sand and clayey silt, grading to gravel and sand towards mtns.	24 -35 % - f	10 - 400 gpd/ft^2 - c 1.3 - 50 ft/day -f vert.: horiz perm = 1:40 -f	--	2,000 - 1,000,000 gpd/ft -c	"c" = from Camp Dresser McKee, 1989B, p. 3-16; "f" = from Fonseca and Melgin, 1996, p. 1-17.

[1] Seventeen tests from 7 different test sites in the study area are repeated here, from the literature. See attachment 3 map, this current report, for sample locations. Samples 1.1, 1.2, etc. are from location "1" on the attachment 3 map; samples 2.1. 2.2, etc., are from location "2" on the attachment 3 map, and so on.

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upper parts of exploratory borings and trenches done by previous workers (see attachments 1, 2, 3, 4, this report) contain similar information that will be useful in this regard.

Of particular interest to this study may be the plant communities currently associated with the geohydrologic units currently under discussion (see figs. 10-12). That topic is expanded to include plant communities currently associated with all geologic units that are in the study area (table 1). Collectively, this table shows what plants are likely to be supported by the various geologic units (and thus be supported by existing surficial materials or soils in the study area) as well as what invasive species may be troublesome to eradicate. Tamarisk, an invasive and highly troublesome species, is present, at least in some parts of the study area (fig. 12). Desert broom (fig. 10) appears to be one of the more prolific of the acceptable ("native") plant species. See table 1 for more literature-based information on what plant communities are known to be supported in the study area and vicinity.

Geologic hazards.
Land subsidence and earth fissures. These inter-related problems share their source with over-pumping of groundwater from the Tucson Basin. In general, more groundwater is taken out of the Basin each year than naturally recharges and groundwater levels fall each year. The resulting drawdown of the water table elevation leads to compaction of the formerly saturated sediments, including the aquifer, as the groundwater supplied a "supporting" force which is eliminated when the groundwater is removed. Following compaction, the surface of the overlying land can subside, in general by even by as much as tens of feet, in places. In the Tucson Basin, where groundwater elevation levels have been lowered several hundred feet (Pearthree and Biggs, 1999, p. 14), subsidence has been known since 1952; as of 1980, the total maximum surface subsidence was 0.5 ft (Platt, 1963; Anderson, 1988). Newer studies of the problem suggest the problem of surface subsidence is accelerating, having increased markedly since 1980, and that effects will be noticed more strongly in the future. One study determined a surface subsidence rate of 1 cm/yr over the time period of 1987 to 1991, while another determined a rate of 2.4 cm/yr for the three years immediately preceding March 1997[9]. Some parts of the Tucson Basin may expect 10 ft or more of total subsidence by year 2030 (Pearthree and Biggs, 1999, pp. 14-16).

Earth fissures are a related problem, being found where surface subsidence exceeds a few feet; *none* are known within the Tucson basin, but of all the deep, Arizona groundwater basins in which overdraft is occurring, the Tucson Basin is the only one to as yet not demonstrate this phenomenon; this is expected to change (Pearthree and others, 1999, p. 16). Slaff (1993, pp. 11, 12,14) ties the existence of earth fissure directly to groundwater overdraft. As the land adjusts to the collapse of void space at depth, unequal forces are distributed among the various geologic materials and shear stresses can cause a "tearing" of the soils. The result is an earth fissure. These can be substantially large features, in the range of 175 to 1,500 ft deep. They can be several feet wide, and one has been noted as 1,000 ft long (near Picacho, AZ, far from the study area). Much more important with regard to the current study is the ability of earth fissures to absorb large quantities of sediment (and thus water). Also of concern is the "life-span" of these

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[9] Based on 9 cm total subsidence in that three-year time period, using SAR (satellite-based synthetic aperture radar) interferometry.

features, i.e., how much time will pass until they are sufficiently filled in to cease being an outlet for sediment and water. Time periods of a few years to more than 50 years have been estimated.

Co-related problems of subsidence and earth fissures are best circumvented by replenishing the groundwater overdraft and stopping the drawdown (Slaff, 1993, p. 19). Nevertheless, it should be remembered that once an aquifer compresses in response to groundwater overdraft, it does not necessarily return to its original capacity, so not all subsidence can be repaired.

Faults. There are no faults occurring within the immediate vicinity of the study area, according to Collins/Pina and others (2000, p. 12). The closest fault to the study area is the Catalina detachment fault, 3 mi to the northeast, and its related splay, named the Finisterra fault, which is as close as 2.6 mi to the study area. Both are normal faults. Movement along the Catalina fault strongly deformed some of the late Oligocene to early Miocene sediments deposited at the base of the Santa Catalina Mountains, and to a lesser degree deformed younger, unconformably overlying Miocene sediments. But geologic units along the Santa Catalina front that are known to be of Pliocene age and younger are not deformed (Klawon and others, 1999, p. 11). Therefore the fault has not been active for about the last 5 million years or perhaps more.

Seismicity. Seismicity was addressed previously by the Corps of Engineers in the Design Memorandum for soil-cement bank stabilization, in the bend area and at the confluence of the Santa Cruz River and *el Rillito* (USACE, 1992, p. A4-5, pl. 3); those conclusions, drawn from numerous literature sources, also are applicable for the current study area:

- the study area is astride zone 1 and zone 2 (low to moderate seismic potential) on the Seismic Zone Map of the Contiguous States
- earthquakes with magnitudes greater than 4.0 on the Richter scale have been concentrated in this particular zone 2;
- earthquake intensities with Modified Mercalli shaking intensities greater than VI have been known in this particular zone 2 (on a scale of I - XII, with XII being the greatest shaking);
- estimated recurrence interval of surface-rupturing earthquakes (which can be among the most damaging to structures) has been 3,00 to 4,000 years (over the past 20,000 years);
- the strongest shaking intensity likely felt within the confines of the study area was intensity VII, resulting from the 130-mile-away, Sonora, Mexico earthquake of 1887, with its maximum epicentral shaking intensity of XII and estimated magnitude of 7.2; note that this earthquake caused landslides and rockfalls in the Santa Catalina Mountains and widespread damage to structures, even in Phoenix. Some smaller walls around the San Xavier Mission grounds collapsed at the time (cite AGS publ. on the event here);
- the three largest known historical earthquakes within 100 miles of the study area are:
    - in 1916, 60 mi south of Tucson, max. epicentral intensity of VI;
    - in 1961, in western Pima County, 90 mi W-NW of Tucson, *M* 4.7;
    - in 1969, near Globe, AZ, 85 mi NE of Tucson, *M* 4.4;
        - others, within 25 miles:
    - in 1888, two earthquakes 3 mi southeast of Tucson, max. epicentral intensities of IV;
    - in 1965, 25 mi west of Tucson, *M* 4.4.

Analysis of the historical information by USACE (1992, pp. A4-5 to A4-6), involved development of attenuation curves based on horizontal acceleration in rock:

- maximum bedrock accelerations of less than 0.1 *g* would have resulted from any of the historical earthquakes mentioned above;
- the maximum credible earthquake, theoretically to be generated by 12 to 36 miles of rupture along the Santa Rita fault, would produce maximum bedrock accelerations of 0.2 *g* in the study area;
- designs should be based on a seismic coefficient of 0.1 *g*.

Potentially hazardous materials. Potentially hazardous materials and petroleum releases into the environment, also referred to as "HTRW" (potentially hazardous, toxic, or radioactive wastes) are an integral part of a Corps of Engineers Geotechnical Appendix. For this study, the responsibilities of assessing the potential HTRW situation in the study area are being addressed as an in-kind service by the "local sponsor" (Pima County Dept. of Transportation and Flood Control District--PDTFCD). The results are appended to the feasibility report separately from this geotechnical appendix. Of interest will be documentation and risk analysis of potentially problematic businesses or former businesses within or near the study area. The type of businesses that would be of interest in this regard are those working with, transporting, or storing potentially hazardous materials.

There are sanitary landfills within the study boundary (fig. 16). As previously summarized by the Corps of Engineers, these landfills have the following characteristics (USACE, 1992, pp. A4-15 to A4-18):

Landfill general characteristics, along *el Rillito*.

Name	total volume (yd^3)	max. depth	type of materials	status
Columbus landfill	2,581,000	20 ft	"trash" (but see text below)	*abandoned; *obliterated by flood flows in 1960s but see text below); *concern is potential leachate if groundwater levels are raised
Walnut landfill	202,000	70 ft	"trash" (but see text below)	*abandoned; *concern is potential leachate if groundwater levels are raised.

To assess risk to the current study, site assessments including soil and groundwater sampling and some trenching into the debris in order to examine them would be in order. All have been undertaken regarding the Columbus landfill, determining (PAG, 2000, pp. 13-19):

- no groundwater contamination found in wells near or downgradient of the landfill;
    - no strong evidence of landfill leachate or VOC contamination subsequent to assessment of numerous groundwater samples from wells;
- no strong evidence of methane production subsequent to soil vapor probe monitoring;
- spilled fuel observed in one area at the surface [*an occurrence not further described*];
- boundaries are difficult to ascertain (reportedly storm flows in the 1960's washed way the landfill on the north bank and anything in *el Rillito's* streambed).
- three soil samples from 38 trenches (in 1993 by AJAY) were tested and had no TPH (total petroleum hydrocarbons) or other hazardous waste above regulatory levels,

although one near-surface sample had *BTEX* (benzene at 0.38 mg/kg; toluene at 1.05 mg/kg; ethylbenzene at 0.79 mg/kg; and total xylene at 2.37 mg/kg);

- three other samples from recently dumped dirt on the surface had 100 ppm TPH;
- many suspect ACMs (asbestos containing materials) were encountered during trenching with tests revealing 10 to 40% asbestos in these materials.

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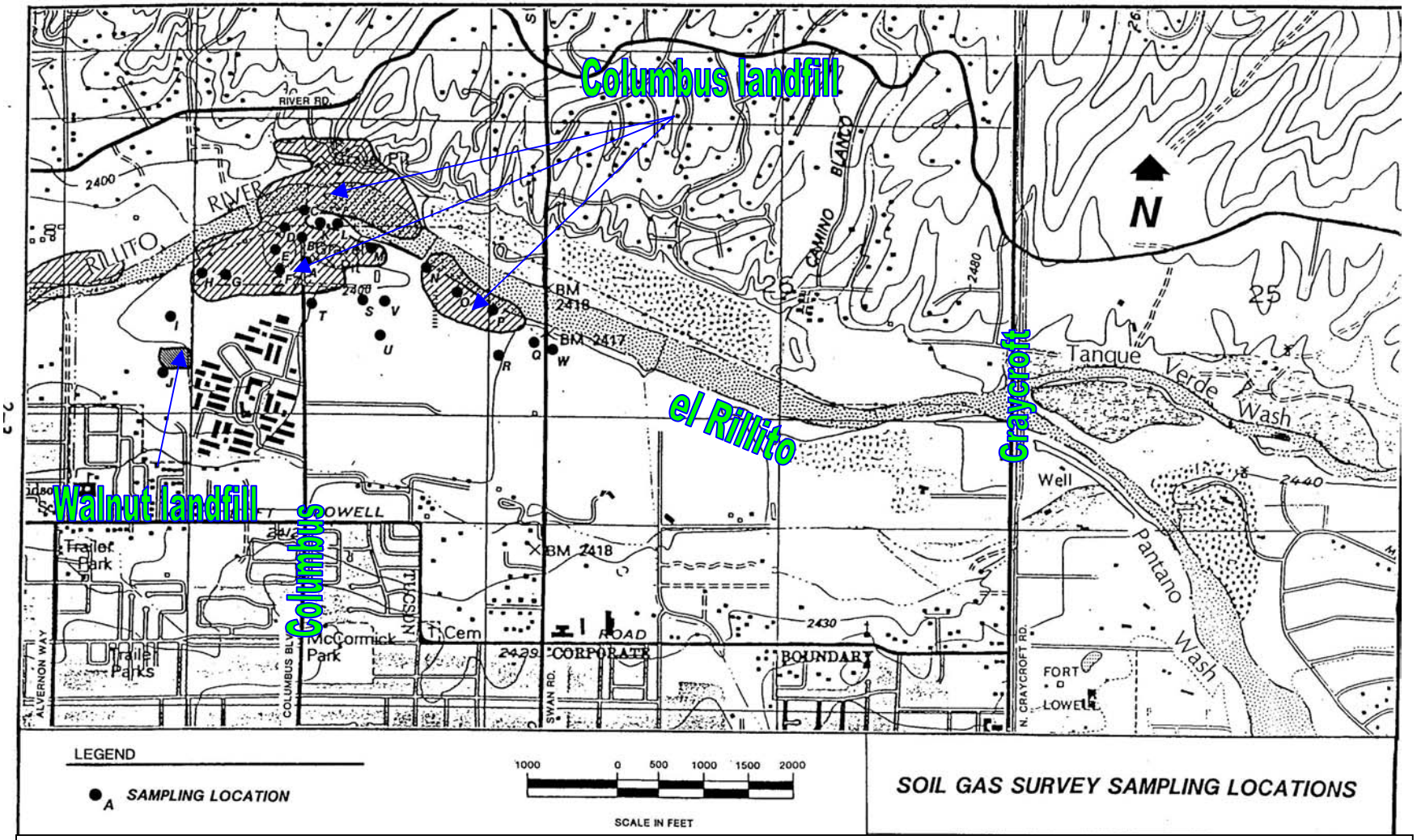

Figure 17.--Location map of Columbus and Walnut landfills, both within the study area, showing landfill-assessment-related soil gas survey locations (black circles). Map scanned from Camp Dresser and McKee (1989B, p. 2-3), with slight modifications.

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abbreviations used in the cited references:
"PAG" is "Pima Association of Governments"
"PDTFCD" is "Pima County Dept. of Transportation and Flood Control District"
"USACE" is "US Army Corps of Engineers"
"SLI" is "Simons Li Incorporated"

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Attachment 1. US Army Corps of Engineers 1988 boring and trench logs and laboratory test results in the Campbell-to-Craycroft vicinity of the study area (USACE, 1992).

Specific data in some instances were illegible due to printing problems with the original document, including washout and opaque source illustrations (photocopied in black-and-white for the publication, using, apparently, densely-colored, blue-line originals). Thus, locations of many of the workings were obliterated, along with the precise identification number of others. See fig. 13 for the locations that are known with certainty. None of the printed logs in USACE (1992) were of a quality that would allow scanning or photocopying for incorporation into this report. The logs, therefore, all were re-typed for this report (see below), and a summary table was made describing the locations, as best as possible. The re-typed log format is extremely simplified for expediency. Each row has a "depth" entry. For example, for log TT88-01, there are depth entries on the first two rows of "2" and "3". For the row marked "2", the data are for material between 0 ft and 2 ft of depth; for the row marked "3", the data are for materials between 2 and 3 ft. Elevations are given for the top and bottom of the excavation only, as in the original log format. The complete list of explorations includes:

Attachment 1.--USACE geotechnical explorations: location information.

to-tal	explora-tion no.	type (t = trench; b = boring)	location (stationing as per the soil cement bank stabilization DM by USACE, 1992)
1	TT 88-01	t	on left (south) bank of *el Rillito*, about 700 ft d/s (west) of Craycroft bridge
2	TT 88-02	t	location not apparent on the DM drawings; it is west of and in the vicinity of the Craycroft bridge, probably between TT88-01 and TT88-02
3	TT 88-03	t	slightly left of c/l of *el Rillito*, about 1,700 ft d/s (west) of Craycroft bridge
4	TT 88-04	t	slightly left of c/l of *el Rillito*, about 1,700 ft d/s (west) of Craycroft bridge
5	TT 88-05	t	near toe of right (north) bank of *el Rillito*, about 2,100 ft d/s (west of) Craycroft bridge
6	TT 88-06	t	location not apparent on the DM drawings; it is west of and in the vicinity of the Craycroft bridge, probably between TT88-01 and TT88-02
7	TH 88-01	b	on c/l; immed. west of Craycroft at the u/s end of project
8	TH 88-03	b	slightly right of c/l of *el Rillito*, about 1,500 ft d/s (west) of Craycroft bridge
9	TT 88-07	t	left of c/l on *el Rillito* invert, 600 ft u/s of Swan Rd. bridge
10	TT 88-08	t	some uncertainty; there is a USACE trench dug at toe of left (southern) bank of el Rillito, 600 ft u/s of Swan Rd. bridge. It's identifying number is obliterated buy the opacity of DM drawings, but this is very likely no. TT88-08, particularly since the locations of TT88-07 and -09 are known
11	TT 88-09	t	at toe of right (north) bank of *el Rillito* 400 ft d/s of Swan Rd. bridge
12	TT 88-10	t	location not apparent on the DM drawings; it is in the vicinity of Swan Rd. bridge on *el Rillito* and likely is between trenches TT88-09 and TT88-11
13	TT 88-11	t	near toe of left (south) bank *el Rillito* 1,5000 ft d/s of Swan Rd. bridge
14	TT 88-12	t	there is one USACE trench at the toe of the right (north) bank of *el Rillito* 1,700 ft d/s of swan Rd. bridge; the identifying number is illegible in the DM; it is either TT88-12 or TT88-13
15	TT 88-13	t	there is one USACE trench at the toe of the right (north) bank of *el Rillito* 1,700 ft d/s of swan Rd. bridge; the identifying number is illegible in the DM; it is either TT88-12 or TT88-13
16	TT 88-14	t	location not apparent on the DM drawings; it is in the vicinity of Swan Rd. bridge on *el Rillito* and likely is over 2,000 ft d/s of that bridge, d/s of trench TT88-11
17	TH 88-02	b	location not apparent on the DM drawings; it is in the vicinity of Swan Rd. bridge on *el Rillito* and likely is over 2,000 ft d/s of that bridge, d/s of trench TT88-11
18	TT 88-15	t	on toe of right (northerly) bank of *el Rillito*, in vicinity of Alvernon Way and *el Rillito*
19	TT 88-16	t	location not apparent on the DM drawings; it is in the vicinity of Alvernon Way and *el Rillito*
20	TT 88-17	t	on toe of right (northerly) bank of *el Rillito*, 200 ft east of boring TH88-04

Attachment 1.--USACE geotechnical explorations: location information.			
to-tal	explora-tion no.	type (t = trench; b = boring)	location (stationing as per the soil cement bank stabilization DM by USACE, 1992)
21	TT 88-18	t	cannot be determined with certainty; either this trench or TT88-19 is on the left (southerly) bank of *el Rillito*, about 600 ft east of TH88-04 (vicinity of Alvernon Way and *el Rillito*); the opacity of the DM drawings does not allow discerning of the number TT88-18 from TT88-19; it is one or the other
22	TT 88-19	t	location not apparent on the DM drawings; it is in the vicinity of Alvernon Way and *el Rillito*
23	TT 88-20	t	location not apparent on the DM drawings; it is in the vicinity of Alvernon Way and *el Rillito*
24	TH 88-04	b	on toe of right (northerly) bank of *el Rillito*, in vicinity of Alvernon Way and *el Rillito*
25	TT 88-21	t	at the toe of the right (northerly) bank of *el Rillito*, in the bend area, west of where Dodge Blvd. intersects *el Rillito*
26	TT 88-22	t	on the right bank of *el Rillito*; adjoins trench TT88-21 (see above)
27	TT 88-23	t	at the toe of the right (northerly) bank of *el Rillito*, in the bend area, east of Country Club Rd., about where Edith Blvd projects to *el Rillito*
28	TT 88-24	t	location is not apparent on the DM drawings; likely is between trench locations TT88-23 and TT88-25; it is in the bend area of *el Rillito*, east of Country Club Rd.
29	TT 88-25	t	at toe of right(easterly) bank of el Rillito, in the bend area, east of Country Club Rd. and about 1/8 mi south of Allen Rd.
30	TT 88-26	t	location is not apparent on the DM drawings; likely is between trench locations TT88-25 and TT88-27; it is in the bend area of *el Rillito*, east of Country Club Rd.
31	TT 88-27	t	near the toe of the right (easterly) bank of el Rillito, approximately sta. 623+00, in the north-south trending segment of the bend area, east of Country Club Rd.
32	TT 88-28	t	location is not apparent on the DM drawings; likely is upstream from (north of) trench location TT88-27; it is in the bend area of *el Rillito*, east of Country Club Rd.
33	TH 88-16	b	slightly right of c/l on el Rillito invert, approximately sta. 626+50, in the north-south trending segment of the bend area, east of Country Club
34	TT 88-29	t	slightly right of c/l on el Rillito, within 5 ft of trench TT88-30 (see below), approximately sta. 613+75, which is in vicinity of where Country Club Rd would project northward to el Rillito.
35	TT 88-30	t	at toe of right (northerly) bank, el Rillito, approximately sta. 613+75, which is in vicinity of where Country Club Rd would project northward to el Rillito.
36	TT 88-31	t	at toe of right (north) bank, *el Rillito*, approximately station 597+75, about where Country Club Rd. would project northward to *el Rillito*
37	TT 88-32	t	adjoins TT88-31; on upper part of wash bank
38	TH 88-05	b	on *el Rillito* c/l, approximately sta. 544, about 200 ft u/s of vicinity of Campbell

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TT88-01, a trench. Explorations of August and September 1988.

ELEV. FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2426.0	0					-4	-200	
	2	SP	2			83	3	Poorly graded sand with gravel, grayish brown, gravel to ¾ in.
	3					67	1	brown gravel to ½ in.
	5		7			78	2	
	8	SW-SC	21	62	31	70	8	Well graded sand with clay and gravel: brown gravel to ¾ in; few cobbles to 4 in.
	11	SP	22			52	3	Poorly graded sand with gravel: brown, gravel to 1 ½ in. GROUNDWATER at -11 ft
	15	SW				71	3	Well graded sand with gravel: brown, wet, occasional cobble to 5 in.
2411.0								--

TT88-02, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2430.0	0					-4	-200	
	2	SP-SM	5		NP	83	5	Poorly graded sand with silt and gravel; dark brown occasional cobble to 4 ½ in.
	5	SM		22	2	100	31	Silty sand: brown, moist, fine grained.
	8	SP-SM			NP	80	5	Poorly graded sand with silt and gravel; brown, moist, gravel to ¾ in.
	11.5				NP	90	12	Poorly graded sand with silt
	14	SW-SM			NP	ille-gible	8	Well graded sand with silt and gravel: dark brown, moist, gravel to ¾ in, occasional cobble to 4 in.
	17	SP	14			68	4	Poorly graded sand with silt and gravel;
2413.0								--

groundwater not encountered

TT88-03, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2414.0	0					-4	-200	
	1	SP	6			75	3	Poorly graded sand with gravel: brown, gravel to 1 ½ in.
	3					81	3	
	6		8			67	4	few cobbles to 6 in
	9	SW-SM			NP	73	8	Well graded sand with silt and gravel: dark brown, wet, gravel to 1 ½ in.
	12	SP				64	4	Poorly graded sand with gravel: brown, gravel to 1 ½ in.
	15	GP				40	3	GROUNDWATER at -12 ft
	17	SM			NP	91	27	
2397.0								--

TT88-04, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2414.0	0					-4	-200	
	1	SP				89	3	Poorly graded sand: light brown, few gravel to ¾ in.
	3		4			89	2	
	6					70+ (ille-gible	4	Poorly graded sand with gravel: brown, moist, gravel to 1 ½ in.
	9					67	3	
	12	SW-SM			NP	77	5	Well graded sand with silt and gravel: dark brown, wet, gravel to ¾ in.
	15	SW	9			66	4	Well graded sand with gravel: dark brown, gravel to ¾ in.
2399.0								--

groundwater not noted

TT88-05, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2414.0	0					-4	-200	
	1	SP	2			76	2	Poorly graded sand with gravel: grayish brown, gravel to 1 ½ in.
	3.5					75	0	damp to moist
	7	GP				46	2	Poorly graded gravel with sand: dark brown, wet, gravel to ¾ in., occasional cobble to 5 in.
	10	SP				60	4	Poorly graded sand with gravel: dark brown, wet, gravel to 2 in., occasional cobble to 5 in.
	13.5					74	3	
	17	SP_SM			NP	81	5	Poorly graded sand with silt and gravel: dark brown, wet, gravel to 1 ½ in.
2397.0								--

groundwater not noted

TT88-06, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2420.0	0					-4	-200	
	2	SP	2			85	3	Poorly graded sand with gravel: light brown, gravel to ¾ in.
	5					55	1	brown, moist, gravel to 1 ½ in
	7		3			59	1	
	8.5					61	2	dark brown
	11.0					83	3	gravel to ¾ in
	14.0					78	2	gravel to 1 ½ in
	16.0	SW				76	2	Well graded sand with gravel: dark brown, wet, gravel to 1 ½ in
2404.0								--

groundwater not noted

TT88-07, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2406.0	0					-4	-200	
	2	SP				82	3	Poorly graded sand with gravel: light brown, gravel to 1 ½ in.
	3		3			83	1	
	6					98	4	Poorly graded sand: brown, moist, few gravel to ¼ in.
	7.5		14			74	4	Poorly graded sand with gravel: dark brown, gravel to ¾ in.
	10.5					67	2	wet, gravel to 3 in
	14					70	4	gravel to ¾ in
	17					78	3	
2389.0								--

groundwater not noted

TT88-08, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2412.0	0					-4	-200	
	2	SC-SM		24	6	95	43	Silty, clayey sand: brown, dry, fine to medium grained, few gravel to ¾ in.
	4	SP				83	3	Poorly graded sand with gravel: light gray, dry, gravel to 1 ½ in.
	7		2			63	0	gray, gravel to 2 in
	9					82	1	moist
	12					70	1	brown, gravel to 1 ½ in
	15		3			75	2	dark brown, occasional cobble to 5 in
	18					80	2	moist
2394.0								--

groundwater not encountered

TT88-09, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2398.0	0					-4	-200	
	2	SW-SM	4		NP	77	10	Well graded sand with silt and gravel: brown, gravel to 1 ½ in.
	3.5	SP				84	2	Poorly graded sand with gravel: grayish brown, moist, gravel to ¾ in.
	5.5		9			65	4	dark brown, gravel to 1 ½ in, occasional cobble to 6 in.
	9.5	SW				60	3	Well graded sand with gravel: dark brown, wet, gravel to 1 ½ in., occasional cobble to 6 in..
	12					74	4	
	16	SP				68	4	Poorly graded sand with gravel: dark brown, wet, gravel to 1 ½ in.
2382.0								--

groundwater not noted

TT88-10, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2404.0	0					-4	-200	
	1	SP-SC		26	7	74	11	Poorly graded sand with silty clay and gravel: brown, dry, gravel to 1 ½ in.
	3	CL-ML		19	5	100	52	Sandy silty clay and gravel: brown, dry to moist
	6.5	SP	1			71	2	Poorly graded sand with gravel: grayish brown, gravel to 1 ½ in.
	10					92	ille-gible	Poorly graded sand: moist, occasional cobble to 5 in.
	13		2			65	3	Poorly graded sand with gravel: dark brown, gravel to 1 ½ in.
	16.5					65	2	moist, gravel to ¾ in.
2387.5								--

groundwater not encountered

TT88-11, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2394.0	0					-4	-200	
	1	SP				78	4	Poorly graded sand with gravel: dark brown, moist, gravel to 1 ½ in., occasional cobble to 4 in.
	3	SW	5			84	1	Well graded sand with gravel: dark brown, gravel to 1 ½ in.
	6	SM			NP	96	21	Silty sand: brown, moist, few gravel to 3/8 in.
	10		13		NP	78	13	Silty sand with gravel: gravel to 1 ½ in., few cobbles to 4 in.
	13	SP-SM			NP	90	10	Poorly graded sand with silt: brown, moist, few gravel to ¾ in.
	17	SW-SM			NP	73	11	Well graded sand with silt and gravel: brown, wet, gravel to 1 in., few cobbles to 5 in.
2377.0								--

groundwater not noted

TT88-12, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2398.0	0					-4	-200	
	1	SP-SM			NP	100	11	Poorly graded sand with silt: brown, moist, fine grained
	3.5	SC-SM	4	25	6	85	27	Silty clayey sand with gravel: brown, gravel to ¾ in.
	8			26	5	88	13	Silty clayey sand: moist, few subrounded to subangular gravel to 1 ½ in., one 12-in. by 16-in. boulder.
	12	GP-GC		27	11	44	10	Poorly graded gravel with clay and sand: brown to rust, moist, subangular gravel to 2 in., occasional cobble to 8 in.
2386.0								--

groundwater not noted

TT88-13, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2390.0	0					-4	-200	
	2	SW-SM	3		NP	84	9	Well graded sand with silt and gravel: brown, gravel to ¾ in.
	5	SP				96	1	Poorly graded sand: grayish brown, moist, occasional gravel to 3/8 in.
	7					58	1	Poorly graded sand with gravel: brown, gravel to 1 ½ in., occasional cobble to 6 in.
	10.5	SM			NP	98	22	Silty sand: grayish brown to blackish brown, moist, occasional gravel to ½ in.
	12			26	2	72	42	Silty sand with gravel: dark brown, slight cohesion, gravel to ½ in., occasional cobble to 5 in.
	16	SW	16			76	3	Well graded sand with gravel: dark brown, medium to coarse grained, gravel to 1 ½ in.
2374.0								--

groundwater not noted

TT88-14, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2400.0	0					-4	-200	
	2	SM			NP	89	29	Silty sand: brown, moist.
	5	CL		29	8	100	66	Sandy lean clay: brown, moist, cohesive, occasional gravel to 1 in.
	8	SC-SM	3	22	4	100	47	Silty clayey sand: brown, fine grained, occasional gravel to 1 ½ in., occasional cobble to 5 in.
	11.5	SP				85	3	Poorly graded sand with gravel: light brown, moist, gravel to 2 in.
	14.5					88	4	Poorly graded sand: dark brown, few gravel to 1 ½ in.
	17	SP-SM	8		NP	94	10	Poorly graded sand with silt: dark brown, few gravel to ¾ in.
2383.0								--

groundwater not noted

TT88-15, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2386.0	0					-4	-200	
	1.5	SP	4			79	4	Poorly graded sand with gravel: brown, gravel to ¾ in.
	3.5					70	4	wet
	7	SP-SC	14	61	32	81	12	Poorly graded sand with clay and gravel: brown, gravel to 1 ½ in., occasional cobble to 6 in.
	10	SW-SM			NP	76	7	Well graded sand with silt and gravel: dark brown, wet, gravel to 1 ½ in., few cobbles to 5 in.
	13				NP	67	5	few cobbles to 8 in.
	17				NP	73	8	gravel to ¾ in., trench walls caving
2369.0								--

groundwater not noted

TT88-16, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2390.0	0					-4	-200	
	1	SP	3			100	1	Poorly graded sand: light brown.
	4					79	2	Poorly graded sand with gravel: damp, gravel to 1 ½ in.
	7.5					62	2	subrounded to subangular gravel to 3 in, occasional cobble to 4 in.
	10	SW	5	41	17	63	4	Well graded sand with gravel: dark brown, gravel to 1 ½ in.
	13	SW-SC		47	27	83	7	Well graded sand with clay and gravel: dark brown, moist, cohesive, gravel to 1 ½ in.
	17	SC		29	8	82	40	Clayey sand with gravel: dark brown, moist, cohesive, gravel to ¾ in
2373.0								--

groundwater not noted

TT88-17, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2382.0	0					-4	-200	
	3	SW-SM	3			82	9	Well graded sand with silt and gravel: brown, gravel to ¾ in.
	4.5	SP	5			86	2	Poorly graded sand: brown, few gravel to ¾ in., occasional cobble to 5 in.
	6		11		NP	82	1	Poorly graded sand with gravel: gravel to ¾ in.
	8	SW-SM		28	5	89	41	Well graded sand with silt and gravel: brown, moist, gravel to ¾ in., few silt lenses.
	11	SM			NP	74	6	Silty sand: brown, moist, slight cohesion, few gravel to ¾ in.
	14	SP-SM				69	3	Poorly graded sand with silt and gravel: dark brown, moist, gravel to 1in., few cobbles to 5 in.
	17	SP						Poorly graded sand with gravel: dark brown, moist, gravel to ¾ in.
2365.0								--

groundwater not encountered

TT88-18, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2387.0	0					-4	-200	
	2	SM				85	37	Silty sand with gravel: light brown, moist, gravel to 1 ½ in.
	5	SP				80	2	Poorly graded sand with gravel: brown, moist, subrounded to subangular gravel to 1in., occasional cobble to 5 in.
	8.5	SW	2			79	4	Well graded sand with gravel: brown, gravel to 1 ½ in.
	11	SP-SC		20	4	89	5	Poorly graded sand with silty clay: dark brown, moist, slight cohesion, few gravel to ¾ in.
	13.5	SW-SM			NP	79	6	Well graded sand with silt and gravel: dark brown, moist, gravel to ¾ in.
	16		4		NP	73	8	
2371.0								--

groundwater not encountered

TT88-19, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2376.0	0					-4	-200	
	1.5	SP				83	4	Poorly graded sand with gravel: brown, moist, gravel to ¾ in.
	3.5					85	1	gravel to 2 in.
	7	SW-SM	10	NP		78	6	Well graded sand with silt and gravel: dark brown, gravel to 1 in., few cobbles to 4 ½ in.
	9	GP-GM		NP		45	5	Poorly graded gravel with silt and sand: dark brown, wet, gravel to 1 ½ in., occasional cobble to 5 in.
	12	GP				49	1	Poorly graded gravel with sand: dark brown, wet, gravel to 2 in., few cobbles to 4 in.
	16	SP-SM	11	NP		59	5	Poorly graded sand with silt and gravel: dark brown, gravel to 2 in., few subrounded to subangular cobbles to 8 in.
2360.0								--

groundwater not noted

TT88-20, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2382.0	0					-4	-200	
	3	SP				64	4	Poorly graded sand with gravel: brown, moist, gravel to 1 ½ in.
	4					61	1	dark brown, few cobbles to 4 in.
	7.5	SW-SM	4		NP	81	6	Well graded sand with silt and gravel: brown, gravel to 1 ½ in., some wire debris
	11				NP	82	6	wet, gravel to 2 in., few cobbles to 5 in.
	14	SP-SM	9		NP	61	8	Poorly graded sand with silt and gravel: dark brown, gravel to 2 in., few cobbles to 5 in.
	17	GP				52	4	Poorly graded gravel with sand: dark brown, wet, gravel to 3 in., occasional cobble to 4 in.
2365.0								--

groundwater not noted

TT88-21, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2370.0	0					-4	-200	
	2	SP	4			66	3	Poorly graded sand with gravel: brown, gravel to 1 ½ in., few surface debris.
	5	SC-SM		19	4	88	27	Silty clayey sand: brown, moist, cohesive, fine grained, few gravel to ¾ in., occasional cobble to 4 in.
	7	GW	11			34	3	Well graded gravel with sand: dark brown, gravel to 1 ½ in., few cobbles to 5 in.
	10	SP-SM			NP	62	6	Poorly graded sand with silt and gravel: light brown, wet, gravel to 1 ½ in., few cobbles to 5 in.
	13	GP-GM			NP	50	5	Poorly graded gravel with silt and sand: light brown, wet, gravel to 1 ½ in., cobbles to 5 in., few cobbles to 12 in.
	17	GW-GM			NP	49	7	Well graded gravel with silt and sand: light brown, wet, gravel to 2 in., cobbles to 5 in., few cobbles to 12 in.
2353.0								--

groundwater not noted

TT88-22, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
23878.0	0					-4	-200	
	2	SP-SM			NP	67	8	Poorly graded sand with silt and gravel: brown, dry to moist, gravel to 1 ½ in., few cobbles to 5 in.
	5	SM			NP	96	18	Silty sand: brown, moist, fine grained, few gravel to 1 in.
	8	SP	2			91	4	Poorly graded sand: light brown, few gravel to ¾ in., occasional cobble to 5 ½ in.
	11					76	0	Poorly graded sand with gravel: brown, moist, gravel to 1 ½ in., ., occasional cobble to 5 in.
	14					81	0	
	17		2			ille-gible	2	dark brown, gravel to ¾ in.
2361.0								--

groundwater not encountered

TT88-23, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2366.0						-4	-200	
	2	SP	7			87	3	Poorly graded sand: brown, few gravel to ¾ in.
	4.5	ML			NP	98	54	Sandy silt: brown, wet, occasional gravel to ½ in.
	7		17	45	18	99	62	Silty sand: dark brown to black, stopped excavating a 7 ft depth due to water . groundwater encountered at - 7 ft
2359.0								--

TT88-24, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2374.0	0					-4	-200	
	2	SM	6		NP	90+ (ille-gible)	48	Silty sand: brown, fine grained, roots to 6-in. depth, on surface occasional cobble to 5 ½ in.
	5	SP				ille-gible	4	Poorly graded sand with gravel: brown, moist to wet, gravel to ¾ in., occasional cobble to 4 in.
	8	GP				44	4	Poorly graded gravel with sand: moist to wet, gravel to 1 ½ in., occasional cobble to 4 in. groundwater encountered at -8 ft
	11		7			40	3	gravel to 2 in.
	13	GW				23	2	Well graded gravel with sand: brown, wet, coarse grained, gravel to 3 in., few cobbles to 6 in.
	16	SW-SC		29	9	ille-gible	8	Well graded sand with clay and gravel: brown, wet, cohesive, fine to medium grained, few cobbles to 6 in.
2358.0								--

TT88-25, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2366.0	0					-4	-200	
	1.5	SP-SM			NP	99	5	Poorly graded sand with silt: brown, moist, fine to medium grained, occasional gravel to ¼ in.
	3.5	SP	3	20	3	69	6	Poorly graded sand with silt and gravel: gravel to 3 in.
	7					90	4	Poorly graded sand: brown, moist, few gravel to ¾ in., occasional cobble to 5 ½ in.
	10					94	4	wet, few subangular gravel to ½ in.
	13		10			66	2	Poorly graded sand with gravel: gravel to 1 ½ in.
	17	GP				49	2	Poorly graded gravel with sand: brown, wet, gravel to 1 ½ in.
2349.0								--

groundwater not noted

TT88-26, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2370.0	0					-4	-200	
	1	SP				79	2	Poorly graded sand with silt: brown, moist, gravel to 1 in., occasional cobble to 5 ½ in.
	3		3			66	2	gravel to 1 ½ in., few cobbles to 4 ½ in.
	7	GP				36	3	Poorly graded gravel with sand: dark brown, moist, gravel to ¾ in., few cobbles to 4 ½ in.
	10.5	SW				80	4	Well graded sand with gravel: dark brown, moist, gravel to ¾ in., few cobbles to 6 in.
	13.5	SP-SC		31	12	53	5	Poorly graded sand with clay and gravel: dark brown, moist, cohesive, gravel to ¾ in., few cobbles to 6 in.
	17	SW-SC	ille-gible	35	15	66	8	Well graded sand with clay and gravel: dark brown, cohesive, gravel to 1 ½ in., few cobbles to 6 in.
2353.0								--

groundwater not noted

TT88-27, a trench. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2354.0	0					-4	-200	
	2	SP				82	4	Poorly graded sand with gravel: brown, wet, cohesive, gravel to ¾ in.
	4.5		8			81	4	
	7.5					61	1	subrounded to subangular gravel to 1 ½ in.
	10.5	GW				29	1	Well graded gravel with sand: brown, wet, gravel to 1 ½ in., few cobbles to 6 in.
	13	SP				58	3	Poorly graded sand with gravel: brown, wet, gravel to 1 ½ in.
	16		10			70	4	
2338.0								--

groundwater not noted

TT88-28. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2366.0	0					-4	-200	
	3	SP				94	3	Poorly graded sand: brown, moist, few gravel to ¾ in., few cobbles to 5 in.
	7					68	3	Poorly graded sand with gravel: subangular gravel to ¾ in.,
	10		17			94	4	Poorly graded sand: few gravel to 1 ½ in.
	13.5					95	2	wet, few gravel to 3/8 in.
	18		10			96	1	occasional gravel to 2 in.
2348.0								--

groundwater not noted

TT88-29, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2350.0	0					-4	-200	
	2.5	SM			NP	100	36	Silty sand: brown, moist, fine grained, occasional gravel to 1 ½ in.
	5.5	SP-SM	4		NP	81	5	Poorly graded sand with silt and gravel: brown, gravel to 1 ½ in., few cobbles to 5 in.
	8.5	SC-SM		26	7	63	17	Silty clayey sand with gravel: brown, moist, gravel to ¾ in.
	11	SW-SM			NP	74	6	Well graded sand with silt and gravel: brown, wet, gravel to ¾ in., trench walls caving.
	14	SP-SM			NP	64	6	Poorly graded sand with silt and gravel: brown, wet, gravel to 1 ½ in., large rock or pipe, trench walls caving.
2336.0								--

groundwater not noted

TT88-30, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2362.0	0					-4	-200	
	2	SM		23	2	98	44	Silty sand: brown, moist, fine to medium grained.
	5	SP	3			59	1	Poorly graded sand with gravel: brown, gravel to 1 ½ in.
	8					63	2	moist, gravel to 2 in., few cobbles to 5 in.
	11					75	1	
	14					57	1	wet, gravel to 3 in., few cobbles to 8 in.
	17	GP	7			45	3	Poorly graded gravel with sand: brown, gravel to 3 in.
2345.0								--

groundwater not noted

TT88-31, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2344.0	0					-4	-200	
	1.5	SW-SM			NP	84	8	Well graded sand with silt and gravel: brown, moist, gravel to 1 ½ in., one piece of concrete 18 in X 18 in X 4 in..
	3.5	GW	8			31	3	Well graded gravel with sand: brown, gravel to 1 ½ in.
	7.5	GP				43	3	Poorly graded gravel with sand: brown, wet, gravel to 2 in., occasional cobbles to 5 in.
	10.5	SP				74	4	Poorly graded sand with gravel: brown, wet, gravel to 1 ½ in.
	13					74	3	
	17		8			52	2	gravel to 1 ½ in.
2327.0								--

groundwater not noted

TT88-32, a trench. Explorations of August and September 1988.								
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		DESCRIPTION
2364.0	0					-4	-200	
	2	SW-SM	5		NP	77	9	Well graded sand with silt and gravel: brown, gravel to 1 ½ in.
	5	SP				76	2	Poorly graded sand with gravel: brown, moist, gravel to ¾ in.
	9	SW-SM		22	3	65	9	Well graded sand with silt and gravel: brown, moist, gravel to ¾ in., stopped excavating due to large rock or pipe.
2355.0								--

groundwater not encountered

TH88-01, a boring. Explorations of August and September 1988.									
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2428.0	0					-4	-200		
	3	SW-SM	5		NP	81	5	9	Well graded sand with silt and gravel: brown, loose, gravel to ¾ in.
	5.5	SP	10			84	3		Poorly graded sand with gravel: brown, wet, gravel to ¾ in. groundwater encountered at -5.5 ft
	7	SP-SM			NP	75	12		Poorly graded sand with silt and gravel: brown to black, gravel to ¾ in.
	10	SP				84	4		Poorly graded sand with gravel: dark brown, gravel to 1 ½ in., few cobbles to 5 in.
	13	SP-SM			NP	72	6	19	Poorly graded sand with silt and gravel: dark brown, gravel to 1 ½ in., few cobbles to 5 in.
	16	SP				62	3		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 5 in.
	19					55	3		few cobbles to 6 in.
	21	SW-SM			NP	64	5		Well graded sand with silt and gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	24	SP				59	3		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
2404.0									--

TH88-02, a boring. Explorations of August and September 1988.									
ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2400.0	0					-4	-200		
	3	SW-SM	4		NP	89	5		Well graded sand with silt: brown, few cobbles to 4 in.
	6				NP	71	7		Well graded sand with silt and gravel: dark brown, gravel to 1 ½ in. few cobbles to 6 in
	9	GP-GM			NP	37	6		Poorly graded gravel with silt and sand: dark brown, gravel to 1 ½ in., few cobbles to 6 in.
	12	SP-SM			NP	88	5		Poorly graded sand with silt: dark brown, few gravel to 1 ½ in., few cobbles to 6 in.
	15	SW-SM			NP	93	10		Well graded sand with silt: few gravel to 1 ½ in.
	18	SP				75	4		Poorly graded sand with gravel: dark brown, gravel to 1 ½ in., occasional cobble to 6 in.
	21					60	3		brown, occasional cobble to 8 in.
	24	GP				47	2		Poorly graded gravel with sand: brown, gravel to 1 ½ in., few cobbles to 8 in
	27	SP				57	1		Poorly graded sand with gravel: dark brown, gravel to 1 ½ in., few cobbles to 8 in.
	28	GW-GM				50	5		Well graded gravel with silt and sand: brown, gravel to 1 ½ in., few cobbles to 8 in.
2372.0									--

groundwater not noted

TH88-03, a boring. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2318	0					-4	-200		
	3	SW-SM	4		NP	85	6		Well graded sand with silt and gravel: brown, few gravel to ¾ in.
	6	SP-SM	5		NP	77	5	15	Poorly graded sand with silt and gravel: brown, gravel to ¾ in.
	9		16		NP	92	6	16	Poorly graded sand with silt: brown, few gravel to 3/8 in.
	12	SW-SM			NP	79	9		Well graded sand with silt and gravel: gravel to 3 in.
	15	GP-GM			NP	48	7		Poorly graded gravel with silt and sand: brown, gravel to 1 ½ in., few cobbles to 6 in.
	18	GP				47	4		Poorly graded gravel with sand: brown, gravel to 1 ½ in., few cobbles to 6 in.
	21	GP-GM			NP	47	5		Poorly graded gravel with silt and sand: brown, gravel to 1 ½ in., few cobbles to 6 in.
	24	SP				56	4		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	27					57	4		
2291.0									--

groundwater not noted

TH88-04, a boring. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2386.0	0					-4	-200		
	3	SP	5			88	4		Poorly graded sand: brown, few gravel to ¾ in.
	5	SM	6	42	15	90	15	30	Silty sand: brown.,
	8	SP				56	3		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	11	SP-SM	13		NP	66	7	27	Poorly graded sand with silt and gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	14	GP-GM			NP	43	7		Poorly graded gravel with silt and sand: brown, gravel to 1 ½ in., few cobbles to 6 in.
	17	SP-SM			NP	60	6		Poorly graded sand with silt and gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	20	GP				43	4		Poorly graded gravel with sand: brown, gravel to 3 in., few cobbles to 6 in.
	23	SP				56	2		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	26	GP				50	1		Poorly graded gravel with sand: brown, gravel to 1 ½ in., few cobbles to 6 in.
	29.5					44	1		gravel to 3 in.
2356.5									--

groundwater not noted

TH88-05, a boring. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2326.0	0					-4	-200		
	3	SP-SM	7	20	2	76	11		Poorly graded gravel with silt and sand: dark brown, gravel to 1 ½ in., asphalt debris.
	6	SP-SC	7	28	9	54	6		Poorly graded sand with clay and gravel: dark brown, gravel to 3 in., occasional cobble to 4 in., asphalt debris.
	7	CL		39	15	92	56		Sandy clay: dark brown, cohesive, organic matter, fine grained sand, few gravel to ¾ in.
	9	GC	10	39	16	60	23		Clayey gravel: dark brown, cohesive, gravel to 1 ½ in., few cobbles to 5 in.
	12	SW-SM			NP	61	5		Well graded sand with silt and gravel: brown, gravel to 1 ½ in., few cobbles to 5 in.
	15	SP				54	3		Poorly graded sand with gravel: dark brown, gravel to 1 ½ in., few cobbles to 5 in.
	18	SW-SM			NP	87	7		Well graded sand with silt: brown, few gravel to ¾ in., few cobbles to 6 in.
	21	SP				62	4		Poorly graded sand with gravel: brown, gravel to 1 ½ in., few cobbles to 6 in.
	24	SP-SM			NP	60	8		Poorly graded sand with silt and gravel: reddish brown, gravel to 1 ½ in., few cobbles to 8 in.
	27	SM		28	5	90	19		Silty sand: reddish brown, gravel to ¾ in., cobbles to 8 in.
	30			24	3	76	16		Silty sand with gravel: reddish brown, gravel to 1 ½ in., cobbles to 8 in.
2296.0									--

groundwater not noted

TH88-16, a boring. Explorations of August and September 1988.

ELEV FT	DEPTH FT	SOIL CLASS	MC	LL	PI	MECH ANAL		N	DESCRIPTION
2356.0	0					-4	-200		
	3	SP	3			62	2		Poorly graded sand with gravel: gray, gravel to 1 ½ in.
	6	SW-SM			NP	83	12		Well graded sand with silt and gravel: gray, wet, gravel to 1 ½ in., occasional cobble to 5 in.
	9			27	3	67	9		
	12	GP				46	4		Poorly graded gravel with sand: dark brown, wet, gravel to 1 ½ in., few cobbles to 5 in.
	15	GW-GM			NP	51	7		Well graded gravel with silt and sand: dark brown, wet, gravel to 1 ½ in., few cobbles to 5 in.
	18				NP	41	7		
	21	GP-GM			NP	52	9		Poorly graded gravel with silt and sand: dark brown, wet, gravel to 1 ½ in., few cobbles to 5 in.
	24	SP-SM			NP	59	5		Poorly graded sand with silt and gravel: dark brown, wet, gravel to 1 ½ in.
	27				NP	60	8		
	30	SW-SM			NP	72	8		Well graded sand with silt and gravel: light brown, wet, gravel to 1 ½ in.
2326.0									--

groundwater not noted

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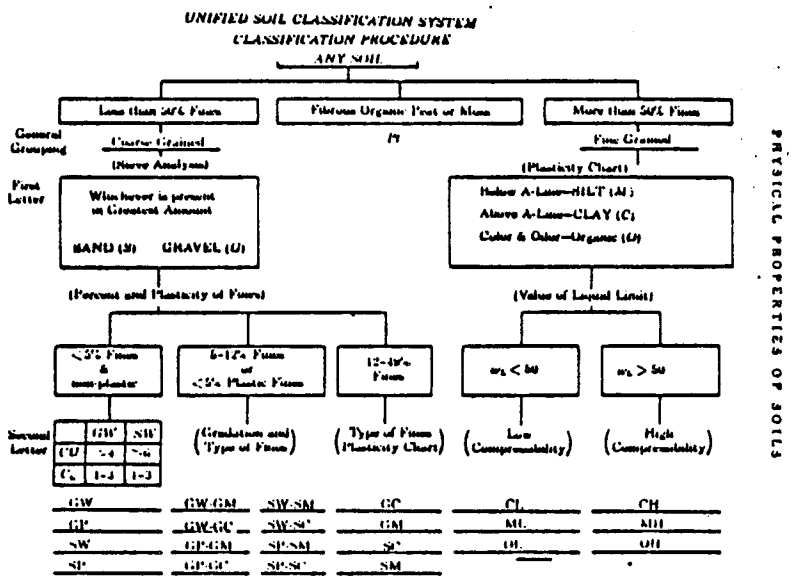
Attachment 2. 1988 Desert Earth Engineering borings logs and laboratory test results in the Campbell-to-Cactus vicinity of the study area (scanned from PDTFCD, 1991). See attached .pdf file. Hole locations shown on fig. 13 of the current report.

See attached .pdf file, which is a separate electronic document

Appendix A.
Soil Boring and Trenching Logs

METHOD OF SOIL CLASSIFICATION



GRAIN SIZE CHART

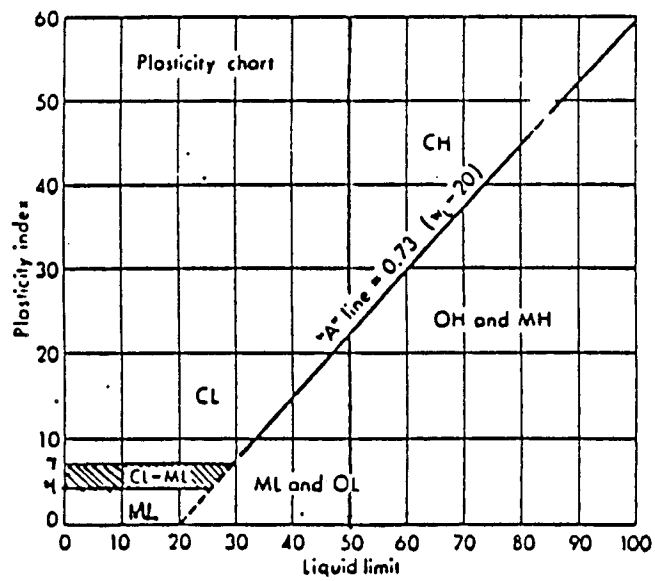
CLASSIFICATION	U.S. Standard Sieve Size
BOULDERS	Above 12"
COBBLES	12" to 3"
GRAVEL Coarse Fine	3" to No.4 3"to3/4" 3/4"toNo.4
SAND Coarse Medium Fine	No.4toNo.200 No.4toNo.10 No.10toNo.40 No.40toNo.200
SILT & CLAY	below No.200

Coarse Grained Scale
(50% retained on #200 sieve)

Adjective	%
with trace	1-12
with some	12-30
add "y" (ey)	> 30

P = poorly graded
W = well graded

Fine Grained Soils
(50% passing #200 sieve)



L = low compressibility
H = high compressibility

P.I.	Adjective	Silt (ML & MH)	Clay (CL & CH)	Organics (OL & OH)
< 1	non-plastic	--	--	--
1-10	slightly plastic	--	silty	--
10-20	medium plastic	clayey	silty to no adj.	silty
20-40	plastic	clayey	--	clayey
> 40	very plastic	clayey	--	--

desert earth engineering

BLOW COUNT - DENSITY RELATIONS

Cohesionless coarse-grain soils

Density	N_{spt}*
very loose	< 4
loose	4 - 10
medium dense	10 - 30
dense	30 - 50
very dense	> 50

* N_{spt} is the Standard Penetration Test (SPT) blows/ft resistance using a 2 in. O.D. x 1 3/8 in. I.D.

Cohesive fine-grained soils

For cohesive fine-grained soils, design is usually governed by the moisture content, plasticity, consolidation, compressiblity, or swell properties. Therefore, field penetrometer readings giving an indication of strength as characterized by the consistency or cohesion of a soil can be misleading and are not presented here.

The blows to drive a 3 in. O.D. x 2.416 in. I.D. ring sampler 1 ft will be greater than for a split spoon sampler if the same driving energy is used for both.

EXPANSION - SWELL

The expansion of clayey soils is measured according to the UBC Std. No. 29-2. Under this proceedure the expansion potential of a soil is measured when remolded to 95% of standard Proctor density at 3% below optimum moisture and subjected to saturation under a surcharge of 144 psf. Expansion potential may be characterized as follows:

Expansion (%)	Swell Characterizations
< 2%	Low
2 - 5%	Moderate
> 5%	High

COLLAPSE - CONSOLIDATION

The collapse or settlement potential of a soil is measured by loading a 2.5 in. O.D - 2.416 I.D. ring sample (trimmed to 1 in. height) to the surcharge anticipated in the field and then saturating the sample. Collapse characterizations for various amounts of settlements on Tucson soils are as follows:

Total Settlement (%)	Collapse Characterizations
< 4	low
4 - 7	moderate
7 - 10	high
> 10	very high

DRILLING, SAMPLING, AND FIELD TESTING EQUIPMENT

DRILLING: The drilling is performed using a Central Mining Equipment CME-55 or CME 75 drill rig capable of auger drilling, rotary wash drilling, and rock coring. Auger drilling is performed using 6 5/8" OD x 3 1/4" ID hollow-stem augers with carbide-tipped teeth. Rotary wash drilling employs a tricone gear bit and core drilling a diamond bit. These latter methods use high pressure water as a drilling fluid.

SAMPLING: Disturbed samples are achieved using a standard 2" OD x 1 3/8" ID split spoon sampler. The ID dimension is that of the inner brass liner. "Undisturbed" samples of cohesive fine-grained soils are obtained using a ring sampler of 3" OD x 2.5" ID. The series of 1" long, 2.416" ID brass rings in the sampler have a 2.5" OD and therefore readily fit into laboratory direct-shear and consolidation equipment.

FIELD TESTING: An approximation of the soil's density and consistency, from which strength estimates can be made, is obtained using the penetration resistance to driving of the samplers. The Standard Penetration Test (SPT) N-value is the number of blows to drive a standard 2" OD x 1 3/8" ID split spoon sampler 1 ft. using a 140-pound weight dropping 30". Where driving resistance is difficult, blows/inches-driven values are presented.

A 3" OD ring sampler will generally have a larger blow count than will the split spoon sampler if the same driving energy is used for both.

Continuous-penetration resistance can be obtained using a 2.0" OD bull-nose penetrometer. When using the SPT driving energy the blow counts on a bull-nosed penetrometer are approximately equal to or greater than the N-value (blows/ft) resistance obtained.

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.c.D.O.T&F.C.D	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT	BORING NO.
CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers	B-1
	SHEET 1 OF 1
SAMPLING METHOD	ENGINEER
Split-spoon Penetrometer	DRM
	TIME
	DATE
CASING DEPTH	9/30/88

DATUM Channel bed ELEVATION +1.5'

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-NOSE BLOWS/FT	WATER LEVEL	SURFACE CONDITIONS
			0	3		North bank cemented with soil cement steep 12' high. Channel exposes coarse to fine SAND with trace silt. South bank has deposition on inside of meander with large cobbles, concrete chunks (cobble-boulder size) with SILTY SAND MATRIX (SW-SM) Brown SAND with trace silt and gravel; medium dense, dry, nonplastic (large cobbles top one foot) becomes slightly moist
SS	18/18	3/5/7	1	—		
			2	14		occasional gravel layers 1.5-5.0 feet "some gravel"
			3	33		
			4	33		
			5	22		(SW) Brown GRAVELY SAND with trace silt medium dense, moist, nonplastic.
SS	18/18	7/10/12	6			
			7			
			8			continued gravely to 10.0 feet
			9			
			10			(GW-GM) Brown SANDY GRAVEL with trace silt; medium dense, wet, slightly plastic.
RS	12/12	19/15	11			
			12			
			13			Bottom of Boring
			14			
			15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

BORING NO.: B-2

SHEET: 1 of 1

ENGINEER: DRM

TIME:

DATE: 9-30-88

DATUM: Channel bed ELEVATION: 0.0

CASING DEPTH:

SURFACE CONDITIONS: NORTH BANK: 6 feet high and steep with trash and roded soil cement. Channel: SANDY on north side with cobbles and few boulders in middle of channel and extending to south bank.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-HOLE BLOWS/FT	WATER LEVEL	
			0			(SW-SM) SAND with some gravel, trace silt; medium dense, moist nonplastic
SS	18/18	4/6/8	1	11		
			2	16		increase in gravel
			3	25		
			4	28		
SS	18/18	5/8/13	5	20		(SP-SM) Brown GRAVELY SAND with trace silt; medium dense, wet, nonplastic.
			6			
			7			
			8			(SP) Brown SAND with some gravel, trace silt; medium dense, wet, nonplastic.
SS	18/18	4/10/10	9			
			10			
			11			
			12			Material consistent
RS	12/12	12/17	13			
			14			Bottom of Boring.
			15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING: See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-3

SHEET: 1 OF 1

ENGINEER: DRM

TIME:

DATE: 9-30-88

DATUM: Channel bed ELEVATION: 0

SURFACE CONDITIONS: On north side of channel on sand bar with SILTY SAND with coarse gravels and cobbles. Southern half of channel is "clean" SAND with a high 12 feet tall silty SAND south bank.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-NDSI BLOWS/FT	WATER LEVEL	
			0			(SW-SM) SAND with some gravel and trace silt; medium dense, dry, nonplastic.
SS	18/18	5/6/5	1	12		increase in sand and moist
			2	14		
			3	18		
			4	17		cuttings show GRAVELLY SAND with trace silt. moist to 4.0 feet.
			5	18		
SS	18/18	7/7/11	6			(SW) Brown SAND with trace silt and gravel; medium dense, moist, nonplastic.
			7			
			8			
			9			becomes "wet"
			0			
			11			
RS	12/12	11/16	12			(SW) Brown SAND with some gravel, trace silt, medium dense, moist, nonplastic.
			3			Bottom of Boring
			4			
			5			
			6			
			7			
			8			
			9			
			0			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D.	Rillito Wash Campbell to Cactus Blvd

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-4

SHEET: 1 OF 1

ENGINEER: DRM

TIME:

DATE: 9-30-88

DATUM Channel bed ELEVATION +1.0

SURFACE CONDITIONS: ON SAND BAR: Drainage converges on the north bank with 4-6 feet high bank. South bank has large cobble and boulder size concrete with other "trash" 12 feet high.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-HOLE BLOWS/FT	WATER LEVEL	
			0			
SS	18/18	3/6/6	1	5		(SW-SM) Brown SAN with some gravel and trace silt; medium dense, dry, nonplastic. becomes moist with more sand.
			2	21		
			3	38		
			4	45		
SS	18/18	9/11/15	5	44		(SW) Brown SAND with trace silt and gravel; medium dense, moist, nonplastic.
			6			
			7			
			8			
RS	12/12	9/11	9			(SW) Brown SAND with some gravel and trace silt; medium dense, wet, nonplastic.
			10			
			11			Material consistent
SS	18/18	4/6/6	12			
			13			Bottom of Boring
			14			
			15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-5

SHEET: 1 of 1

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: 14-16.0'

SURFACE CONDITIONS: On south bank = 400 feet east of Campbell Ave. Steep bank 14'16.0' high with concrete and gravel at surface large concrete slabs to east of boring on south bank.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-NOSE BLOWS/FT	WATER LEVEL	SURFACE CONDITIONS
			0			
SS	18/18	5/6/2	1	4		(SM) Brown SAND with some silt and gravel; loose, dry, nonplastic.
			2	5		
			3	25		increase in gravel
			4	20		
			5	14		
RS	12/12	12/18	6			(SM) Brown GRAVELLY SAND with some silt; medium dense, dry, nonplastic *disurbed sample.
			7			
			8			becomes finer grained SAND with trace gravel, some silt.
			9			
			10			
SS	18/18	11/11/14	11			(SW) Light Brown SAND with trace silt and gravel; medium dense, dry, nonplastic.
			12			
			13			cuttings show occasional pieces of adobe brick and course gravels at 14.0 feet.
			14			
			15			
SS	18/18	5/8/10	16			Materials consistent.
			17			
			18			
			19			
RS	12/12	6/17	20			(GW-GM) Brown SANDY GRAVEL with trace silt; loose, moist, nonplastic.
						Bottom of Boring.

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd

LOCATION OF BORING: See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-6

SHEET: 1 OF 1

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: +16-18.0'

SURFACE CONDITIONS: On south bank steep 16-18 feet high with large concrete slabs and steel pipe on bank. Other debris includes bricks, wire, plastic, wood and brush piles.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-BOX BLOWS/FT	WATER LEVEL	
			0			(SC) Brown SAND with some clay and gravel;
				21		very dense, dry, medium plastic.
SS	16/16	9/14/25[4]	1			
			2	50[6]		
			3			less gravel, slightly plastic.
			4			(SM) Brown SAND with some silt, trace gravel;
SS		5/6/5	5			medium dense, dry, slightly plastic.
			6			
			7			
			8			
			9			
			10			(SM) Dark brown SILTY SAND with some coarse gravel, medium dense, moist, nonplastic.
RS		4/16				
			11			coarse gravels in SILTY SAND matrix
			12			
			13			
			14			
			15			(SW-SM) Brown coarse SAND with some gravel,
SS	18/18	4/6/10	16			trace silt; medium dense, moist, nonplastic.
			17			
			18			
RS	12/12	17/20	19			(GW-GM) Brown SANDY GRAVEL with trace silt; medium dense, moist, nonplastic.
			20			Bottom of Boring

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-7

SHEET: 1 OF 1

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: +15

SURFACE CONDITIONS: On south bank-15'10 feet high with debris on bank including: large pieces of concrete, steel pipe, bricks and rusted steel. A converging drainage 30-40' wide by 10' deep drains into Rillito with a broken retaining wall.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-NOSI BLOWS/FT	WATER LEVEL	
			0			(SM) Brown SAND with some silt, trace gravel; medium dense, dry, nonplastic.
SS	18/18	3/9/20	1	14		
			2	37		
			3	23		less silt.
			4	15		
			5	17		
SS	18/18	3/5/8	6			(SW-SM) Brown SAND with trace silt and gravel; medium dense, dry, nonplastic.
			7			
			8			
			9			
			10			
RS	12/12	9/14	11			(SW-SM) consistent with slightly more gravel and moist.
			12			
			13			
			14			
			15			
SS	18/18	4/3/13	16			(SW-SM) consistent
			17			
			18			
SS	18/6	13/17/11	19			Consistent but wet.
			20			Bottom of Boring

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-8

SHEET: 1 of 1

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: +12.0

SURFACE CONDITIONS: On south bank: 12' high with large chunks of concrete and other debris.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-BOSE BLOWS/FT	WATER LEVEL	
			0			(SM) Brown SAND with some silt and trace gravel; very dense, dry, nonplastic. *Sampler bouncing on buried concrete.
SS	6/6	7/8 R/	1	17R		
			2			
			3			consistent but loose.
SS	18/18	3/3/3	4			
			5			Junk: wood, brass rings, cloth, blue marble and an increase in gravel.
			6			
			7			
			8			
			9			(SM) Brown SILTY SAND with some debris; loose, dry, nonplastic.
SS	18/18	3/3/5	10			
			11			
			12			increase in SAND and becomes slightly moist.
			13			
			14			(SW-SM) Brown SAND with trace silt and gravel; medium dense, moist, nonplastic.
RS	12/12	14/23	15			
			16			
			17			
			18			
SS	18/18	4/5/22	19			Consistent but loose with a 4 inch lense of "wet" SILTY SAND IN SHOE OF SAMPLER
			20			Bottom of Boring

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D	Rillto Wash Campbell to Cactus Blvd.

LOCATION OF BORING: See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-9

SHEET: 1 OF 2

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: +14.0

SURFACE CONDITIONS: North bank: 14 inch high cement protection with 4 feet of CLAYEY SAND bank to the north.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-NOSE BLOWS/FT	WATER LEVEL	
			0			(SM) Dark brown SILTY SAND; dense, dry, nonplastic
SS	18/18	4/10/20	1	15 / 44		becomes medium plastic CLAYEY SAND
			2			
			3	50"		(CL) Dark brown SANDY CLAY; hard, dry, medium plastic.
SS	12/12	18/34/-	4			
			5			
			6			
			7			
			8			No recovery of sample.
RS	12/0	12/17	9			
			10			
			11			becomes slightly moist
			12			
			13			(SW-SM) light brown SAND with trace silt and some fine gravel; medium dense, moist, nonplastic.
SS	18/18	6/6/6	14			
			15			
			16			
			17			
			18			
			19			see page two
RS	12/12	7/15	20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D.	Billito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH

BORING NO.: B-9

SHEET: 2 OF 2

ENGINEER: DRM

TIME

DATE: 10-3-88

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-NOSE BLOWS/FT	WATER LEVEL	
	12		20			(SW-SM) Light brown SAND with trace silt and gravel; medium dense, moist, nonplastic.
RS	12	7/15				*plasic moist clay in top of ring sampler
			21			
			22			
			23			material consistent but wet
			24			
	18		25			
SS	18	7/10/10				
			26			Bottom of Boring
			27			
			8			
			9			
			0			
			1			
			2			
			3			
			4			
			5			
			6			
			7			
			8			
			9			
			0			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-10

SHEET: 1 OF 2

ENGINEER: DRM

TIME:

DATE: 10-3-88

DATUM: Channel bed ELEVATION: +13

SURFACE CONDITIONS: Horse Corral on north bank; height of bank estimated to be 12-14 feet high, with no previous bank protection present.

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-DOSE BLOWS/FT	WATER LEVEL	
SS	18/18	5/7/7	0			(SM)Dark brown SILTY fine SAND; medium dense, dry, nonplastic.
			1	13		
			2	15		
			3	14		
			4	12		(SW-SM) Light brown SAND with trace silt and gravel; loose, dry, nonplastic. *small recovery
RS	12/1	4/6	5	9		
			6	9		
			7	11		increase in gravel.
			8	10		
			9	20		(SP-SM) Light brown GRAVELLY SAND with trace silt; medium dense, dry, nonplastic, with a small lense of slightly plastic SANDY SILT-CLAY in sampler.
SS	18/16	17/10/12	10	26		
			11			
			12			
			13			
			14			
			15			(SW-SM) Brown SAND with trace silt and gravel; medium dense, moist, nonplastic.
RS	12/6	8/15	16			* Poor recovery - No rings
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T&F.C.D	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT	CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers
SAMPLING METHOD	Split-spoon Penetrometer
CASING DEPTH	
BORING NO.	B-10
SHEET	2 OF 2
ENGINEER	DRM
TIME	
DATE	10-3-88

DATUM ELEVATION

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-BOSS BLOWS/FT	WATER LEVEL	SURFACE CONDITIONS
			20			
SS	18/18	6/6/7	21			(SW) Brown SAND with some gravel, trace silt; medium dense, moist, nonplastic.
			22			
			23			
			24			
			25			
RS	12/5	5/8	26			Consistent * Poor recovery - no undisturbed rings
			7			Bottom of Boring
			8			
			9			
			0			
			1			
			2			
			3			
			4			
			5			
			6			
			7			
			8			
			9			
			0			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT	BORING NO.
CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers	B-11
	SHEET 1 OF 2
SAMPLING METHOD	ENGINEER
Split-spoon Penetrometer	DRM
	TIME
	DATE
CASING DEPTH	10-7-88

DATUM Channel bed ELEVATION +12

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-ASSI BLOCK/FT	WATER LEVEL	SURFACE CONDITIONS
						Converging drainage to the west of boring. Old cars on bank to the south of boring anchored to the bank for bank protection. Bank is 12 feet high with a sand bar beneath in channel then 2 feet to channel bottom.
			0			
			1	8		(SM) Brown SILTY SAND Medium dense, dry, nonplastic.
SS	18/18	2/5/6				
			2	16		Increase in plasticity
			3	19		
RS	12/12	8/15				(CL) Dark brown SANDY CLAY.
			4	16		Stiff, dry, medium plastic.
			5	38		becomes sandy
			6			
			7			
			8			
			9			(SW) Light brown SAND with trace silt and gravel; medium dense, dry, nonplastic.
SS	18/12	10/14/14				
			10			
			11			occasional gravel layers to 14.0
			12			
			13			
			14			
			15			(SM) Brown fine SAND with some silt, trace gravel; medium dense, dry, nonplastic.
			16			* small lenses of CLAYEY SAND, moist, medium plastic in shoe of sampler
SS	18/12	4/6/7				
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-11

SHEET: 2 OF 2

ENGINEER: DRM

TIME:

DATE: 10-7-88

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	FULL-LOGS BLOCKS/FT	WATER LEVEL	
			20			(GM) Brown SANDY GRAVEL with some silt; medium dense, moist, nonplastic
SS	18/3	4/6/6	21			* poor recovery due to non-cohesive nature of soil.
			22			
			23			
			24			
			25			(GP) Brown GRAVELY SAND with trace silt; medium dense, dry, nonplastic.
SS	18/19	10/10/15	26			
			27			Bottom of Boring
			28			
			29			
			30			
			1			
			2			
			3			
			4			
			5			
			6			
			7			
			8			
			9			
			0			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING: See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-12

SHEET: 1 OF 2

ENGINEER: DRM

TIME:

DATE: 10-7-88

DATUM: Channel bed ELEVATION: +12

SURFACE CONDITIONS: On north bank, 12 feet high steep bank with adjacent sand bar. Some small brush piles and isolated junk. Cut bank shows a good soil profile with SILTY SAND 0-2 feet, then gravel layers 2-8 feet, then toe of bank shows caving.

SAMPLE TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BLOWS/FOOT	WATER LEVEL	
			0			(SM) Brown SILTY fine SAND;
SS	18/18	1/2/2	1	2		loose, dry, nonplastic.
RS	12/12	2/5	2	5		consistent.
			3	6		
			4	10		becomes sandy and gravely.
			5	26		
			6			
			7			(SP-SM) Brown GRAVELY SAND with trace silt;
SS	18/12	7/15/24	8			dense, dry, nonplastic.
			9			
			10			continued gravely to 13.5 feet.
			11			becomes moist.
			12			
			13			
			14			(SP) Brown, coarse SAND with some gravel, trace silt; medium dense, moist, nonplastic.
SS	18/12	8/10/7	15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
88-435	P.C.D.O.T.&F.C.D.	Rillito Wash Campbell to Cactus Blvd.

LOCATION OF BORING

See Site Plan, Figure 1.

DRILLING METHOD & EQUIPMENT: CME-75 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer

CASING DEPTH:

BORING NO.: B-12

SHEET: 2 OF 2

ENGINEER: DRM

TIME:

DATE: 10-7-88

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULK-DISTURBED BLOCKS	WATER LEVEL	
			20			(SP) Brown GRAVELY SAND with trace silt; medium dense, moist, nonplastic.
SS	18/12	8/10/14	21			
			22			
			23			
			24			
			25			(GP) Light brown GRAVEL (highly fractured) with some sand, trace silt; dense, moist, nonplastic.
SS	18/18	14/20/17	26			
			27			Bottom of Boring.
			28			
			29			
			30			
			1			
			2			
			3			
			4			
			5			
			6			
			7			
			8			
			9			
			0			

Appendix B.
Laboratory Results

Summary of Laboratory Testing Results

Gradation and Plastic Index Tests

Boring No.	Depth (ft)	% Passing #200 Sieve	LL	PI	USCS Symbol
B-1	10-11	6.3	-	NP	GW-GM
B-5	0-1.5	23.3	-	NP	SM
B-6	0-1.5	24.9	34	14	SC
B-7	15-16.5	5.3	-	NP	SP

Consolidation Characteristics of Soil Subject to Saturation

Boring No.	Depth (ft)	Initial Dry Density (pcf)	Surcharge Pressure (psf)	Consolidation (%)
B-2	12-13	118.6	700	0.5
			1400	0.9
			1400SAT	1.0
B-7	10-11	102.9	700	0.4
			1400	1.1
			2100	1.5
			2100SAT	4.0
B-12	1-2	88.9	700	0.9
			1400	1.6
			2100	2.4
			2100SAT	5.8

Results of Moisture/Density Testing

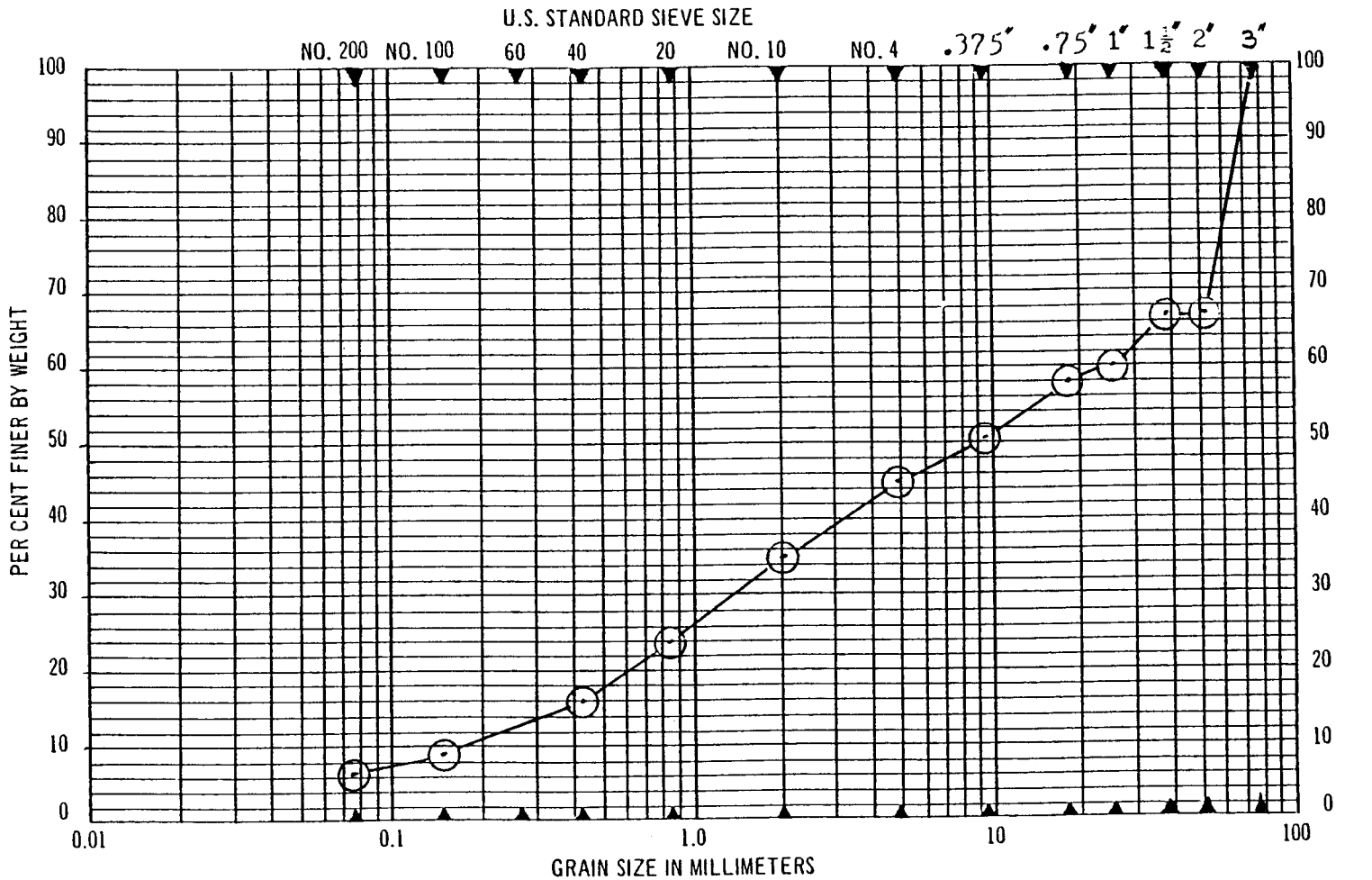
Boring No.	Depth (ft)	Moisture Content (%)	Dry Density (pcf)
B-1	10-11	7.2	119.6
B-2	12-13	8.9	118.6
B-3	11-12	7.2	111.2
B-6	9-10	15.7	85.6
B-7	10-11	2.8	102.9
B-12	1-2	2.6	88.9

Coefficient of Permeability (Falling Head)

Boring No.	Depth (ft)	k(cm/sec)
B-1	10-11	5.66×10^{-7}
B-3	11-12	1.22×10^{-2}
B-6	9-10	7.76×10^{-5}

JOB NO. 88-435 BY G.J. DATE 11/15/88

KEY	BORING	DEPTH	ELEV.	SOIL CLASSIFICATION
⊙	B-1	10-11.0		SANDY GRAVEL with trace silt
				PI-NP USCS(GW-GM)



SILT OR CLAY	SAND			GRAVEL		*
	FINE	MEDIUM	COARSE	FINE	COARSE	

*COBBLES

GRAIN-SIZE DISTRIBUTION
(UNIFIED SOIL CLASSIFICATION SYSTEM)

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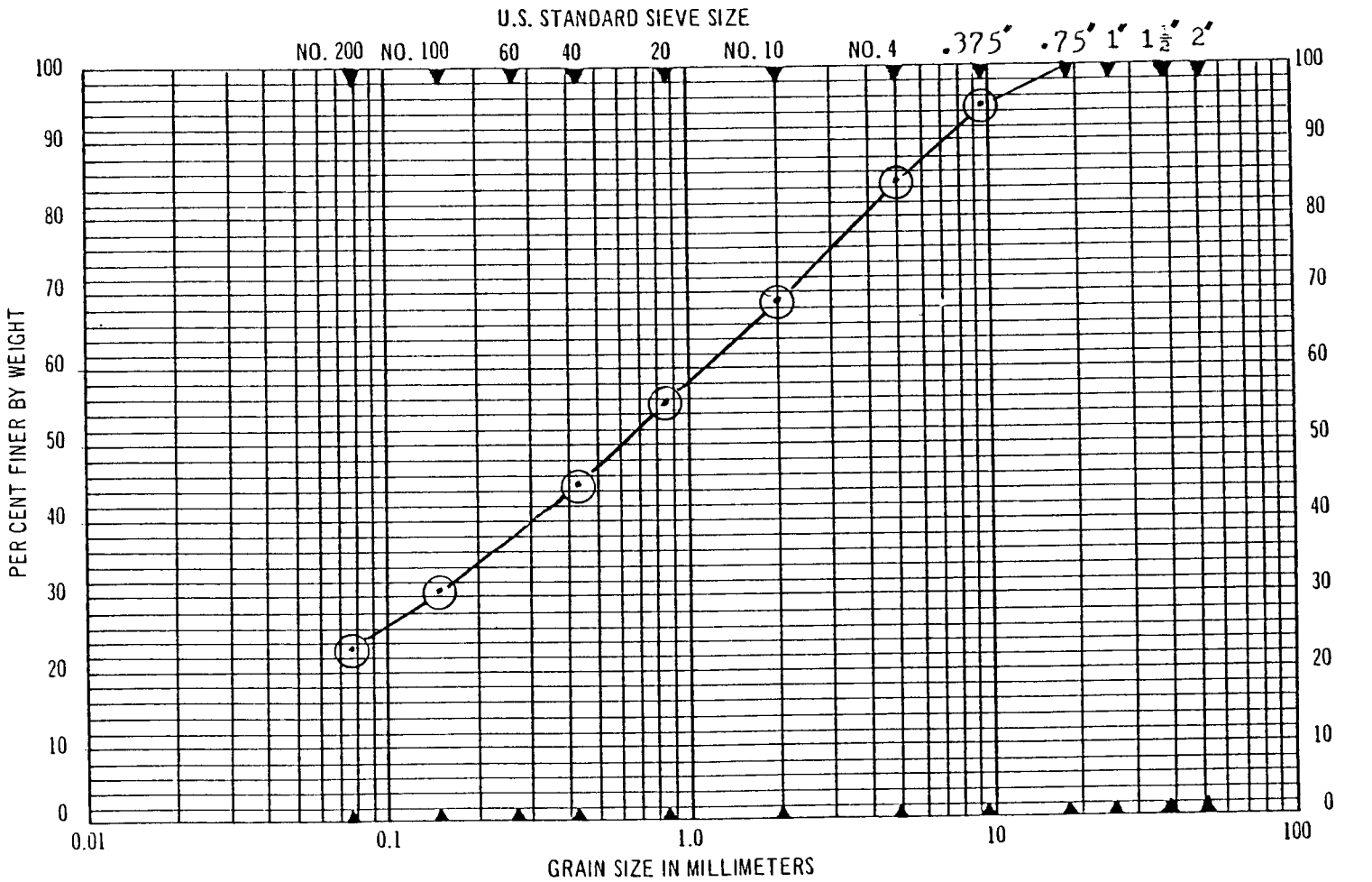
JOB NO. 88-435 BY G.J. DATE 11/15/88

KEY	BORING	DEPTH	ELEV.	SOIL CLASSIFICATION
⊙	B-5	0-1.5		SAND with some silt and gravel
				PI-NP USCS(SM)



SILT OR CLAY	SAND			GRAVEL		*
	FINE	MEDIUM	COARSE	FINE	COARSE	

*COBBLES

GRAIN-SIZE DISTRIBUTION
(UNIFIED SOIL CLASSIFICATION SYSTEM)

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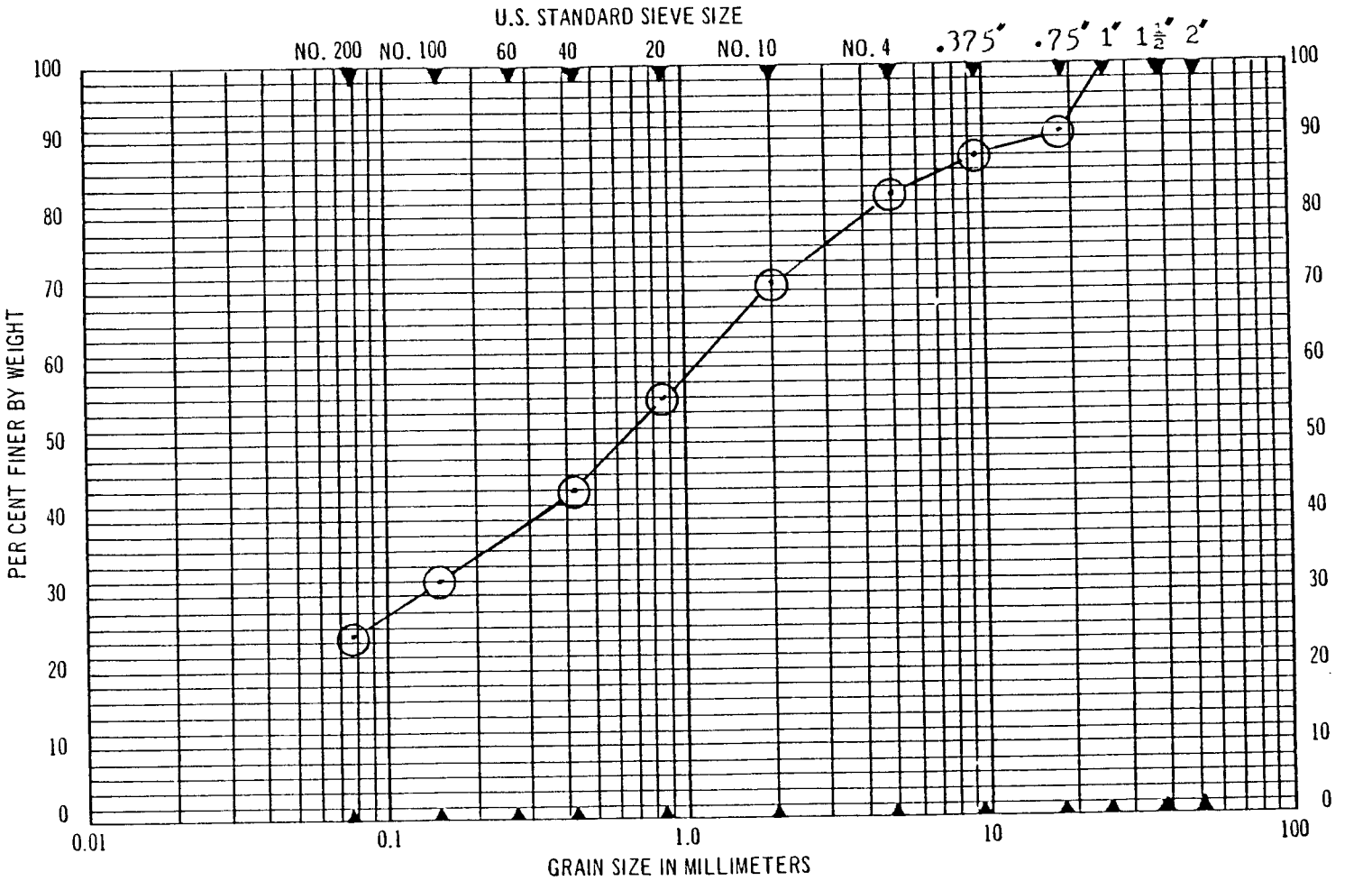
JOB NO. 88-435 BY G.J. DATE 11/15/88

KEY	BORING	DEPTH	ELEV.	SOIL CLASSIFICATION
⊙	B-6	0-1.5		SAND with some clay and gravel
				PI-14 LL-34 USCS(SC)



SILT OR CLAY	SAND			GRAVEL		*
	FINE	MEDIUM	COARSE	FINE	COARSE	

*COBBLES

GRAIN-SIZE DISTRIBUTION
(UNIFIED SOIL CLASSIFICATION SYSTEM)

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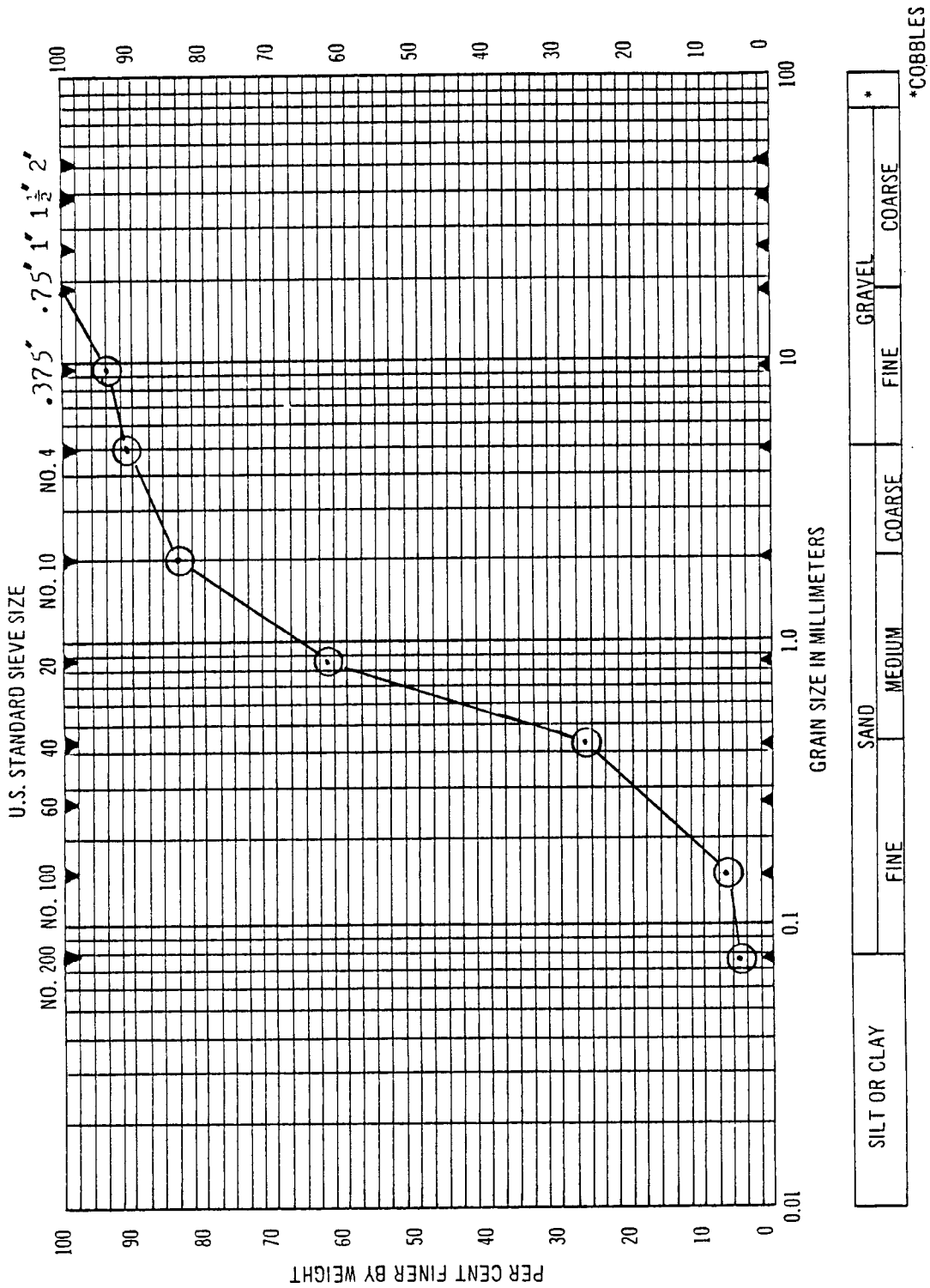
GRAIN-SIZE DISTRIBUTION
(UNIFIED SOIL CLASSIFICATION SYSTEM)

JOB NO. 88-435 BY G.J. DATE 11/15/88

KEY	BORING	DEPTH	ELEV.	SOIL CLASSIFICATION
⊙	B-7	15-16.5		SAND with trace silt and gravel.
				PI-NP
				USCS(SP)



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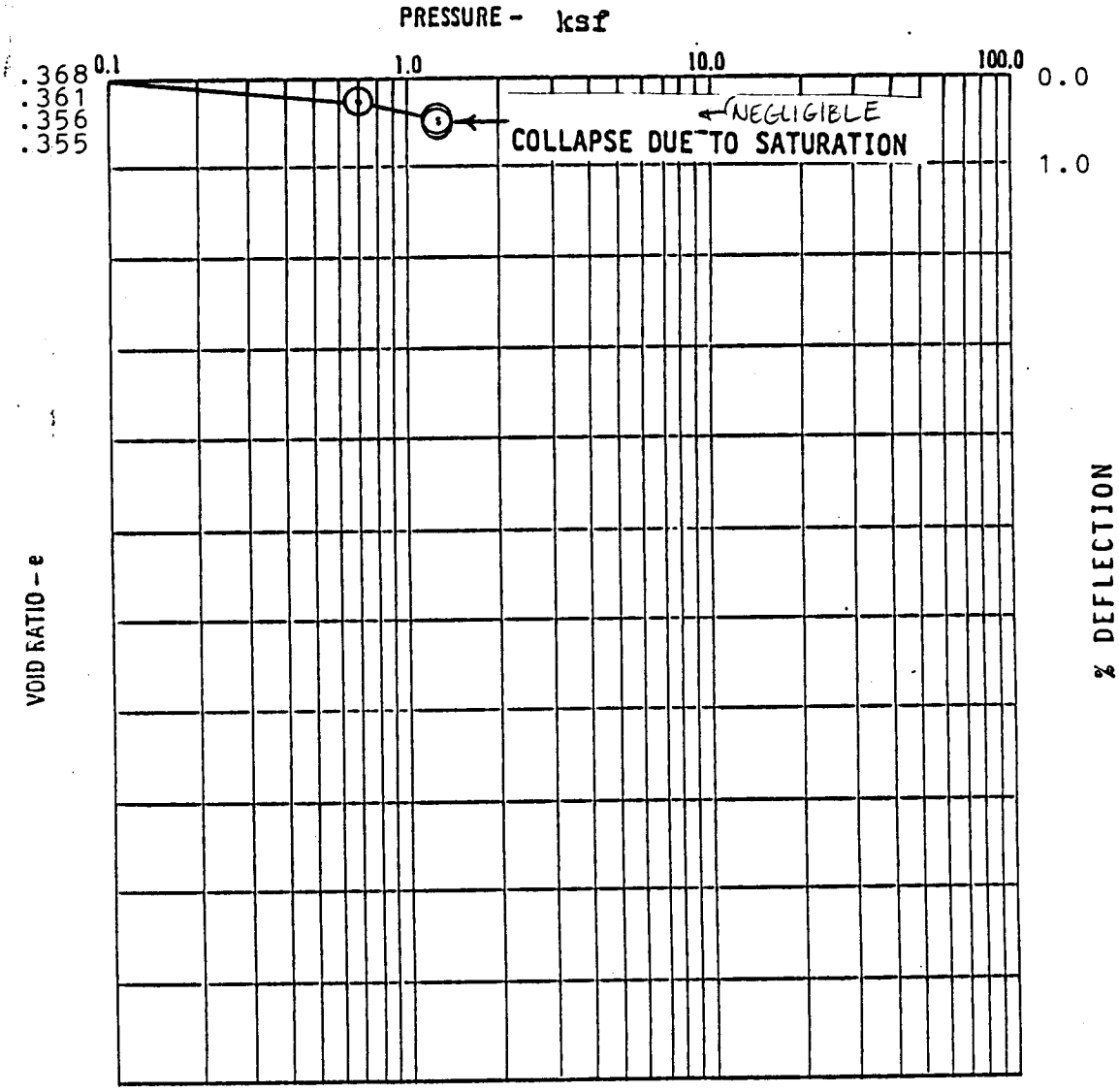
COLLAPSE-CONSOLIDATION TEST DATA



JOB NO. 88-435 BY JMM DATE 11-3-88

DESCRIPTION OF SAMPLE: SAND with some gravel and trace silt					
BORING: B-2		DEPTH: 12-13.0		ELEVATION:	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c |			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o |	
COMPRESSION INDEX (C_c)			SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	8.9	VOID RATIO	INITIAL - e_o	.368
	FINAL	13.7		FINAL - e_f	.355
DRY DENSITY (PCF.)	INITIAL	118.6	DEGREE OF SATURATION %	INITIAL	63.0
	FINAL	119.7		FINAL	SAT

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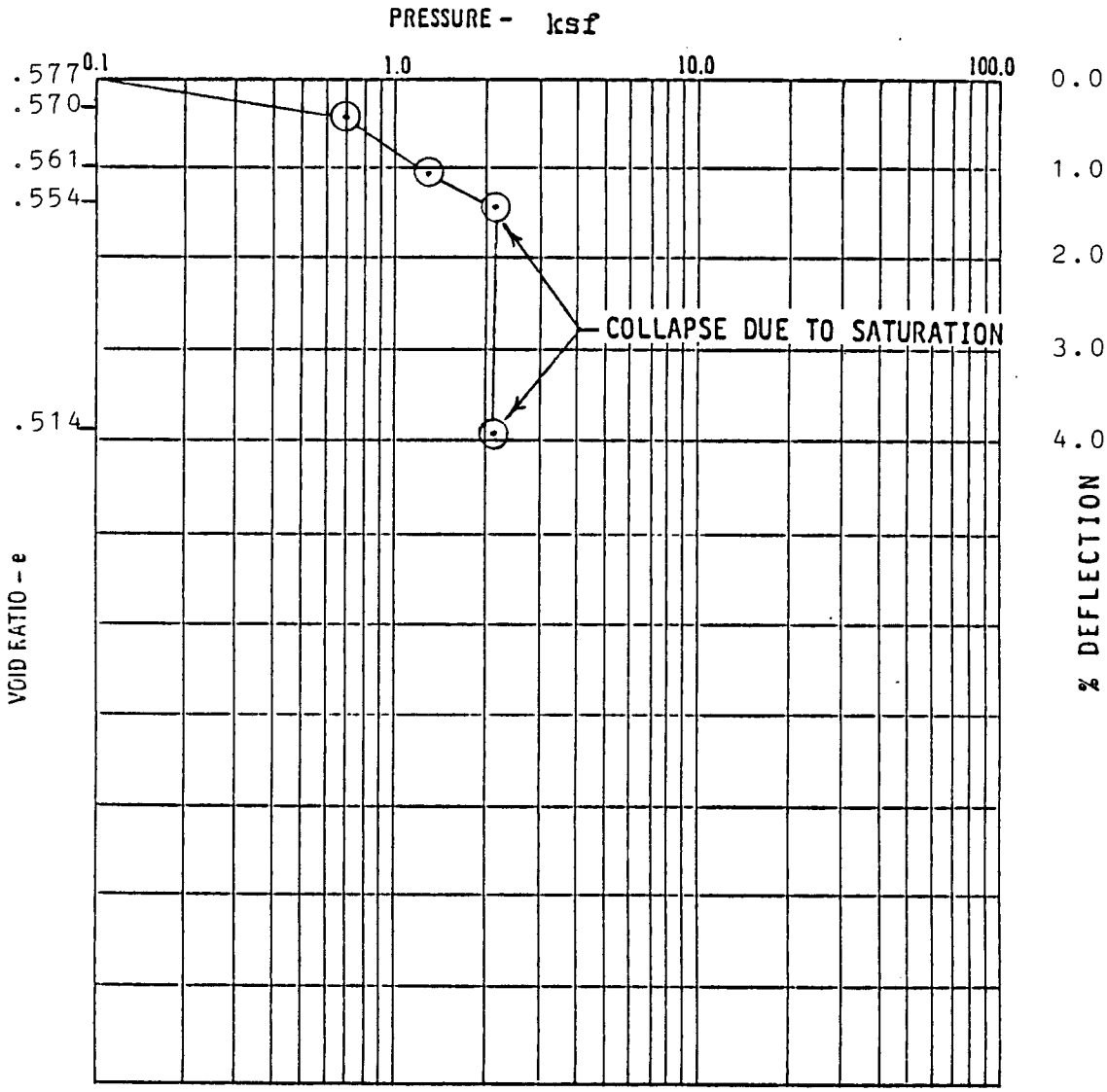
COLLAPSE-CONSOLIDATION TEST DATA



JOB NO. 88-435 BY JMM DATE 11-3-88

DESCRIPTION OF SAMPLE: SAND with trace silt and gravel					
BORING: B-7		DEPTH: 10-11.0		ELEVATION:	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c |			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o |	
COMPRESSION INDEX (C_c)			SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	2.8	VOID RATIO	INITIAL - e_o	.577
	FINAL	19.8		FINAL - e_F	.514
DRY DENSITY (PCF.)	INITIAL	102.9	DEGREE OF SATURATION %	INITIAL	12.6
	FINAL	107.1		FINAL	SAT

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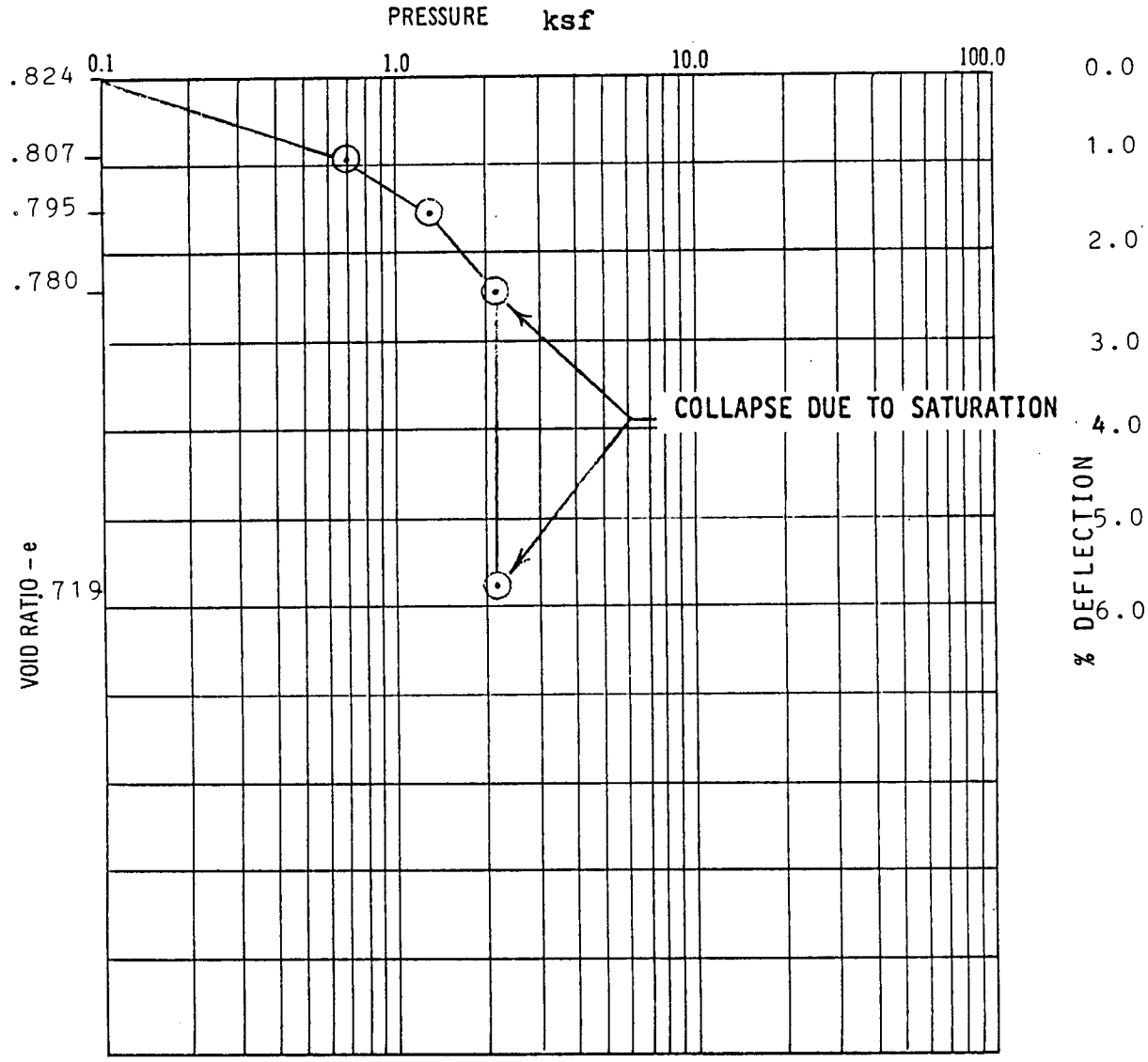
COLLAPSE-CONSOLIDATION TEST DATA



JOB NO. 88-435 BY JMM DATE 11-8-88

DESCRIPTION OF SAMPLE: Silty SAND					
BORING: B-12		DEPTH: 1-2		ELEVATION:	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c ↓			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o ↓		
COMPRESSION INDEX (C_c)			SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	2.6	VOID RATIO	INITIAL - e_o	.824
	FINAL	27.6		FINAL - e_F	.719
DRY DENSITY (PCF.)	INITIAL	88.9	DEGREE OF SATURATION %	INITIAL	8.3
	FINAL	94.4		FINAL	SAT

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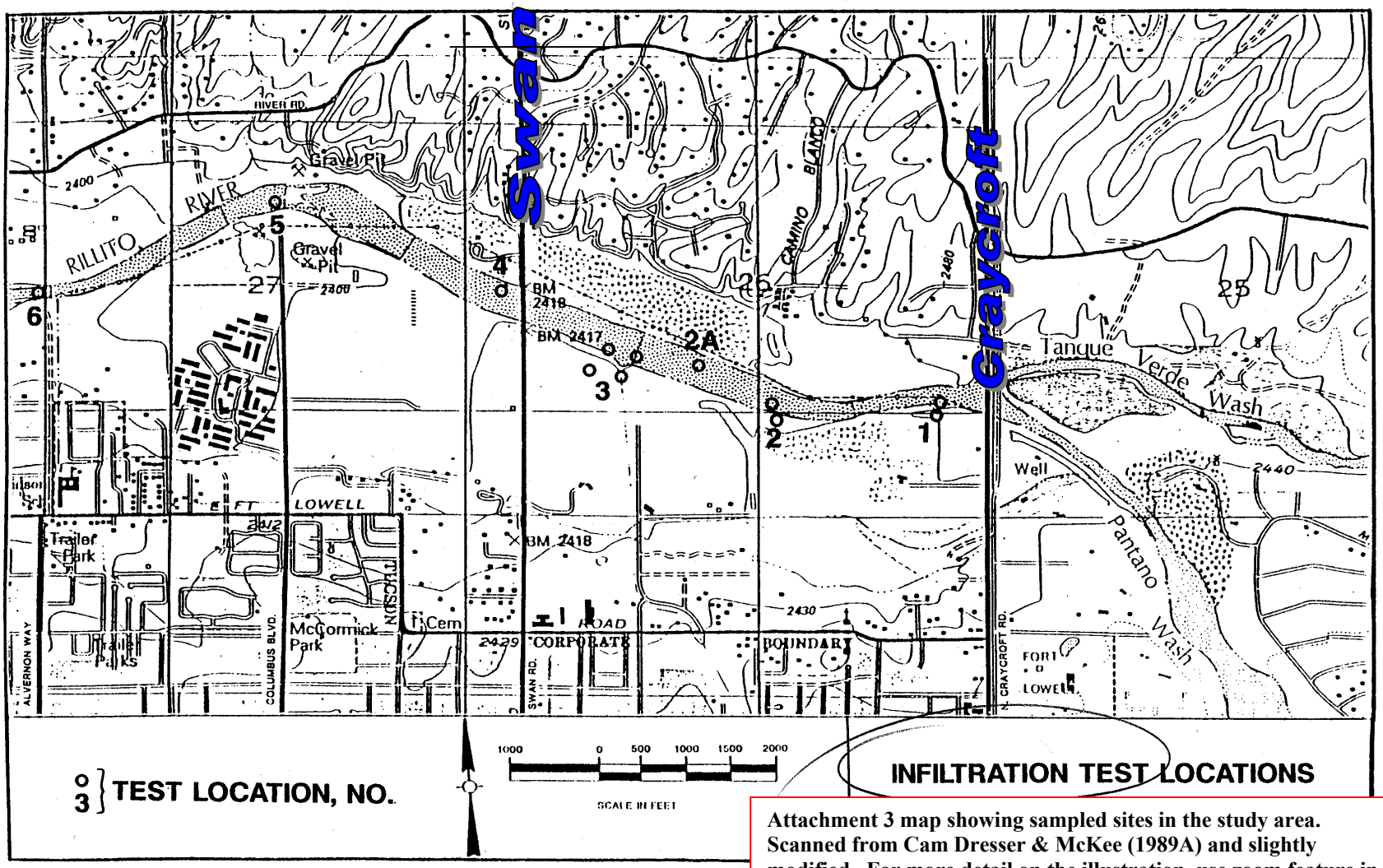
Attachment 3. Late 1980's (pre-1989) Camp Dresser and McKee ***surface*** and ***near-surface*** (18-in.-deep) sediment characterization test results, taken in and along *el Rillito* between Craycroft and Swan (data from Camp Dresser and McKee, 1989A). Hole locations shown on map, directly below. All are within the current study area.



Attachment 3 map showing sampled sites in the study area. Scanned from Cam Dresser & McKee (1989A) and slightly modified. For more detail on the illustration, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard. add more buttons. then turn on the "zoom" button.

Refer to attachment 3 map, above for sample locations. Tests 1.1, 1.2, 1.3, etc., are from well location identified as "1" on map above; tests 2.1., 2.2, etc., are from well "2", and so on.

Sediment Particle Size Analysis for Surface Samples

	PERCENT PASSING GIVEN SIEVE SIZE (mm)					
TEST NO.	38.10	9.42	4.70	2.36	1.17	0.59
1.1	100	97	91	78	58	35
1.2	100	100	98	96	95	92
1.3	(Same as 1.1)					
2.1	100	93	86	72	53	33
2.2	100	91	81	69	55	41
2.3	100	98	96	88	75	58
2.4	(Same as 2.3)					
2A	100	99	89	65	32	8
3.1	100	96	84	60	34	17
3.2	(No samples taken)					
3.3	100	94	88	76	53	22
3.4	100	91	80	66	46	23
3.5	100	92	84	70	46	27
3.6	100	100	100	99	99	98
4.1	100	98	88	65	26	4
5.1	100	98	90	73	42	15
6.1	100	96	88	68	38	16
MAXIMUM	100	100	100	99	99	98
MINIMUM	100	91	80	60	26	4
AVERAGE	100	96	89	75	54	35
LIM AVG[1]	100	95	87	71	47	25
COUNT	14					

[1] Limited average excludes tests 1.2 and 3.6, made on river bank.

Refer to attachment 3 map, above for sample locations. Tests 1.1, 1.2, 1.3, etc., are from well location identified as "1" on map above; tests 2.1., 2.2, etc., are from well "2", and so on.

Sediment Particle Size Analysis for Samples Taken from 18 In. Below Surface

TEST NO.	PERCENT PASSING GIVEN SIEVE SIZE (mm) 38.10	9.42	4.70	2.36	1.17	0.59
1.1	(Sample lost)					
1.2	100	100	100	100	100	99
1.3	(Same as 1.1)					
2.1	100	86	78	65	45	28
2.2	85	80	71	53	31	18
2.3	100	91	80	64	45	24
2.4	(Same as 2.3)					
2A	100	86	73	53	32	16
3.1	100	89	77	56	32	14
3.2	(No samples taken)					
3.3	(Sample lost)					
3.4	100	82	73	52	24	8
3.5	100	84	72	52	28	11
3.6	100	100	100	100	87	84
4.1	100	93	83	63	39	18
5.1	100	94	88	73	39	14
6.1	100	94	88	73	39	14
MAXIMUM	100	100	100	100	100	99
MINIMUM	85	80	71	52	24	8
AVERAGE	99	90	82	66	44	29
LIM AVG[1]	99	88	78	59	34	29
COUNT	12					

[1] Limited average excludes tests 1.2 and 3.6, made on river bank.

Refer to attachment 3 map, above. The two wells characterized in the data below are within the study area boundary, and presumed to be in or near *el Rillito* but their precise locations were not identified in the literature.

Well Cuttings Particle Size Analyses
(Data from Tucson Water)

WELL NO.	DEPTH RANGE	PARTICLE SIZE DISTRIBUTION % GRAVEL	% SAND	% FINES	
PR-001	0-30	47	37	16	Recent alluvium
	30-70	32	56	22	Ft. Lowell
	70-110	47	39	14	Ft. Lowell
	110-160	53	34	13	Ft. Lowell/Tinaja?
	160-193	52	30	18	Tinaja?
PR-004	0-32	26	60	15	Recent alluvium
	32-100	33	47	20	Ft. Lowell
	100-115	52	31	17	Ft. Lowell
	115-159	58	26	16	Ft. Lowell/Upper Tinaja
MAXIMUM		58	60	22	
MINIMUM		25	26	13	
AVERAGE		44	40	17	

Attachment 4. U.S. Geological Survey borings in study area (Hoffman and Ripich, in press, p. 54). Hole locations shown on fig. 13 of the current report. Data for hole (D-13-14)26daa not available in the draft Hoffman and Ripich report. If data become available later, they will be added here. Data for hole (D-13-14)28dba are below, next page, scanned directly from Hoffman and Ripich (in press, p. 54).

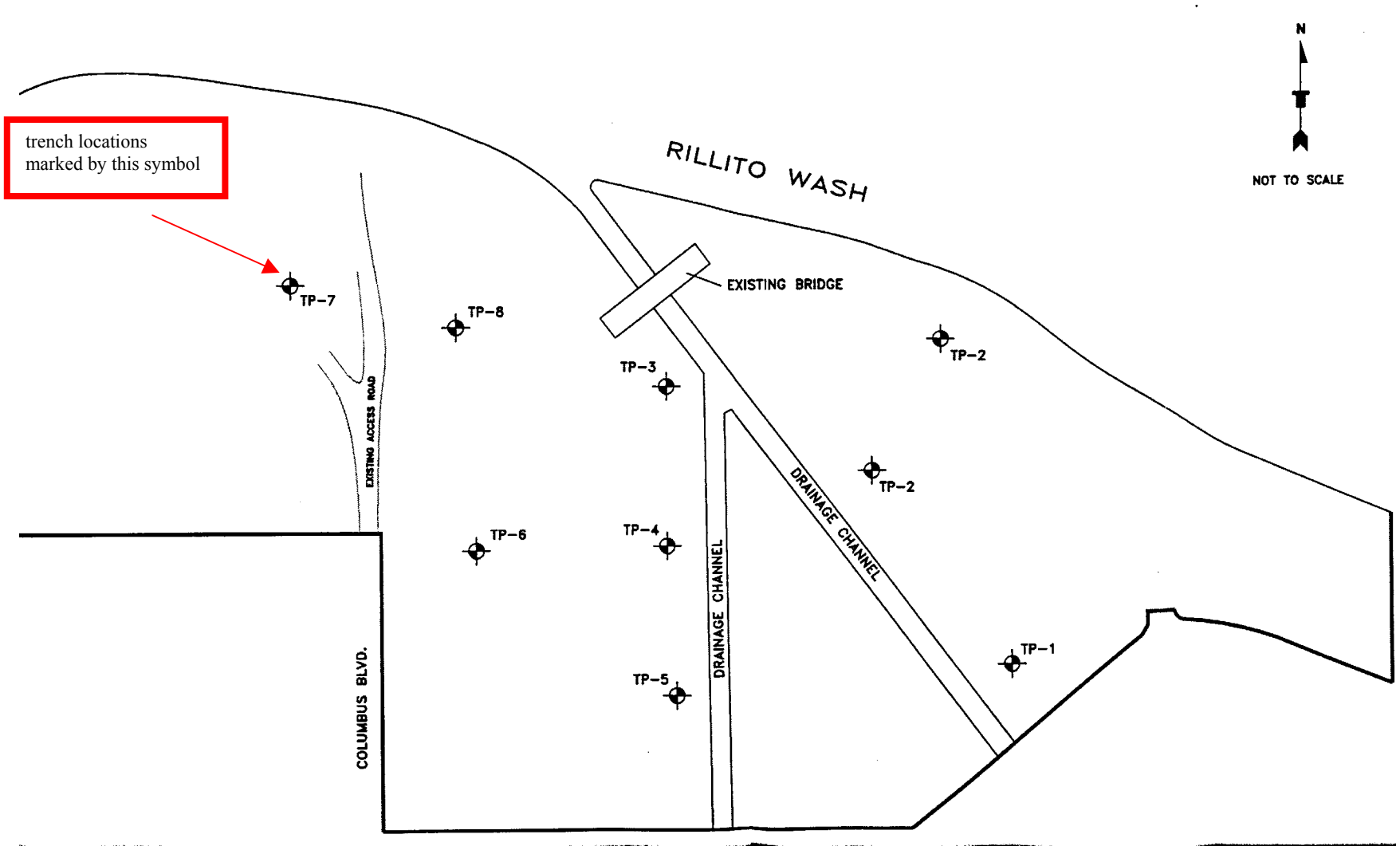
Particle-size analysis of core samples from boreholes, Rillito Creek, Pima County, Arizona

[N/A, not applicable. Dashes indicate no data. Deposit type: SC, stream-chnnel deposits; BF, basin-fill deposits]

Type of deposit	Depth, in feet	Overall sample particle size, in percent				Gravel fraction, in percent				Less than 2-millimeter particle size, in percent		
		Gravel	Sand	Silt	Clay	Greater than 19 millimeters	9.5–19.0 millimeters	4.75–9.5 millimeters	2.0–4.75 millimeters	Sand	Silt	Clay
For more detail on the illustration, use zoom feature in WORD. To activate the zoom feature, go to view, toolbars, standard, add more buttons, then turn on the "zoom" button.												
(D-13-14)26daa (data not available as of March. 2001)												
(D-13-14)28dba												
SC	1.0	36	55	4	4	6	6	8	16	86	7	7
SC	8.0	18	29	29	24	5	0	1	12	35	35	30
SC	13.0	51	43	2	4	20	6	9	15	88	4	8
SC	18.0	68	25	2	5	16	11	14	27	78	7	15
SC	23.0	61	33	4	1	27	12	9	12	87	10	3
BF	27.5	7	77	14	2	0	0	1	6	84	15	2
BF	38.0	23	62	12	2	7	2	4	10	81	16	3
BF	47.5	38	53	8	1	17	8	6	8	85	13	1
BF	57.5	12	72	14	2	0	0	2	9	82	16	2
BF	78.0	35	52	11	1	3	6	8	18	81	17	2
BF	98.0	27	65	3	4	7	7	4	10	90	5	6
BF	118.0	47	36	7	10	6	11	10	19	68	14	18
BF	138.0	46	44	3	7	5	7	12	21	82	5	14

Attachment 5. 2000 Terracon trench logs and soil classification in the Columbus landfill of the study area (scanned from Terracon, 2000). See attached .pdf file. Hole locations shown on map, below on next page.

See attached .pdf file, which is a separate electronic document


trench locations
marked by this symbol
RILLITO WASH
N
NOT TO SCALE
EXISTING BRIDGE
TP-7
TP-8
TP-3
TP-2
TP-2
TP-6
TP-4
TP-5
TP-1
EXISTING ACCESS ROAD
DRAINAGE CHANNEL
DRAINAGE CHANNEL
COLUMBUS BLVD.

LOG OF TEST PIT NO. TP-1

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY (in)	SAMPLES BLOWS/FT.	TESTS WATER CONTENT, %	TESTS DRY DENSITY pcf	TESTS LIQUID LIMIT	TESTS PLASTICITY INDEX	TESTS -200
	LEAN CLAY WITH SAND TRACE GRAVEL; brown		CL	1								
		5										
	9											
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-2

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY (in)	BLOWS/FT.	TESTS WATER CONTENT, %	DRY DENSITY pcf	LIQUID LIMIT	PLASTICITY INDEX	-200
	CONCRETE AND BRICK FRAGMENTS IN A CLAYEY SAND MATRIX; brown		SC	1								
2												
	SAND WITH GRAVEL AND CLAY; brown		SP SC	2								
		5										
7												
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-3

CLIENT Collins Pina Consulting Engineers

SITE Columbus Boulevard and Rillito River, Tucson, Arizona

PROJECT Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY (in)	BLOWS/FT.	TESTS WATER CONTENT, %	DRY DENSITY pcf	LIQUID LIMIT	PLASTICITY INDEX	-200
	WOOD, CONCRETE, BRICK, AND REBAR IN A CLAYEY SAND MATRIX; brown	5	SC	1								
7	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-4

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY (in)	BLOWS/FT.	TESTS WATER CONTENT, %	DRY DENSITY pcf	LIQUID LIMIT	PLASTICITY INDEX	-200
	SAND WITH SILT TRACE GRAVEL; brown		SP SM	1								
		5										
	6											
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-5

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY (in)	SAMPLES BLOWS/FT.	TESTS WATER CONTENT, %	TESTS DRY DENSITY pcf	TESTS LIQUID LIMIT	TESTS PLASTICITY INDEX	TESTS -200
	LEAN CLAY WITH SAND; brown		CL	1								
5		5										
	SAND WITH CLAY TRACE GRAVEL; brown		SP SC	2								
6												
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	∇ None WD	▼ None AB
WL	∇	▼
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-6

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY (in)	SAMPLES BLOWS/FT.	TESTS WATER CONTENT, %	TESTS DRY DENSITY pcf	TESTS LIQUID LIMIT	TESTS PLASTICITY INDEX	TESTS -200
	LEAN CLAY WITH SAND; brown		CL	1								
3												
	SAND WITH SILT AND GRAVEL; brown		SP SM	2								
		5										
6												
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-7

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY (in)	SAMPLES BLOWS/FT.	TESTS WATER CONTENT, %	TESTS DRY DENSITY pcf	TESTS LIQUID LIMIT	TESTS PLASTICITY INDEX	TESTS -200
	SILTY SAND WITH GRAVEL; brown, some municipal type waste, such as plastic bags and cans in isolated zones		SM	1								
		5										
		10										
	13											
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-8

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY (in)	SAMPLES: BLOWS/FT.	TESTS: WATER CONTENT, %	TESTS: DRY DENSITY pcf	TESTS: LIQUID LIMIT	TESTS: PLASTICITY INDEX	TESTS: -200
	CONCRETE, BRICK, METAL, PLASTIC, AND STYROFOAM IN A CLAYEY SAND WITH GRAVEL MATRIX; brown	5	SC									
	6											
	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	▽ None WD	▼ None AB
WL	▽	▼
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161

LOG OF TEST PIT NO. TP-9

CLIENT
Collins Pina Consulting Engineers

SITE
Columbus Boulevard and Rillito River
Tucson, Arizona

PROJECT
Proposed Rillito River Habitat Enhancements

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY (in)	SAMPLES BLOWS/FT.	TESTS WATER CONTENT, %	TESTS DRY DENSITY pcf	TESTS LIQUID LIMIT	TESTS PLASTICITY INDEX	TESTS -200
	SAND WITH CLAY TRACE GRAVEL; brown		SP SC	1								
4	Bottom of Test Pit											

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	None WD	None AB
WL		
WL	Backfilled Upon Completion	

Terracon

BORING STARTED	8-25-00		
BORING COMPLETED	8-25-00		
RIG	CAT BH	FOREMAN	MYW
Approved	RWP	JOB #	63005161