RGDSS Memorandum

To:	Mike Sullivan, P.E.	Colorado Division of Water Resources
	Andy Moore, P.E.	Colorado Water Conservation Board
From:	HRS Water Consultants, Inc.	
	Eric J. Harmon, P.E., G. Eric Saenger, CPG, Steven K. Barrett	
Subject:	Hydrogeologic Review and Data Collection, Rio Grande, Del Norte to Rio Grande – Alamosa County Line	
Date:	July 17, 2012	

Introduction

This memorandum documents two stages of hydrogeologic investigation done by HRS in the reach of the Rio Grande and its floodplain between Del Norte and the Rio Grande / Alamosa County Line (see Figure 1). The first stage of work, done in 2009, consisted of hydrogeologic data review and field observations. The 2009 work is documented in a separate memorandum. [1] The second stage of work was done in two parts: the first part in November, 2011, and the second part in April – May, 2012. The 2011 - 2012 work consisted of field observations, test drilling, aquifer testing, and evaluation of lithology in and adjacent to the Rio Grande streambeds in the study area. The 2011 - 2012 part of this investigation was done with the authorization of the State, based on recommendations made by HRS in the 2009 the hydrogeologic evaluation. This memorandum documents the 2011-2012 work.

[1] HRS Water Consultants, Inc., July 17, 2012 , RGDSS memorandum: 2009 Hydrogeologic Evaluation of Del Norte – Sevenmile Plaza Area.

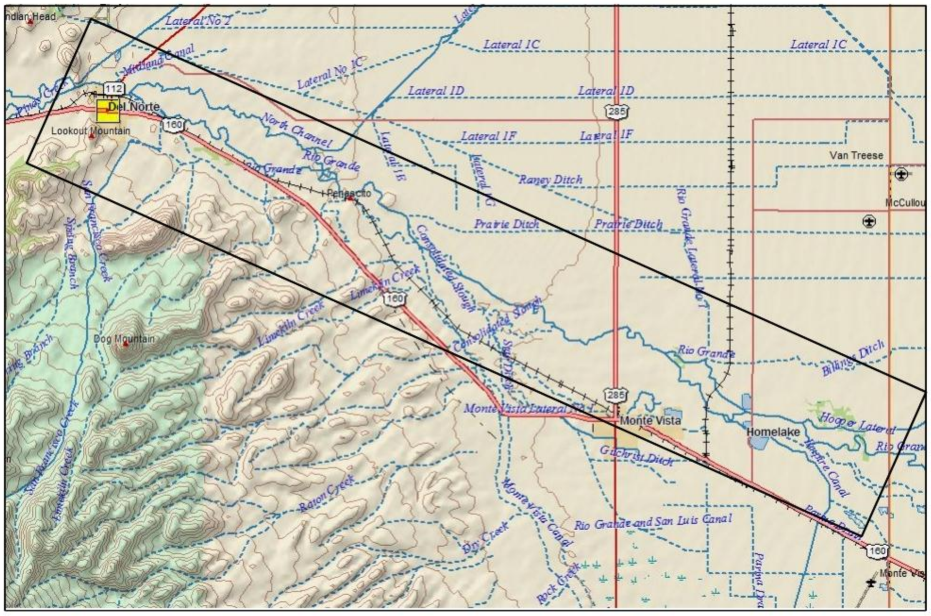

Figure 1: General location of the study area: Rio Grande valley from Del Norte to Rio Grande – Alamosa County Line.

Statement of the Problem

Work done as part of the RGDSS Peer Review Team (PRT) has raised questions about the nature of the hydrogeology of the Rio Grande and its floodplain in this reach, including:

- Base flow evaluation by PRT members showed relatively little gain/loss of water in the river observed in the Del Norte – Monte Vista reach of the Rio Grande, as compared to a gaining reach from Monte Vista to Alamosa, from base flow estimates (see figures 2 and 3).
- Anomalous water levels exist in the unconfined aquifer in the Del Norte – Sevenmile Plaza area, including indications of a perched water table in some areas (see figure 4)
- The presence and relative stability during historic times of two separate channels of the Rio Grande (North Channel and South Channel) between Del Norte and Sevenmile Plaza, in contrast to a single channel below this reach. In contrast, there is evidence of recent

channel meander, cutoff, channel avulsion[2] and lateral channel migration within the present Rio Grande floodplain downstream of Sevenmile Plaza and Monte Vista[3].

- Calibration efforts of the RGDSS model indicate an improvement in match to observed gain/loss using relatively low streambed conductance values in the Del Norte – Monte Vista reach, of the Rio Grande.
- HRS was asked by the State and the PRT to investigate the hydrogeology of the near-surface deposits in the Rio Grande floodplain, to see whether these questions could be answered by observations and data collection building upon the earlier HRS preliminary study of part of this study area (HRS, 2009).

HRS studied the hydrogeology of the Del Norte – Sevenmile Plaza reach, a subset of the Del Norte – County Line Road study area in the 2009 evaluation, and concluded that there is a shallow, perched water table in some localities in this area, and also that there may be some shallow normal faulting in the area.[4] One recommendation of the 2009 HRS work was to drill shallow test holes to check near-surface formation materials in the Rio Grande floodplain in this reach to test the hypothesis that a relatively fine-grained layer of low hydraulic conductivity exists in and adjacent to the Rio Grande streambeds in this reach. The 2011-2012 work confirmed this hypothesis.

[2] Avulsion: abandonment of a river channel to a new channel course.
[3] Jones, L.S., 1996, The Evolution of the Modern Rio Grande Floodplain, San Luis Valley, Colorado: Implications for Alluvial Stratigraphy. Ph.D. Thesis, University of Wyoming. 147p. plus appendixes.
[4] HRS Water Consultants, Inc., July 17, 2012 , RGDSS memorandum: 2009 Hydrogeologic Evaluation of Del Norte – Sevenmile Plaza Area.

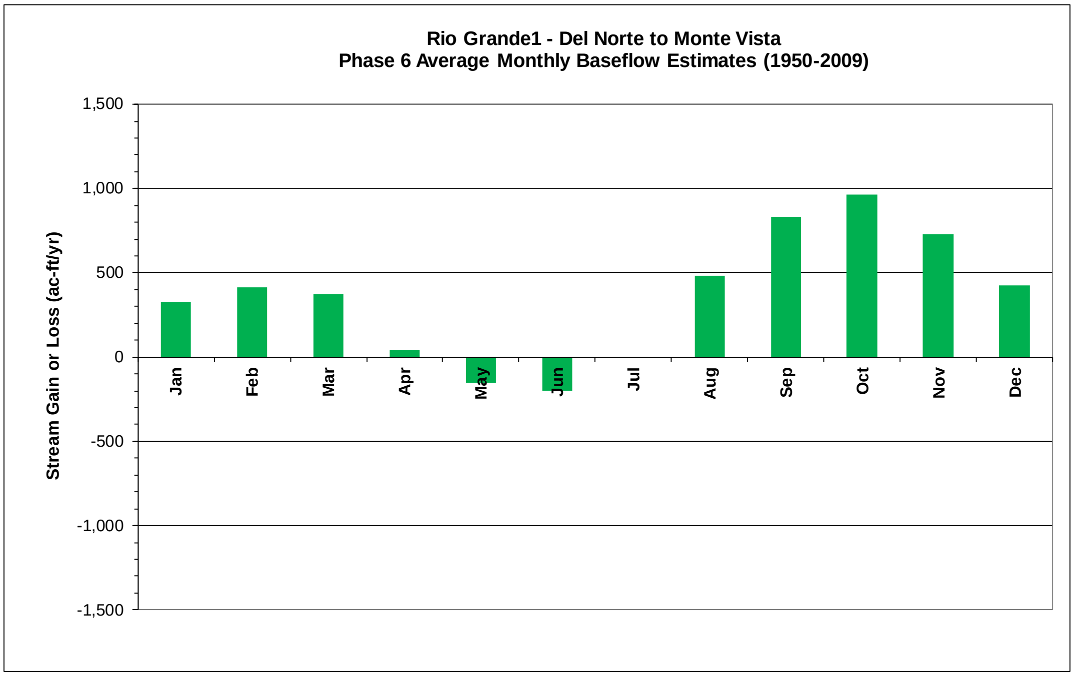

Figure 2: Base flow in Rio Grande, Del Norte to Monte Vista (source: RGDSS Phase 6).

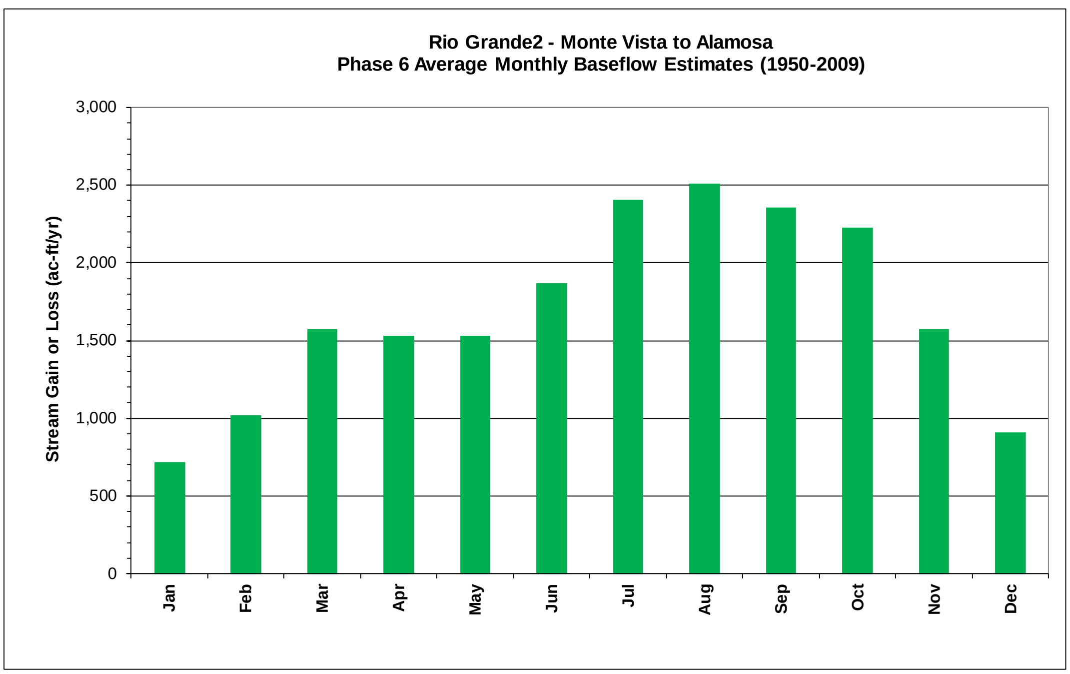

Figure 3: Base flow in Rio Grande, Monte Vista to Alamosa (source: RGDSS Phase 6)

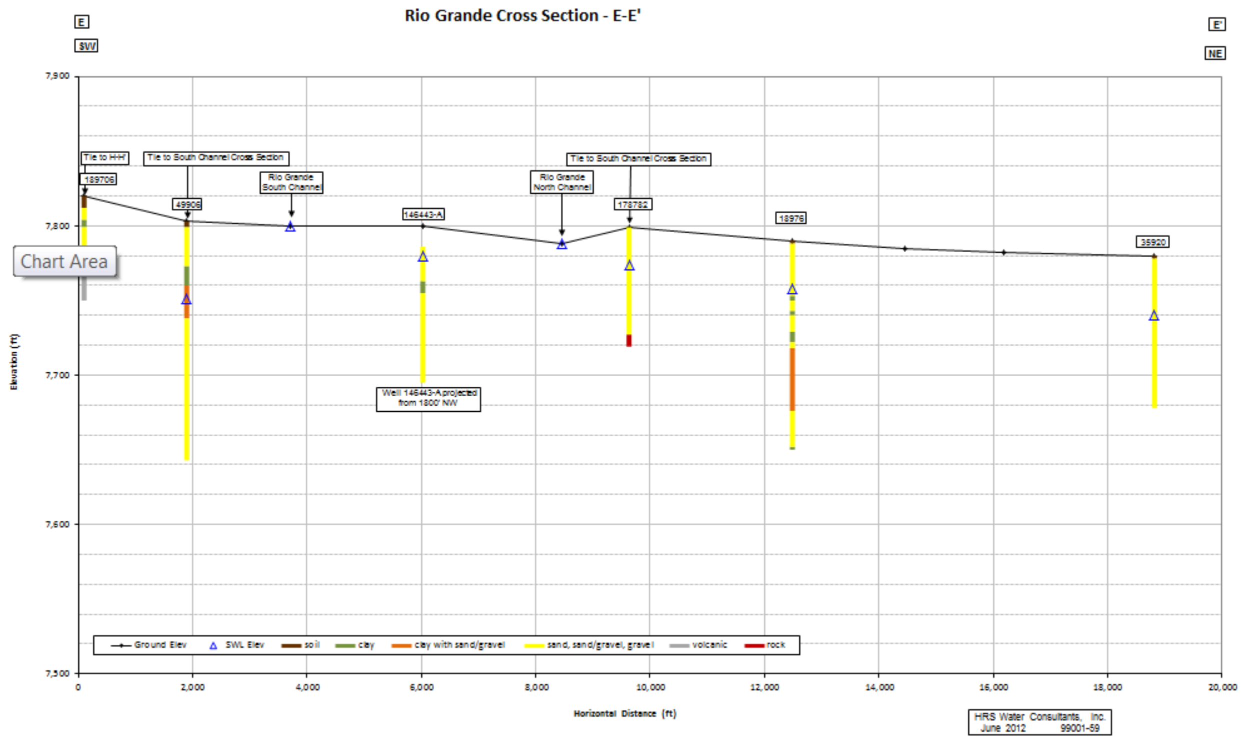

Figure 4: SW to NE Cross Section from driller's logs of water wells. Located approximately 2 ½ miles NW of Sevenmile Plaza.

Review of the Rio Grande County soil survey[5] indicates a prevalence of soils that are sandy loam or sandy clay loam that have a substantial percentage of silt/clay materials (passing a no. 200 sieve) (see Figure 5). A problem in these data sources is the lack of information on the nature of the soil materials in the river channels. The driller's logs are somewhat general in their descriptions, and wells are not drilled within the present river channels. The soil survey is quite detailed in its descriptions of material types in the floodplain, but again, offers no data on the nature of the soil material in the present river channels.

[5] USDA Soil Conservation Service, 1980, http://soildatamart.nrcs.usda.gov/manuscripts/CO631/0/riogrande.pdf

Soil Types Predominant in the Rio Grande Flood Plain Del Norte - Sevenmile Plaza Reach					
Soil Series	Map Symbol	Depth Range (inches)	USDA Texture	Unified Soil Classification	Percent passing no. 200 sieve (0.074 mm)
Typic Torrifluvents	Tu	0-15	gravelly sandy loam	SM	20-30
		15-60	gravel and sand	GP or SP	0-5
Dunul	Du	0-10	cobbly sandy loam	SC-SM or SM	15-30
	Du	10-60	very gravelly sand	GP or SP	0-5
Gerrard	Ge	0-14	loam	ML	50-75
	Ge	14-60	very gravelly clay loam	GM or SM	10-20
Alamosa	Am	0-9	loam	ML	60-75
	Am	9-48	clay loam, sandy clay loam	CL	70-80
	Am	48-60	sand and gravel	SM-SP	5-10
Shawa	Sma	0-60	loam	ML	60-75
Schrader	Sh	0-7	sandy loam	SM	30-40
	Sh	7-60	fine sandy loam, and loam	SM or ML	45-60
Source: USDA SCS, 1980, Soil Survey of Rio Grande County Area. Maps 3 and 4; and Table 6 pp. 56-63.					

Figure 5: soil types in the Rio Grande flood plain, Del Norte – Sevenmile Plaza

Based on the 2009 hydrogeologic review and in subsequent discussions with the State and the Peer Review Team (PRT), HRS was requested to conduct a preliminary field investigation to observe and sample riverbed material to determine whether further testing and/or drilling would be warranted for the RGDSS. This work is discussed in the 2011 Investigation part of this memorandum. The initial observations indicated to the State and the PRT that further investigation was warranted, and HRS was asked to design and implement a test hole drilling program (2012 Investigation part of this memorandum). This memorandum discusses the results of the 2011 - 2012 investigations.

Part 1: 2011 Investigation

Methods of Investigation

During the 2011 investigation of the Rio Grande floodplain hydrogeology, HRS performed the following:

- Compared the stream geomorphology in terms of the expected sequence of floodplain deposits with the aquifer materials observed in water wells in the present Rio Grande floodplain.

- Compared the present river channels in the study area (Del Norte to County Line Road) based on recent satellite imagery, against historical maps of the area to see whether historic-era channel changes can be identified and correlated with streambed materials.

- Visited and photographed accessible sites along the Rio Grande accompanied by Mr. Steve Baer, District 20 Water Commissioner, to check suitability for sampling and observations.

- Sampled Rio Grande streambed materials at several locations, and described the material types observed.

- Performed two constant-head permeameter tests at upstream and downstream locations within the study area, on the stream bank adjacent to the present river channel.

<u>Observations</u>

Several observations were made in the field and by review of maps and related information after HRS' November 2011 field trip to the study area. The following characteristics were noted with respect to the streambed and channels of the Rio Grande progressing from upstream to downstream in the study area.

- The stream gradient changes from relatively high at Del Norte and the North Channel – South Channel "split" to a more moderate gradient below Monte Vista.
- The two-channel Rio Grande is now, and historically has been, relatively constant in location from the "split" to a point about one mile above Sevenmile Plaza since at least the early 1870's as shown by comparison of new imagery with old maps.
- The location of the Rio Grande channel has been less stable in historic times below Sevenmile Plaza, and certainly below Monte Vista, than it has been upstream of Sevenmile Plaza.
- The streambeds between Del Norte and approximately Sevenmile Plaza are cobble-lined. Below Sevenmile Plaza there is progressively smaller cobble and a decrease in the percentage of cobbles. The material lining the streambed becomes progressively finer-grained in a downstream direction.
- Many of the shallow (less than 3 feet) test holes hand-augered or hand-dug into the streambed or adjacent bank at various locations in the study area showed the presence of a fine-grained organic rich layer containing sand, silt, and clay either just below, or intermixed with, the streambed cobble.
- A constant-head permeameter test of the organic-rich material at one location showed a relatively low hydraulic conductivity (K), on the order of 1 feet/day. At a second location, a K test was not successful due to frost in the soil material.

River Channel Morphology

The Rio Grande channel in the Del Norte to Sevenmile Plaza reach of the study area is in two separate stream channels, both of which are sinuous and "meandering" in conformation, as shown on Figure 6. The average gradient of the Rio Grande valley in this 6 mile reach is approximately 0.0036 feet/feet, as compared to an average gradient of 0.0018 feet/feet in the 6 ½ miles between Monte Vista and County Line Road, which is also a meandering (although single) channel (see Figures 6 and 7).

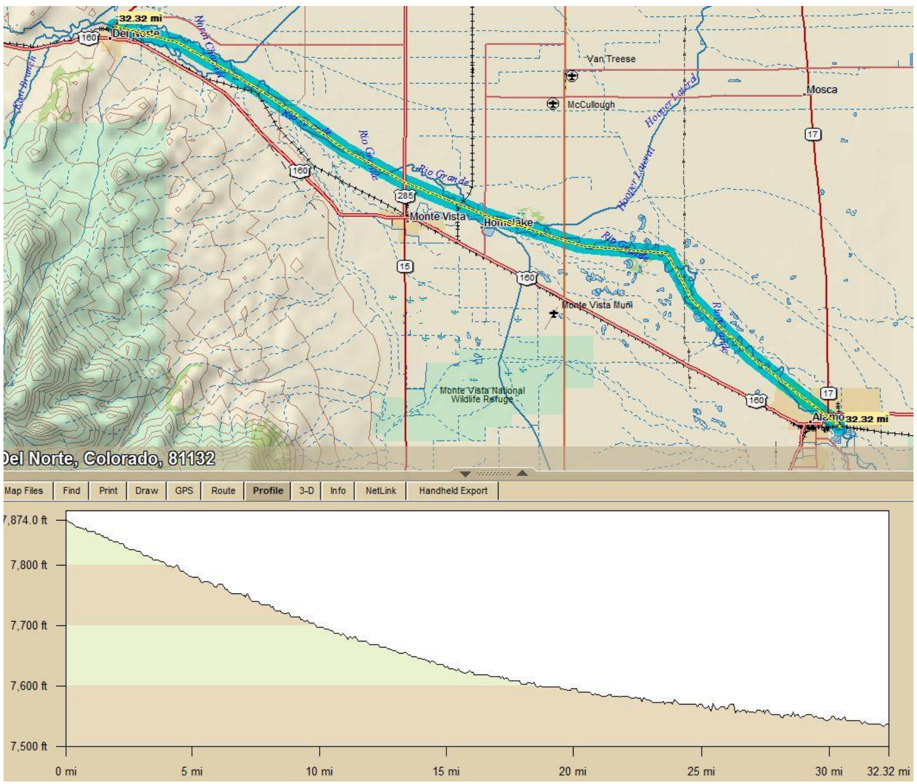

Figure 6: Elevation profile of Rio Grande, Del Norte to Alamosa.

It is notable that the vast majority of the Rio Grande alluvial fan, which covers an estimated 400 to 500 square miles, is composed of alluvial deposits from braided-stream deposition, as can be seen by observing satellite imagery of remnant stream patterns (see Figures 7 and 8) as well as by review of well logs in the unconfined aquifer in the Closed Basin. By contrast, the present Rio Grande flood plain is composed entirely of meandering stream patterns (see Figure 9).

As a secondary objective, the PRT asked HRS to address whether there is any geologic evidence that may help explain why the Rio Grande channel type has changed from braided, as observed in the alluvial fan area, to meandering, as observed in the present floodplain area. One hypothesis is that the change from braided to meandering morphology in the late Pleistocene to early Holocene period (i.e. after the most recent glacial period, ~ 10,000 years ago) may represent the natural evolution of the stream system in response to a dramatic change in climate and reduction in sediment transport capacity following the end of the most recent glacial period.[6] The Rio Grande flood plain also may be undergoing downcutting in response to a lowering of regional base level in the post-glacial period.

[6] Madole, R.F., and others, 2008, On the origin and age of the Great Sand Dunes, Colorado. In Geomorphology. Pp. 99-119.

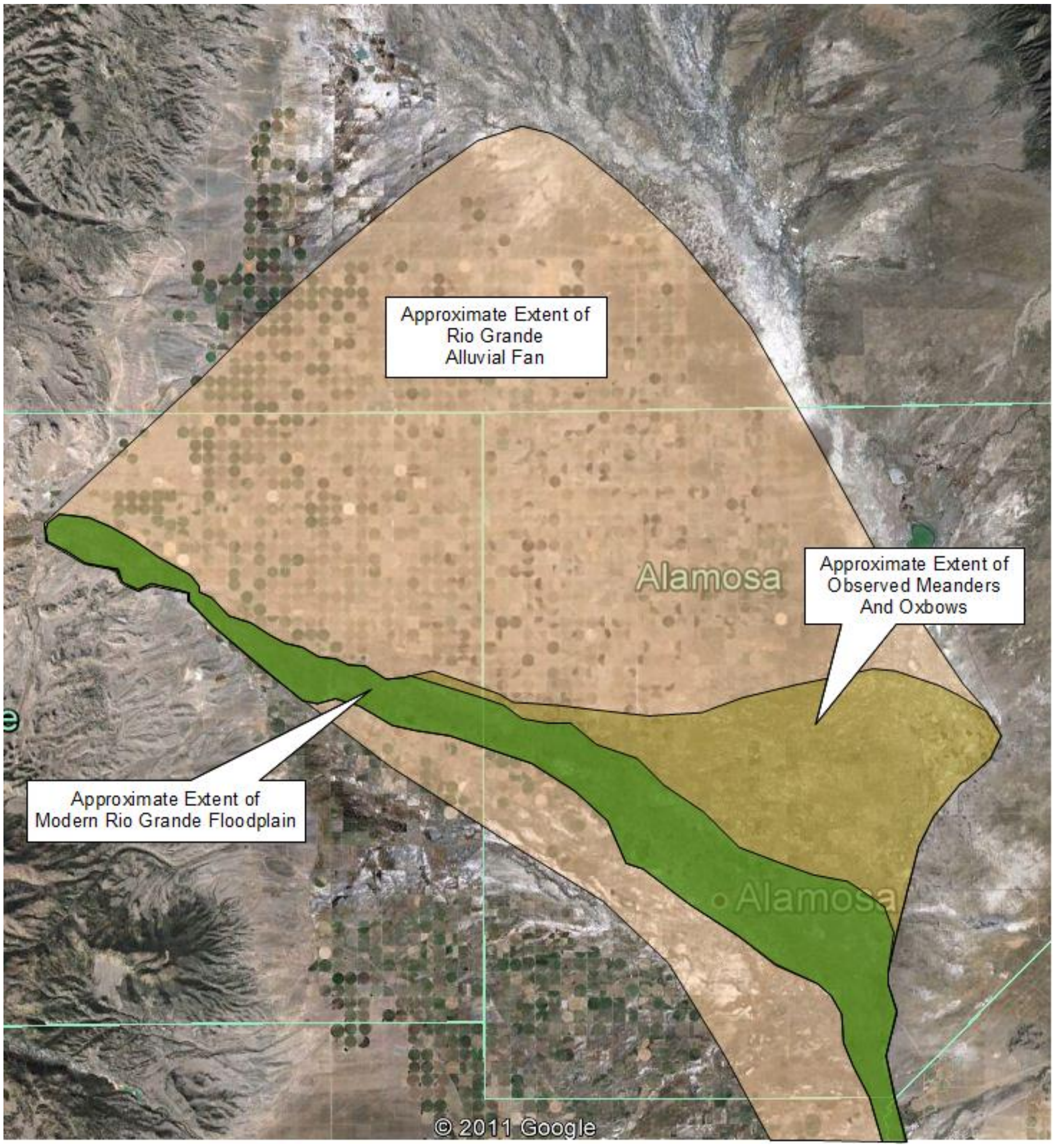

Figure 7: Approximate extent of Rio Grande alluvial fan, observed extent of meanders and oxbows, and the modern Rio Grande floodplain. (see Madole, R.F., et al, 2008).

The topographic gradient of the ancestral Rio Grande channels, as observed on the Rio Grande alluvial fan, and the topographic gradient of the present course of the Rio Grande are virtually identical, and the available sediment in the Rio Grande headwaters in the San Juan mountains has not changed, implying that there has been a change in another factor: possibly the amount of runoff or the seasonal variation (e.g. “flashiness”) of runoff. Generally speaking there are several factors that determine the hydrologic conditions leading to formation of braided streams[7]:

- Streambanks composed of erodible material: Banks that are not readily eroded, either by material cohesiveness or by vegetation, in general are less apt to form braided streams.
- Sediment: Most braided rivers transport large volumes of bed load material (i.e. sediment transported along the bottom of a stream as opposed to material carried in suspension) such as boulders, cobbles, and gravel.
- Rapid variation in discharge: In general large, frequent variations in discharge tend to produce alternating deposition and erosion needed for a braided stream configuration.

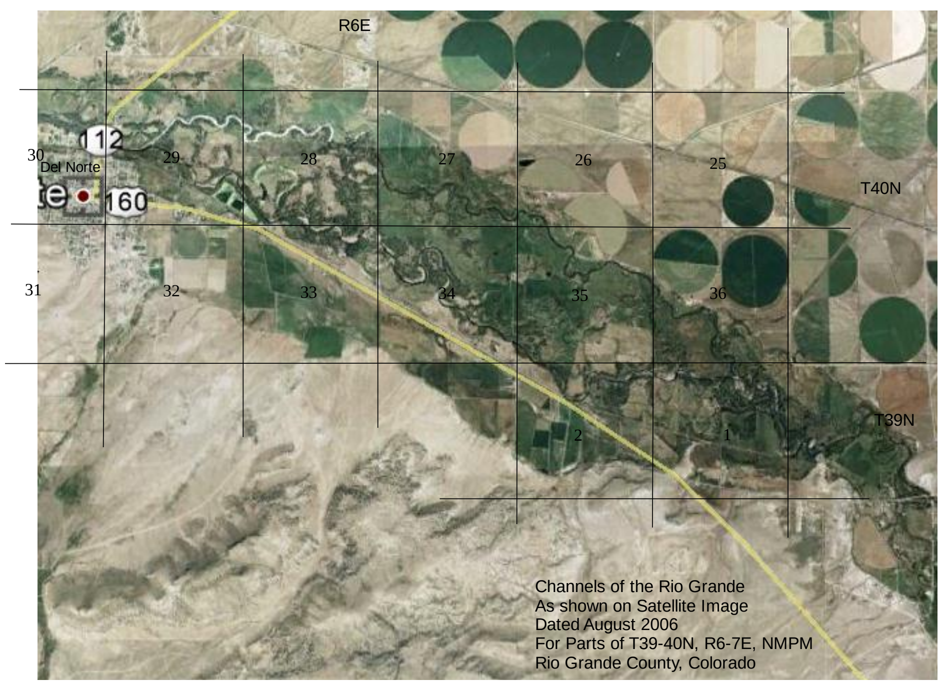

Figure 8: Rio Grande stream channels Del Norte – Sevenmile Plaza, August 2006 (source: Google Earth.)

[7] Ritter, D.F., 1986, Process Geomorphology.   Wm C. Brown Publishers. Pp. 239-240.

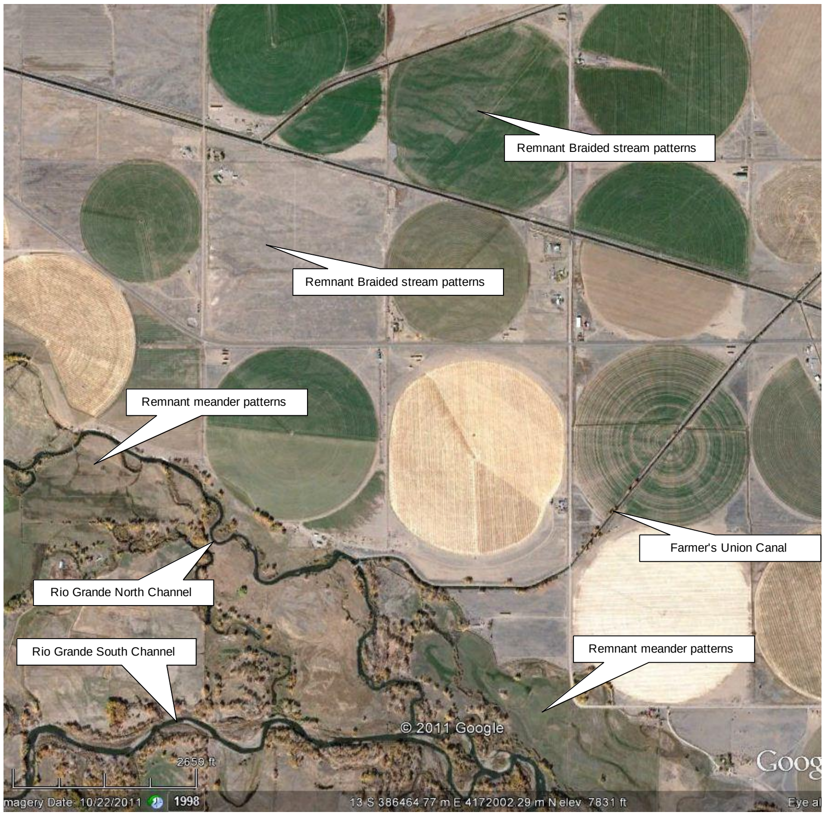

Figure 9: Remnant stream channel patterns in T 39-40N, R6-7E, NMPM near Farmer's Union Canal headgate. (Google Earth satellite image Oct 22, 2011).

A climate-reconstruction study based on dendrochronology research at the Great Sand Dunes, although it may not be capable of accurately reproducing exact climatic conditions for any given year, has shown a relatively strong trend of reduced variability in precipitation over the past ~1,000 years compared to earlier years, culminating in low annual variability in precipitation in this area in the late 19th and early 20th Centuries (see Figure 10).[8]

[8] Grissino-Mayer, H.D., Baisan, C.H., Swetnam, T.W, 1998, A Multicentury Reconstruction of Precipitation for Great Sand Dunes National Monument, Southwestern Colorado. U.S. Dept of the Interior, National Park Service.

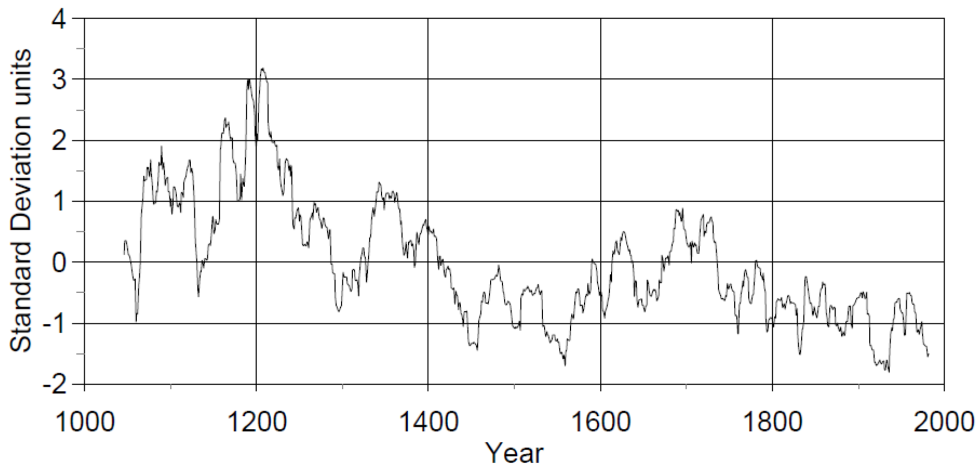

Figure 7. Running variance for the precipitation reconstruction calculated for overlapping 25-year periods, represented as a 10-year cubic smoothing spline. The graph clearly shows declining variability in precipitation during the past 1000 years in this part of southern Colorado.

Figure 10: (includes caption from source; see footnote 6).

A recent study by the U.S. Geological Survey in the San Juan Mountains, using techniques including reconstruction of Holocene tree line along with radiocarbon dating and pollen analysis of alpine bog deposits, suggests that the summer monsoon circulation in the San Juan Mountains was probably more intense during the early Holocene (~9,000 years BP) than it is today.[9] Also, as noted earlier, a change in climate and reduction in sediment transport capacity following the end of the most recent glacial period, around 9,000 to 10,000 years BP.[10]

These sources suggest that reduction in annual precipitation variability and reduction in sediment transport capacity during the Holocene (~9,000 to 10,000 years before present) may be a factor in the change of the Rio Grande in the study area from a braided stream to meandering stream, and also may be a factor in the relative stability of the Rio Grande channels in the Del Norte – Sevenmile Plaza reach. Another factor may be a change in local base level of the stream, thus changing its characteristics for erosion and aggradation. These are hypotheses, and would require investigation beyond the scope of the RGDSS to evaluate.

[9] Carrara, P.E., 2011, Deglaciation and Postglacial Treeline Fluctuation in the Northern San Juan Mountains, Colorado. U.S. Geological Survey Professional Paper 1792, pp. 37-40.
[10] Madole, R.F., and others, 2008, On the origin and age of the Great Sand Dunes, Colorado. In Geomorphology. Pp. 99-119.

Regardless of the cause, the stream channels in the present and ancestral Rio Grande are important in evaluating the hydrogeology of the study area because stream channel morphology helps determine the sequences of sediment that are deposited, and therefore is a factor in whether or not a relatively low hydraulic conductivity layer of sufficient lateral persistence to cause perching of the river above the regional water table is likely to be common in the present Rio Grande floodplain.

Braided and Meandering Stream Deposits

There are differences in the sequences of materials deposited by meandering streams (as we observe along the Rio Grande) as compared to braided streams (as we observe on the Rio Grande fan north of the present Rio Grande floodplain). Figure 10 shows the two types of sedimentary deposition generally observed in meandering channels and braided channels.

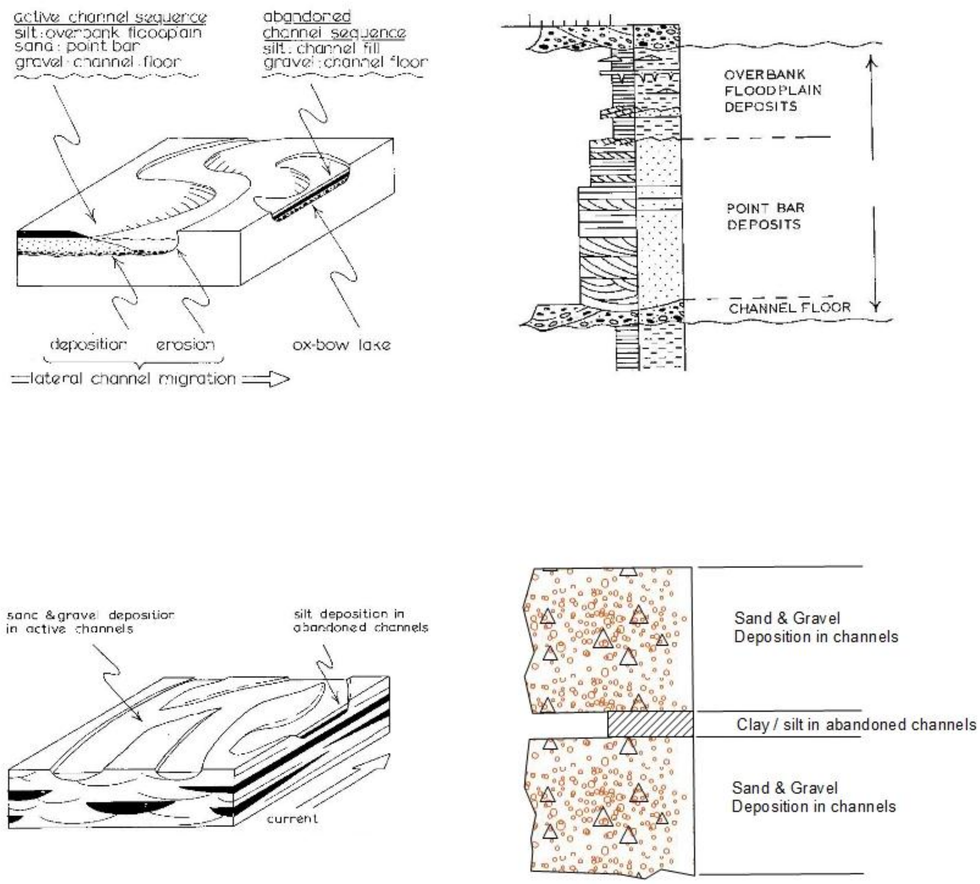

Figure 11: typical sedimentary deposits by meandering stream channels (top) and braided stream channels (bottom).
Modified from R. C. Selley, Ancient Sedimentary Environments, figures 2.1, 2.2, 2.13.

Meandering channels typically show laterally continuous deposits of fine sand, silt, and clay due to “overbank” deposition when stream discharge is sufficiently high to inundate the flood plain and the resulting quiet water during recession of the flood water allows sedimentation of the fine-grained materials. Below the overbank deposits we typically see sand and fine gravel due to lateral migration of point bars, underlain by deposits of channel-floor gravel or cobble beds. By contrast, sediments deposited by braided streams typically show relatively thick deposits of sand, gravel and cobble, with relatively thin and discontinuous deposits of silt and clay in longitudinal bars that are deposited by quiet water in abandoned stream channels. It should be noted, also, that the percentage of fine grained silt and clay deposits increases, and the largest grain size decreases, in a downgradient direction on an alluvial fan such as the Rio Grande fan.

WELL LOG

Ground Elevation____________(if known)

FROM FEET	TO FEET	TYPE OF MATERIAL
0	8	Sand and Gravel
8	11	Clay
11	36	Rock and Gravel
36	44	Clay
44	52	Sand and Gravel
52	57	Clay
57	77	Sand
77	78	Blue Clay

Figure 12: driller's log from well 4322F, SW SW 14, T39N, R7E, NMPM approximately 2 miles NW of Monte Vista and ¼ mile north of Rio Grande.

WELL LOG

From	To	Type and Color of Material
0	3	top soil
3	8	gravel
8	9	clay
9	26	gravel
26	28	clay
28	60	gravel
60	63	clay
63	80	gravel
80	94	sand
94	95	clay

Figure 13: driller's log from well 6026-R-R, NW NE 34, T40N, R7E, NMPM approximately 2 miles west of Highway 285 and 4 miles north of the Rio Grande.

Figures 12 and 13 illustrate the difference in sedimentary deposits in the study area. Figure 12 shows the driller's log from Well 4322F, which is located only about ¼ mile north of the Rio Grande, inside the present meander-belt floodplain. Figure 13 shows the driller's log from Well 6026-R-R, located approximately 4 miles north of the Rio Grande, in an area of the Rio Grande fan clearly subject to braided stream deposition. Although nominally these are similar and quite simple well logs, composed only of alternating sand/gravel and clay layers, the two logs are actually quite different. Well 4322-F, reflective of meandering stream deposition, has clay layers indicated at 3, 8, and 5 feet thick down to 77 feet (above the clay at 77 feet – 78 feet, which may be indicative of lacustrine clays and thus may not be part of the fluvial deposits (see Figure 12). Clay constitutes 21% of the thickness of the drilled deposits in Well 4322-F above the basal clay.

By contrast, in the braided stream deposition area on the Rio Grande fan, well 6026-R-R (see Figure 13) shows clay layers of 1, 2, and 3 feet thick, which is only about 6% of the thickness of the drilled deposits above the clay at 94 feet – 95 feet depth. From our experience reviewing well logs in the San Luis Valley, we have also found that clay or silt layers in the Rio Grande fan area typically are not laterally continuous in the unconfined aquifer. Clay layers near the Rio Grande, based on well to well comparison of driller's logs, typically show a higher degree of lateral continuity.

The differences in fluvial deposition discussed above suggest that, all other factors being equal, hydraulic conductivity (K) is likely to be higher in the braided deposits than in the meander deposits within the floodplain of the Rio Grande. In addition, and perhaps more importantly with respect to RGDSS ground water modeling, the ratio of vertical K to horizontal K (Kv : Kh) is likely to be lower in the meander belt than in the braided fan area due to the greater lateral continuity of the clay and silt layers.

Rio Grande Channel Stability: Implications for Hydrogeology

In the upper part of the study area, from Del Norte approximately to Sevenmile Plaza, the Rio Grande has a relatively high stream gradient (see Figure 6), and there is abundant bed load material composed of boulders, cobbles, and large gravel from the source area in the San Juan Mountains. In addition, although there are several reservoirs in the upper Rio Grande above Del Norte, they are of relatively small size and there are no large flood-control reservoirs. This would lead one to expect high runoff during high snowpack years. Also, in this situation, one would expect to see a river of high erosive capability, and large channel migration and relatively frequent channel avulsion.

However, large channel migration and frequent avulsion have not been observed in historic times in the Del Norte – Sevenmile Plaza reach.   A comparison of early survey maps of the San Luis Valley with recent satellite imagery shows that the North Channel and the South Channel of the Rio Grande in this reach have remained relatively stable, with only minor channel changes observed. Below Monte Vista, there have been some channel avulsions documented, although major channel changes have been relatively infrequent.[11]

Figure 14 is a map of the upper part of the study area composited from scans of two General Land Office maps.[12] The surveys for these maps were done in the 1872-1873 time period. For comparison, Figure 15 shows the river channels and “sloughs” (backwaters) from the GLO maps, overlaid on top of the contemporaneous Wheeler Survey map of the same area.

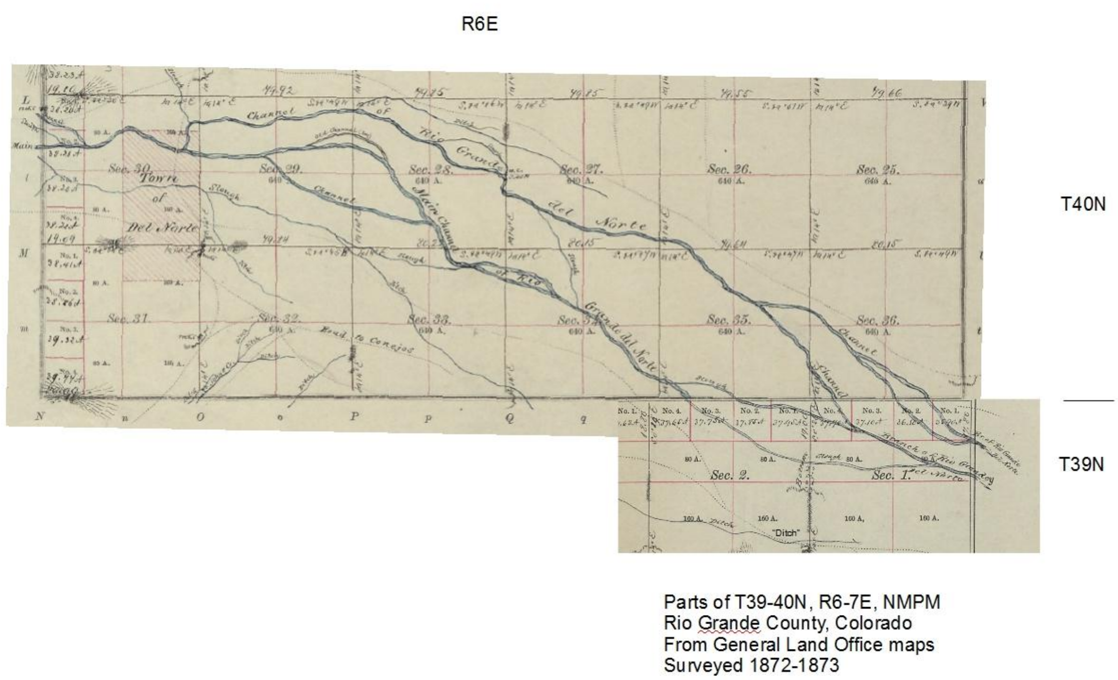

Figure 14: Composite of General Land Office maps of 1872-1873 showing parts of T39-40N, R6-7E, NMPM.

[11] Jones, L.S., 1996, The Evolution of the Modern Rio Grande Floodplain, San Luis Valley, Colorado: Implications for Alluvial Stratigraphy. Ph.D. Thesis, University of Wyoming. 147p. plus appendixes.
[12] http://www.glorecords.blm.gov/search/

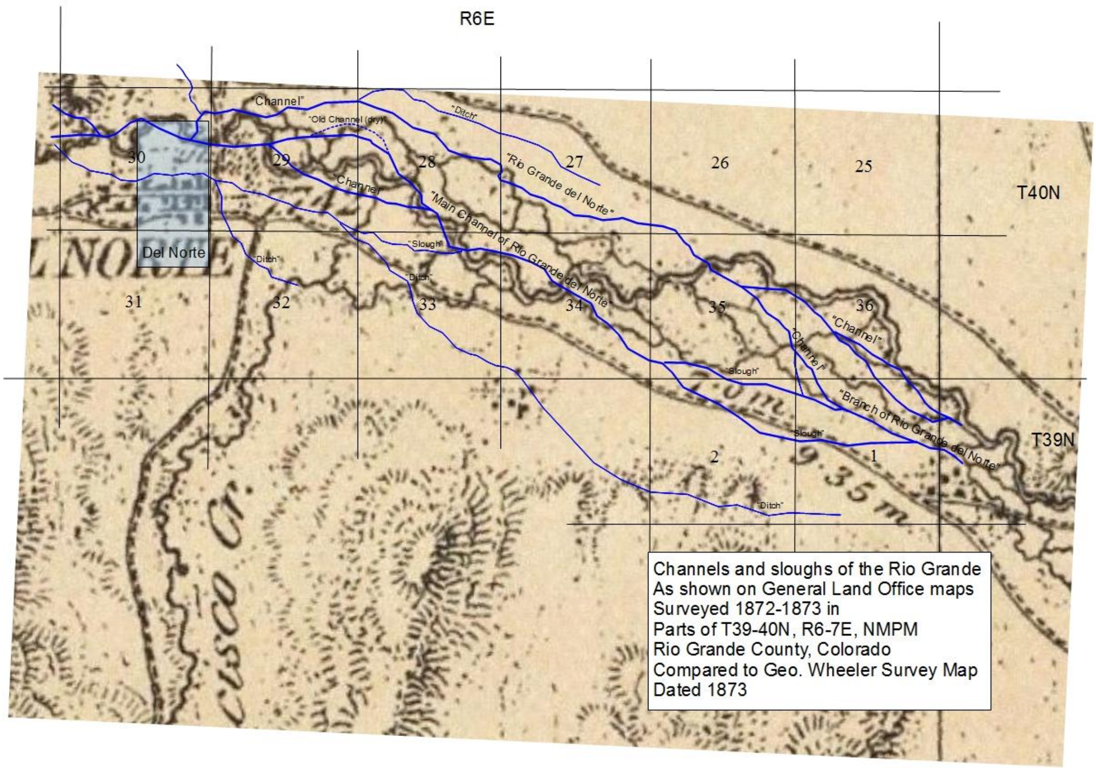

Figure 15: General Land Office mapped location of channels and sloughs, along with Section lines, overlain on Wheeler Survey map of 1873. The blue lines represent the location of channels and sloughs from the 1873 GLO maps.

As can be seen by comparison of the two maps, both from circa 1873, the comparison is rather poor. A third comparison, overlaying the GLO survey channels and sloughs on the Siebenthal map of 1906, is in agreement with the general channel locations from the GLO mapping (see Figure 16).

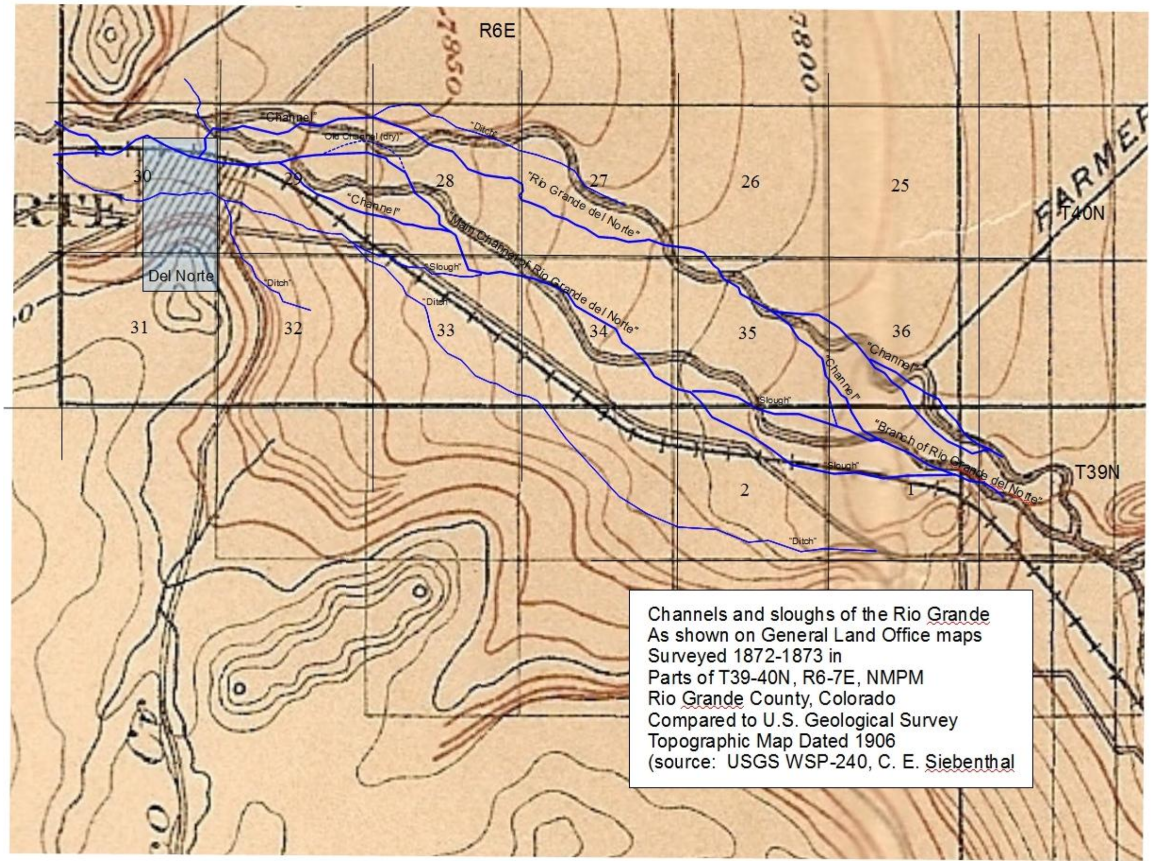

Figure 16: General Land Office mapped location of channels and sloughs, along with Section lines, overlain on Siebenthal map of 1906 (USGS WSP-240). The blue lines represent the location of channels and sloughs from the 1873 GLO maps.

Finally, we compared the 1873 GLO survey maps by overlaying the channel and slough locations on satellite imagery from August, 2006 (see Figure 17).

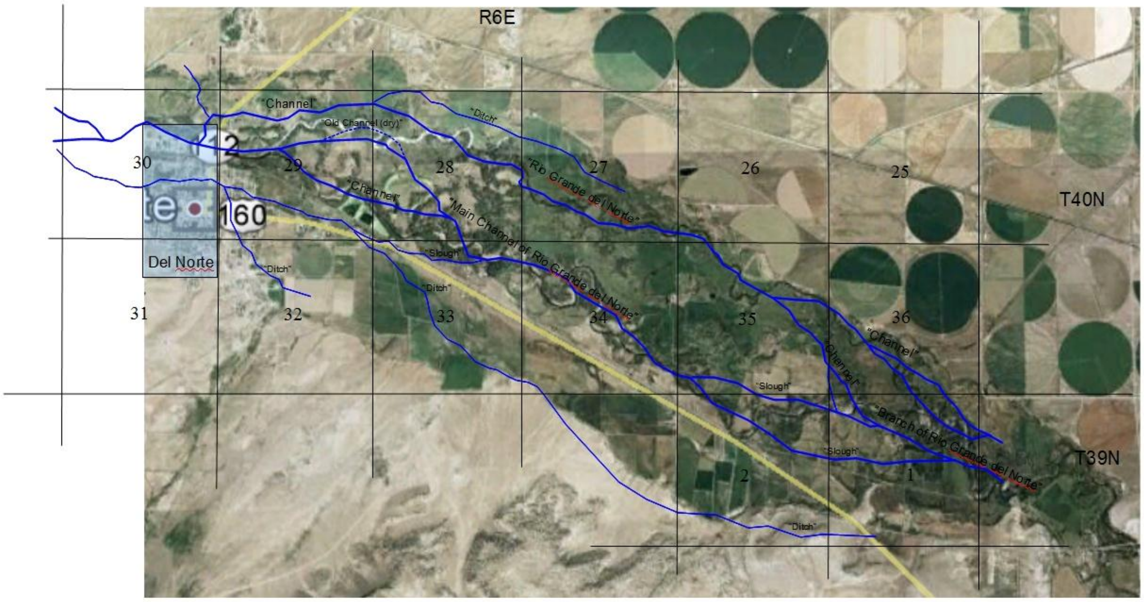

Figure 17: General Land Office mapped location of channels and sloughs, along with Section lines, overlain on a satellite image from August, 2006 (source: Google Earth™). The blue lines represent the location of channels and sloughs from the 1873 GLO maps.

The latter comparison (see Figure 17) presents the best comparison of the stream channels, and suggests that the General Land Office maps of 1872-1873 were the most accurate in terms of the depicted locations of the stream channels. The GLO maps compared to the satellite image from 133 years later shows a remarkably good comparison. Some lateral channel migration is evident, assuming that the ~1873 GLO maps did not generalize the smaller meanders. Overall, we find it remarkable that so little channel change occurred over the course of 133 years, in a stream reach that should be highly erosive, with high sediment bed load, moderate stream gradient, and highly seasonal runoff.

We believe that one major factor in the channel stability of this reach during historic times is the fact that much of the peak runoff is "shaved off" due to diversions by large irrigation canals in this reach (eight on the North Channel and three on the South Channel according to Mr. Steve

Baer, District 20 Water Commissioner). The Rio Grande Canal, in particular, is important in this respect, because it is the largest canal in the San Luis Valley[13], and it diverts up to 1/3 of the water in the river just at the head of the study area at the northern terminus of the narrow water gap through which the Rio Grande passes at Del Norte. In addition, the Rio Grande Canal has a sluiceway just downstream of its diversion dam. In operation, sediment being carried downriver, including cobble- and boulder size material, is allowed to be diverted into the Rio Grande Canal and then is sluiced back to the Rio Grande about 200 yards downstream so that the canal and the diversion dam do not become sediment choked and thus rendered unusable.[14] This diversion activity creates a situation where the Rio Grande has much lower peak flow than it did before the onset of surface water diversions, and so has significantly less energy available to move the bed load material, erode its banks, and allow its channels to migrate, but it has the same amount of sediment that it did in pre-irrigation time (approximately pre-1870).

From this mapping comparison and our discussions with the Water Commissioner and other water managers in the San Luis Valley, we believe the primary reasons for the relative stability of the Rio Grande in the upper reach of the study area are:

- Peak discharge is much lower than it was before the onset of surface water diversions (pre ~ 1870's).
- Seasonal variability of precipitation in the last few thousand years may be less than it was in the early Holocene (~9,000 to 10,000 years BP). In addition, most of the braiding and fan deposits in the Rio Grande alluvial fan, north of the present floodplain, were deposited during glacial periods in the late Pleistocene (greater than ~ 10,000 years BP).
- Bank and channel maintenance activities, although limited, have been done in this reach for sediment removal and to maintain flows to canal headgates.
- Cattle ranching operations on the "island" between the North Channel and the South Channel, and on the north and south sides of these channels, have provided an incentive to maintain pasturelands for grazing. Although some bank degradation along the river due to livestock was noted during this field reconnaissance, overall the pasture vegetation

[13] Steve Baer, District 20 Water Commissioner, personal communication 2011.
[14] Ibid.

appears to aid in slowing the erosion rate of the channel meanders, as compared to poorly-vegetated or non-vegetated stream banks.

The hydrogeology of the stream channels of the Rio Grande have been affected by the relative stability of the channels in historic time. Overall, the stability of the channels over time strongly suggests that whatever materials lined the streambed at the onset of surface water diversions, cattle ranching, and other stability-inducing factors, are still in place today.

November 2011 Field Observations and Measurements

During the period November 14-16, 2011, HRS (Mr. Harmon) observed streambed conditions throughout the study area between Del Norte and the Rio Grande – Alamosa County line (see Figure 1). Part of that time was spent with Mr. Steve Baer, District 20 Water Commissioner. My activities included the following:

- Reconnaissance and familiarization with access to the Rio Grande North Channel and South Channel at many locations.
- Visiting and photographing some of the larger surface water diversions.
- Observing and sampling streambed and bank materials in various locations.
- Conducting two in-situ permeameter tests in stream bank materials.

1.1.1. Channel observations and photographs

Overall, the streambed and bank material in the study area, as would be expected, varies from a highly heterogeneous mix of cobbles > 10 inches in size along with finer-grained materials at the upper end near Del Norte and the "split", down to much finer grained streambed and bank material in the downstream area. The following sequence of photographs illustrates this.

Figure 18 is a photo of the North Channel of the Rio Grande just below the Kane-Callan Ditch headgate, about one mile downstream of the "split". Note cobbles up to ~16 inches on the right and left banks, and armoring the stream channel.

Figure 18: North channel of Rio Grande, approximately 100 feet downstream of Kane-Callan Ditch headgate. Looking downstream (east.)

Figure 19 is a photo of the North Channel of the Rio Grande just below the Raber Ditch headgate, about three miles downstream of the "split". Note cobbles up to ~10 inches on the right bank.

Figure 19: North Channel of Rio Grande at the Raber Ditch headgate. Looking downstream (east).

Figure 20 shows the South Channel at the Off Ranch Bridge located approximately three miles downstream of Del Norte. Note the cobbles up to ~10 inches armoring the streambed.

Figure 20: Rio Grande South Channel at Off Ranch bridge about 3 miles downstream of Del Norte.

Figure 21 shows the streambed of the Rio Grande looking upstream from the County Road 3W Bridge approximately 3 miles below Sevenmile Plaza (~10 miles below Del Norte). At this location, there is only one main channel of the Rio Grande. Note the presence of cobbles up to ~6 inches in size in the streambed.

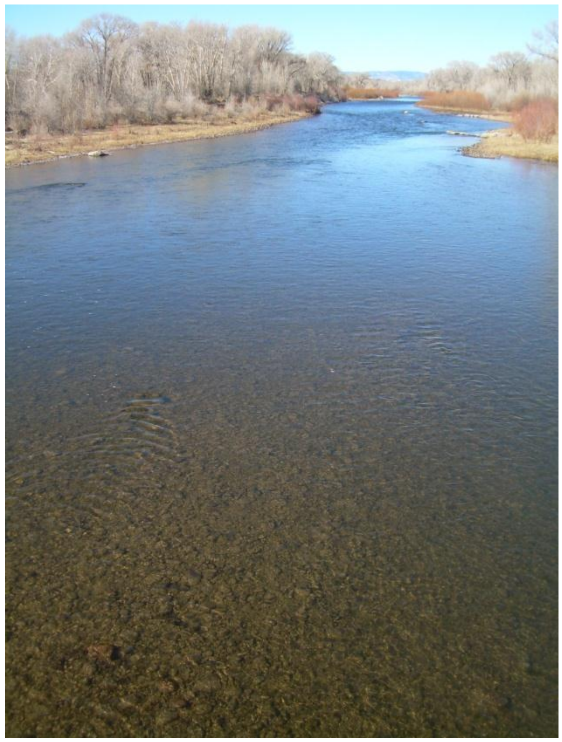

Figure 21: Rio Grande channel at CR 3W bridge, looking upstream (west).

Figure 22 was taken looking downstream at the US 285 bridge just north of Monte Vista. The channel-centered bar is just downstream of a bridge pier. Note the cobbles are much smaller in size than they are further upstream. Largest cobbles are in the ~3 to 5 inch range. The stream channel is partially cobble-armored, with some deep channel scour evident.

Figure 22: Rio Grande at US 285 bridge, looking downstream (east).

Figure 23 shows the Rio Grande channel looking downstream to the bridge at the Rio Grande – Alamosa County line. There is a small percentage of cobble-sized material in the streambed and banks at this location. The channel is composed predominantly of sand and silt-sized material.

Figure 23: Rio Grande at Rio Grande – Alamosa County Line Bridge. Looking downstream (east). Note sand / silt channel at this location.

Shallow hand-dug test holes

At several locations, HRS attempted to dig or auger shallow test holes in the streambed. This was successful more often than not, but in the upper reach of the study area the cobble armoring of the streambed made digging difficult. No test hole exceeded 2 ½ feet depth, and most were 1 to 1 ½ feet. A notable observation was that at many locations we observed fine-grained, organic-rich clayey sand just below the armoring cobble layer at the streambed surface. At some locations cobbles were bedded in the clayey sand matrix. Following is a summary of the test holes dug or augered.

- Raber Ditch headgate, right bank of Rio Grande North Channel (located on the Off Ranch, accessed with owner's permission): 3 of 4 test holes showed at least a 6-inch thickness of organic (peat?) rich clayey sand within 18 inches of streambed level at the bank.

- Off Ranch bridge, left bank of Rio Grande South Channel: 2 of 5 test holes showed silty or sandy clay or clayey sand within 1 ½ feet of streambed level at the bank. Very difficult digging due to cobble armoring of streambed/banks.

- Sevenmile Plaza (Fivemile Road bridge): Lots of concrete and other debris in the channel. 3 of 4 test holes showed the presence of silty sand or clayey sand within 2 feet of streambed level at the bank. Cobble armoring is sporadic in this area.

- Bridge at County Road 3W, left bank: 0 of 3 test holes dug to 1 ½ feet depth showed silt or clay material. Primarily medium grained sand, with some cobble.

- Consolidated Slough at Road 3W: No test holes dug or augered. Some cobble and concrete debris observed in the channel.

- Highway 285 Bridge (sample locations from 30 feet to 100 feet downstream of gage, on left bank): 1 of 4 test holes showed clay or silt, with organic material, within 6 to 24 inches of streambed level at the bank.

- Soldier's Home Road Bridge: 4 of 4 test holes showed at least 6 inches of organic-rich silty or clayey sand within 2 ½ feet of streambed level.

- Rio Grande – Alamosa County Line Road Bridge: Sample locations approximately 225 feet upstream of bridge on left bank: 3 of 3 test holes showed organic-rich silty or clayey sand within 2 feet of streambed level at the bank.

Although access to the center of the present stream channels was limited, the shallow test holes at the bank, or in the river within a few feet of the bank, showed that clayey or silty sand, often observed with peaty organic material, is common even in the upstream cobble-armored reach of the study area. This suggests that the cobble armoring, coupled with the reduced peak flows due to surface diversions, has protected the clayey sand in the streambed against erosion.

2011 Hydraulic Conductivity Tests

HRS tested the hydraulic conductivity (K) of the peaty silty-clayey sand at two locations in the study area, using a field-portable constant head permeameter.[15] A photograph of the testing apparatus is shown in Figure 24, at the upstream test location.

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[15] Guelph Permeameter™. Soilmoisture Equipment Corp. Use of trade names is for descriptive purposes only, and does not imply endorsement by HRS or the Colorado Division of Water Resources.

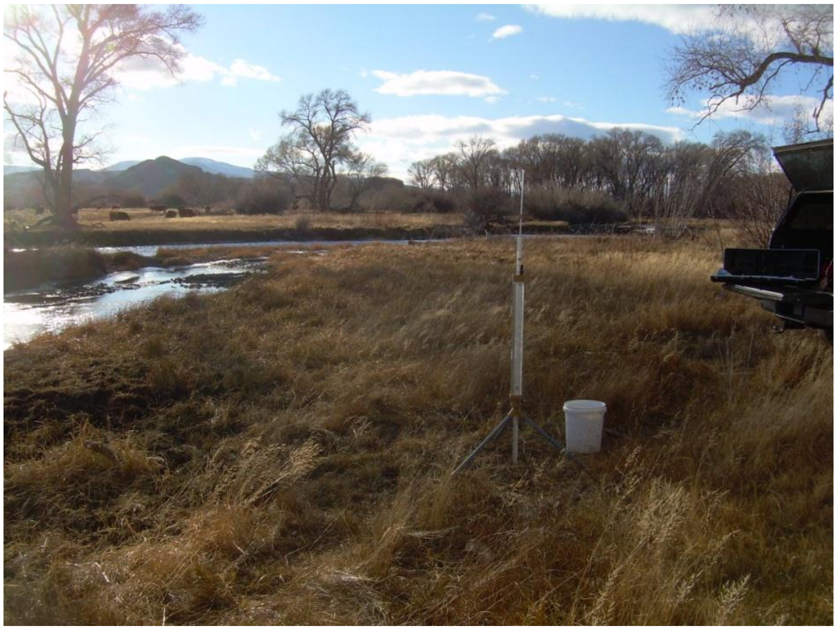

**Figure 24: Field setup of Guelph constant-head permeameter.
Near Kane-Callan headgate, looking upstream (west).**

One test was in the upstream cobble-armored reach, near the Kane-Callan ditch headgate. The other was in the downstream, sand channel, near the Rio Grande – Alamosa County line. In both tests, we attempted to dig the shallow test hole and set up the test so that only the clayey / silty-sand layer was being tested. The manufacturer's recommended auger drilling, borehole cleaning, and testing procedures were followed at both tests.

At both sites, we tried to follow the streambed material to the adjacent bank by test holes, and perform the test in the same fine-grained material observed in the streambed. The test apparatus is not practical for use in a flowing stream.

The results of the permeability tests were as follows.

Upstream test: Observed material: organic-rich, black to gray clayey sand.
$K = 1.5 \times 10^{-3}$ feet/day
Results were rejected due to observed frost in this material in an adjacent test hole after test was completed.

Downstream test: Observed material: gray silty to clayey sand
K = 0.93 feet/day

Due to the observed frost at the first test site, we do not believe the results are accurate. There was no frost in the ground at the second site, and the results, based on Mr. Harmon's experience, appear credible for the observed material.

2012 Test Hole Drilling and Field Investigations

Based on the results of the 2011 part of the investigation, the PRT and the State requested that HRS develop and implement a program of shallow test hole drilling and sample data collection to refine the data in the near-surface sediments in and near the stream channels of the Rio Grande in the Del Norte – Rio Grande County / Alamosa County line study area. This part of the memorandum discusses the data collection and evaluation completed in 2012. Plate 1 shows the locations of the test hole sites.

Method of Investigation

During the week of April 30 through May 4, 2012, HRS Water Consultants, Inc. conducted field investigations in the Rio Grande floodplain approximately between Del Norte on the northwest (upstream) and the Rio Grande – Alamosa County Line Road (aka CR 6E). The investigations consisted of test hole drilling and slug tests on private and public property as close as could be managed to the active channels of the Rio Grande. A total of 20 test holes were drilled, and sediment samples collected, along the Rio Grande from Rio Grande County Rd. 6E (aka County Line Road), progressing west to the east edge of Del Norte (William Miller property). Eight slug tests were performed in eight different test holes. In addition, sieve analysis was done on seven samples from a representative set of the test holes. The purpose of the investigation was to better define the type and characteristics of the sedimentary materials that make up the stream beds of the Rio Grande in the study area.

Property Access

HRS obtained access permission for the test drilling the week of April 16, 2012, from the following private owners and public agencies:

- Mr. William Miller
- Mr. Cory Off (Off Ranch)
- Mr. Craig Cotten
- Mr. Bob Homer
- Rio Grande County Road & Bridge Dept. (Mr. Patrick Sullivan, Supervisor)
- Colorado Division of Parks and Wildlife (Mr. Dave McCannon, Area Manager)

Mr. Harmon also visited each site with Mr. Steve Baer, District 20 Water Commissioner, and staked the approximate location of the test holes. Table 1 lists the various sites and the test holes drilled. Plate 1 shows the locations of the test holes. No test holes were drilled on Mr. Homer's property due to high water in several ditches/swales causing very soft ground, thus preventing the drill rig from reaching the river bank.

Location of Buried Utilities

Once all of the private land access and ROW access points were secured from the owners or the public representatives, buried utility location requests ("utility locates") were called in to the Utility Notification Center of Colorado on April 24 and 25. Eric Saenger of HRS checked the marked utility locates on April 29 and 30. Eric Saenger met with a utility location technician to verify the location of a high pressure gas line along the west side of County Rd. 3E. All sites were determined to be clear of buried utilities.

Test Hole Drilling and Sediment Sampling Procedures

Site Services Inc. of Golden, Colorado was contracted to do the test hole drilling using its Geo-Probe direct push track-mounted drilling rig. This rig uses a hydraulically-operated hammer to push and hammer hollow steel rods into the ground. There is no rotation of the drill pipe in this drilling method. Soil samples were recovered in plastic tubes of 1.75-inch (macro tube) or 1.4-inch (dual tube) outside diameter. In using the Macro sampling method the rods with a plastic tube in the bottom five foot rod are pulled from the borehole to retrieve the sample tube. This method was used in the areas of very cobbly material at the surface to have a better chance of recovering soil materials: Cotten and CR 5W west to Miller. In the dual tube method the sample tube is attached to an inner rod and after penetrating five feet the inner rods and plastic tube are removed from the outer rods leaving the outer rods in the borehole. This method was used in the areas of finer grained material at the surface: east of Cotten and CR 3W. Table 1 lists the test holes that were sampled with each method.

Site Services mobilized to Monte Vista on April 30 and arrived at the first drill site at approximately 11:30 AM. Six test holes were drilled on April 30. Drilling was finished by the end of the day on May 2. A total of 20 test holes were drilled, and sediment samples collected, along the Rio Grande from Rio Grande County Rd. 6E (aka County Line Road) west to the east edge of Del Norte (Miller property). Table 1 shows which test holes were sampled within 10 feet of the bank of the river. The other test holes were not close to the river bank due to lack of access. Sample recovery ranged from zero in some of the 0 to 5 foot depth interval drives to 100% recovery, generally in the 10 to 15 foot depth interval drives. In general the 0 to 5 foot samples recovered less than half the tube (i.e. less than 2.5 feet) due to the softness and lack of consolidation of the soils. One sample tube split during drilling and the samples were placed into labeled sample bags. Several bags of samples from the drive shoe, representative of the bottom of the test hole, were also obtained at various sites.

After reaching total depth (generally 15 feet) a temporary casing consisting of 1-inch diameter PVC was placed inside the outer rods and the rods were then removed from the borehole.

Table 1: Test Holes Information

Land Owner	Location			Test Hole Name	Latitude	Longitude	Map Label	Total Depth of Test Hole below ground level (ft.)	Date Drilled	Macro (M) or Dual Tube (DT) Sampling	Drilled on river bank within 10 ft. of river	Depth to Water below ground level (ft.)	Riv… gro… at…
Colorado Division of Parks & Wildlife	County Rd. 6E	N Parking Lot	SW corner	SWA CR 6E N lot SW	37.5708	-106.0398833	6E N SW	15	4/30/2012	DT	N	4.96	
Colorado Division of Parks & Wildlife	County Rd. 6E	N Parking Lot	SE corner	SWA CR 6E N lot SE	37.57078334	-106.0394833	6E N SE	15	4/30/2012	DT	N	3.63	
Colorado Division of Parks & Wildlife	County Rd. 6E	S Parking Lot	NW corner	SWA CR 6E S lot NW	37.56355	-106.0399167	6E S NW	15	4/30/2012	DT	N	3.12	
Colorado Division of Parks & Wildlife	County Rd. 6E	S Parking Lot	NE corner	SWA CR 6E S lot NE	37.56351667	-106.0396667	6E S NE	15	4/30/2012	DT	N	2.71	
Colorado Division of Parks & Wildlife	County Rd. 3E	Parking Lot	NW corner	SWA CR 3E NW	37.58243334	-106.0945833	3E NW	15	4/30/2012	DT	N	4.03	
Colorado Division of Parks & Wildlife	County Rd. 3E	Parking Lot	NE corner	SWA CR 3E NE	37.58246667	-106.0942833	3E NE	15	4/30/2012	DT	within 20 ft.	4.52	
Craig Cotten	N bank of River	east		Cotton E	37.6045	-106.134	Cot E	15	5/1/2012	M	Y	2.99	
Craig Cotten	N bank of River	west		Cotton W	37.60475001	-106.1346167	Cot W	15	5/1/2012	M	Y	14.31	
Rio Grande County	County Rd. 3W east edge		S hole	CR 3W E S hole	37.61731667	-106.2041667	3W E S	15	5/1/2012	DT	N	11.65	
Rio Grande County	County Rd. 3W east edge		N hole	CR 3W E N hole	37.61793334	-106.2041	3W E N	15	5/1/2012	DT	N	12.64	
Rio Grande County	County Rd. 3W west edge		N hole	CR 3W W N hole	37.622	-106.2043	3W W N	15	5/1/2012	DT	N	11.01	
Rio Grande County	County Rd. 3W west edge		S hole	CR 3W W S hole	37.62135	-106.2042833	3W W S	15	5/1/2012	DT	N	10.01	
Rio Grande County	County Rd. 5W at County Rd. 5N		edge of river	CR 5W E	37.64695	-106.2405667	5W E	15	5/1/2012	M	Y	11.03	
Rio Grande County	County Rd. 5W at County Rd. 5N		next to slough	CR 5W W	37.64703334	-106.2411	5W W	15	5/1/2012	M	on slough	8.24	
Bill Miller	SW corner of bridge			B Miller	37.68288334	-106.34155	Mill	15	5/2/2012	M	Y	9.69	
Off Ranch at Kane-Callen Ditch headgate	N bank of river W of headgate		W	Off K-C ditch W	37.68575	-106.3284833	Off KC W	15	5/2/2012	M	Y	10.24	
Off Ranch at Kane-Callen Ditch headgate	N bank of river at headgate		Middle	Off K-C ditch Midd.	37.68543334	-106.3277167	Off KC M	15	5/2/2012	M	Y	10.48	
Off Ranch at Kane-Callen Ditch headgate	N bank of river E of headgate		E	Off K-C ditch E	37.68548334	-106.327	Off KC E	15	5/2/2012	M	Y	10.41	
Off Ranch at bridge	N bank of river NE of bridge		E	Off bridge E	37.67161667	-106.28425	Off E	14	5/2/2012	M	Y	12.52	
Off Ranch at bridge	N bank of river west of bridge		W	Off bridge W	37.67131667	-106.28505	Off W	15	5/2/2012	M	Y	11.85	

The bottom six inches of the PVC casing was slotted with a saw. This was done to be able to measure the groundwater level. Water level was measured in all of the test holes from one to three days after installation. Table 1 lists the measured depth to water and the date measured. For the test holes drilled on the river bank the river water level below ground level at the test hole was measured by leveling between the test hole and river.

As each sample tube was removed from the drill rods, flexible plastic end caps were placed on the tube ends with a red cap at the top and black at the bottom. The tubes were marked with the name and number of the test hole and the depth interval, both on the tube and red end cap. Each sample tube was briefly described in the field. A more detailed lithologic description was performed in the office by cutting open the tubes to get an unobscured view of the samples. Certain of the samples were viewed under a low-power stereomicroscope to verify lithology, grain size, sorting, and rounding. After the material in each tube was described selected material from each tube was placed into a marked sample bag. The sample descriptions are appended at that back of this memorandum.

Summary of Sample Descriptions

The samples recovered, in general, were composed predominantly of sand and gravel with varying amounts of clay and silt matrix. Some thin intervals of very clayey sand and gravel to very sandy clay also were observed. Some of the samples showed weakly graded bedding with finer sediments at the top grading to coarser material downward. The shallowest five feet at each test hole site was generally very soft and uncompacted, as indicated by the drilling. This indicated the presence of poorly compacted, clay-rich organic soil and overbank deposits. When many of the samples were allowed to dry out, the material became very hard and cemented due to the presence of a clay matrix that cemented the sand and gravel together. Virtually all of the samples in every test hole showed the presence of some clay – often disseminated in the matrix of the poorly stratified samples.

Sieve Analysis

Several samples were selected for sieve analysis using standard dry sieving methods. The purpose of the sieve analysis was check the percentage of silt and clay material (minus 200 sieve size) and to obtain a first approximation value of hydraulic conductivity for a representative set of the test hole samples in and near the channels of the Rio Grande in the study area.

After drying the samples, it was found that sufficient clay was present that it had adhered to the larger, sand and gravel sized granular material. Test sieving showed that the clay coating was skewing the sieve analysis toward the larger grain sizes. The decision was made to have representative samples from seven test holes analyzed by Advanced Terra Testing, Inc. (ATT), of Lakewood, Colorado, using a standard wet sieve analysis method (ASTM D422[16]). In brief, this method involves wet-sieving the sample through a series of progressively finer sieve screens, then taking the wet material passing the No. 200-mesh sieve (i.e. silt and clay-sized material) and allowing it to settle over time through a clear cylinder, using a hydrometer to determine the particle distribution of the finest fraction of the sedimentary material. The ATT analysis sheets are appended to this memorandum.

The data from the ATT wet-sieve and hydrometer analysis showed that the clay fraction ranged from 4.8% to 6.7% by weight in all of the samples except for the CR 5W East test hole, which had a 34.4% clay fraction. CR 5W East sample was described by HRS as sandy clay with thin gravelly lenses. The rest of the samples were described by HRS generally as poorly sorted sand and gravel with some clay matrix.

The results of the ATT sieve analysis then were input to a spreadsheet, which was then used to estimate an effective grain size, and to calculate a first-approximation estimate of hydraulic conductivity. Hydraulic conductivity (K) was estimated using the Hazen Formula[17]:

$$K = C(D_{10})^2$$

[16] http://www.astm.org/Standards/D422.htm
[17] Fetter, C.W., 1988, Applied Hydrogeology, page 81

- K is hydraulic conductivity in cm/sec
- D_{10} is the effective grain size in cm
- C is a coefficient based on a set of empirical values listed below:

Very fine sand, poorly sorted	40-80
Fine sand with appreciable fines	40-80
Medium sand, well sorted	80-120
Coarse sand, poorly sorted	80-120
Coarse sand, well sorted, clean	102-150

The results of this analysis are shown in Table 2.

Table 2: Summary of Hazen Analysis

Summary of Estimated Kh Ranges from Grain Size Analysis					
Test Site	Estimated Kh (low range)		Estimated Kh (high range)		Distance Downstream of Rio Grande Bifurcation
	cm/sec	ft/day	cm/sec	ft/day	miles
Miller Bridge site	4.9E-03	1.4E+01	9.7E-03	2.8E+01	0.2
Off Ranch Kane-Callen West site	2.2E-02	6.3E+01	4.5E-02	1.3E+02	0.9
Off Ranch Bridge West site	2.0E-03	5.7E+00	4.0E-03	1.1E+01	3.4
County Rd 5W East site	5.6E-05	1.6E-01	1.1E-04	3.2E-01	6.2
County Rd 3W West side, North site	1.0E-03	3.0E+00	2.1E-03	5.9E+00	8.8
County Rd 3W East side, South site	2.0E-03	5.7E+00	4.0E-03	1.1E+01	9.0
Cotten East site	8.9E-04	2.5E+00	1.8E-03	5.1E+00	12.8

This analysis shows that the vertical hydraulic conductivity of the alluvial material underlying the Rio Grande, from its bifurcation east of Del Norte to a point downstream approximately 13 miles, is relatively low in comparison with deeper alluvial material as described in water well driller's logs from the area. We conclude that the silt and clay fraction present in the very recent (Holocene) alluvial material within and adjacent to the present streambeds, will slow or impede the downward percolation of river water to the unconfined aquifer underlying the Rio Grande in this reach of the river. We believe this is a primary reason why the gain and loss of the Rio Grande in this reach is relatively low, and also is a primary reason for the perching of the river and the associated water table in the very near surface Holocene material, as compared to a deeper water table noted on water well records in the area, as seen in the 2009 hydrogeologic study of the Del Norte – Sevenmile Plaza reach.

Slug Testing

Slug tests were attempted at a number of the test holes (see Table 1). The slug tests were performed by measuring the static water level and inserting a pressure transducer into the PVC tube and set far enough below the static water level to accommodate the slug. The pressure transducer was set to record data in milliseconds for some and seconds for others. A 0.8 foot long solid steel rod was used as the slug. After allowing the water level to equilibrate after insertion of the pressure transducer, the slug was inserted into the PVC so that it was fully submerged. The transducer readings of the height of water above the transducer were used to measure the resulting rise and then decline in water level due to the insertion of the slug. The decline in water level was very slow in nearly all tests. Most tests were stopped after one hour due to the slowness of recovery.

Analysis of the slug tests were done using the standard Bouwer and Rice method.[18] The results indicate very low hydraulic conductivities (K) (see Table 3). The K values generally fall into the range expected of clay (about 1×10^{-9} to $1x\ 10^{-6}$ cm/sec)[19]. These values are several orders of magnitude lower than the first-approximation values estimated from the sieve analyses. Although care was taken to scarify the test holes with a bottle brush before the slug tests we believe there was still a smearing layer present on the wall of the test holes due to the clay-size material in the sediments, so that the slug tests yield values of K representative of the clay-size materials, not the composite K of the materials representative of each test hole, as were analyzed from the sieve and hydrometer testing.[20]

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[18] Bouwer, H., and Rice, R.C., 1976, A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells. Water Resources Research, Vol. 12 No. 3, pp. 423-428.
[19] Fetter, W., Applied Hydrogeology, Table 4.5, p.80.
[20] Yang, Y.J, Gates, T.M., 1997 Wellbore skin effect in slug-test data analysis for low-permeability geologic materials. Groundwater Journal, Vol. 35, no. 6, pp. 931-937.

Table 3: Summary of Slug Test Analysis

Test Hole No.	Total Depth (ft)	SWL (ft below GL)	Borehole Diameter (2*rw) (inches)	ID of temp PVC casing (2*rc) (inches)	Test Hole Penetration SWL to TD (H) (Ft)	Slotted Length (L) (ft)	Estimated Saturated Aquifer Thickness (D) (ft)	L / rw	Rw' ft	Rc ft	Coeff A	Coeff B	Coeff C	$\ln \frac{R_e}{r_w}$	t (sec)	t (days)	Initial SWL Displacement (y0) (ft)	SWL Displacement at time t (y) (ft)	Kh estimated (ft/day)	Kh estimated (cm/sec)
Slug Tests Attempted																				
SWA CR 6E N lot SW	15	4.96	2.25	1.00	10.04	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.371	4,091	0.04735	8.029	7.899	5.2E-04	1.8E-07
SWA CR 6E N lot SE	15	3.63	2.25	1.00	11.37	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.364	4,494	0.052014	7.067	7.012	2.2E-04	7.9E-08
SWA CR 6E S lot NW	15	3.12	2.25	1.00	11.88	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.361	3,849	0.044549	7.59	7.558	1.4E-04	5.0E-08
SWA CR 6E S lot NE	15	2.71	2.25	1.00	12.29	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.359	3,755	0.043461	4.839	4.716	8.8E-04	3.1E-07
SWA CR 3E NW	15	4.03	2.25	1.00	10.97	0.50	80	5.33	0.094	0.042	1.90	0.20	0.90	2.379	4,001	0.046308	6.783	6.715	3.3E-04	1.2E-07
CR 3W E N hole	15	12.64	2.25	1.00	2.36	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.482	98	0.001134	1.27	1.206	7.2E-02	2.5E-05
CR 3W W N hole	15	11.01	2.25	1.00	3.99	0.50	60	5.33	0.094	0.042	1.90	0.20	0.90	2.433	*poor data - not evaluated*					
CR 5W W	15	8.24	2.25	1.00	6.76	0.50	40	5.33	0.094	0.042	1.90	0.20	0.90	2.377	4,722	0.054653	5.585	5.563	1.1E-04	3.8E-08

Fetter, Table 4.5, p80: clay K ~ 1e-9 to 1e-6 cm/sec

No Slug Tests				
SWA CR 3E NE	15	4.52	2.25	1.00
Cotten E	15	2.99	2.25	1.00
Cotten W	15	14.31	2.25	1.00
CR 3W E S hole	15	11.65	2.25	1.00
CR 3W W S hole	15	10.01	2.25	1.00
CR 5W E	15	11.03	2.25	1.00
B Miller	15	9.69	2.25	1.00
Off K-C ditch W	15	10.24	2.25	1.00
Off K-C ditch Midd.	15	10.48	2.25	1.00
Off K-C ditch E	15	10.41	2.25	1.00
Off bridge E	14	12.52	2.25	1.00
Off bridge W	15	11.85	2.25	1.00
CR AA E	20	7.01	2.25	1.00
CR AA Midd.	20	8.07	2.25	1.00
CR AA W	20	7.91	2.25	1.00

Bouwer, H., and Rice, R.C., 1976, A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells. Water Resources Research, Vol. 12 No. 3, pp. 423-428.

Est: Kh / Kv 10

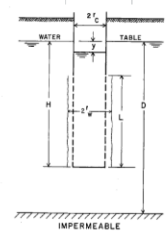


Fig. 1. Geometry and symbols of a partially penetrating, partially perforated well in unconfined aquifer with gravel pack or developed zone around perforated section.

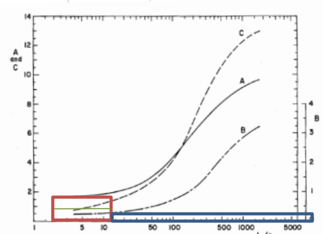


Fig. 3. Curves relating coefficients A, B, and C to L/r_w.

Conclusions

1. Shallow sediments composed in part of clayey sand or sandy clay (occasionally peat-rich) lies just below a cobble-rich armoring layer that forms the present streambed of the Rio Grande in the study area between Del Norte and the Rio Grande – Alamosa county line. The fine-grained material was observed in over half of the shallow (1 ½ to 2 ½ feet) hand-dug test holes, and in all of the direct-push test holes. The fine-grained material is also present in the streambed downstream as far as County Line Road, but in the lower part of this reach there is a decreasing amount of armoring of the streambed with cobble-sized sediment. The fine-grained layer is of relatively low hydraulic conductivity based on the 2011 constant head test and the 2012 wet-sieve analyses of the drill cuttings. The relatively low K serves to impede the downward percolation of water from the stream to the ground water system.

2. The cobble armoring layer and the relative lack of lateral migration or downstream migration of the stream channels during historic times appear to be the primary reasons that the channels, and the fine-grained layer at and below the streambed in the study area, have been relatively well protected from erosion. At the same time, the cobble-armored stream channels, although modified to some extent by the actions of man (channel modification, canal headgates, etc.) appear to have remained relatively stable in terms of location since at least the 1870's. We conclude that this is due in part to the fact that canal diversions in the Del Norte area since at least the 1870's have reduced peak runoff significantly, thus reducing the erosive capability ("stream competence") of the Rio Grande in this reach.

3. The ratio of vertical K to horizontal K (Kv:Kh) is likely to be lower in the meander belt that is roughly coincident with the current Rio Grande floodplain, and higher in the braided Rio Grande alluvial fan just to the north, due to greater lateral continuity of the clay and silt layers in the meandering stream area.

4. The organic-rich silty clay material in and adjacent to the streambeds, within about 10 feet of streambed elevation, has not been described in previous work on the Rio Grande in the study area as far as we know. It is not described in the USDA Rio Grande County soil survey because most of this sediment is deeper than 5 feet below the surrounding land surface due to stream incision of 4 to 8 feet in most places (most soil surveys stop describing soils past 5 feet depth). It is not described on driller's logs because typically they do not drill in the streambed, and the fine-grained sediments may be too shallow or perhaps too thin to be noticed by drillers.

5. Two constant-head permeameter tests in apparently the same clayey material, at two separate locations, both on the stream bank (not in the streambed). At the upstream test (near the Kane-Callan Ditch headgate, adjacent to the Rio Grande North Channel; see Plate 1) the test showed a K of 1.5×10^{-3} feet/day. This is probably in error, because the clayey material was partially frozen. The downstream test located near Soldier's Home Road (CR 3E) bridge resulted in a K of approximately 0.9 feet/day.

6. Slug tests were not successful in obtaining reliable K values for the in-place streambed material, although the eight slug tests performed did show a relatively consistent low hydraulic conductivity (1.1×10^{-4} ft/day to 8.8×10^{-4} ft/day; with one test of 0.072 ft/day), showing that clay-rich material is present at most sites tested.

7. Wet-sieve analyses of samples from seven different test holes in the study area show a significant percentage of silt and clay in every sample. These analyses shows that the vertical hydraulic conductivity of the alluvial material underlying the Rio Grande, from its bifurcation east of Del Norte to a point downstream approximately 13 miles, is relatively low in comparison with deeper alluvial material as described in water well driller's logs from the area. We conclude that the clay fraction present in the very recent (Holocene) alluvial material within and adjacent to the present streambeds, will slow or

impede the downward percolation of river water to the unconfined aquifer underlying the Rio Grande in this reach of the river. We believe this is a primary reason why the gain and loss of the Rio Grande in this reach is relatively low, and also is a primary reason for the perching of the river and the associated water table in the very near surface streambed material, as compared to a deeper water table noted on water well records in the area.

8. This investigation has shown that a fine-grained layer of relatively low K in and adjacent to the Rio Grande stream channels exists in all areas test drilled and sampled, between the Rio Grande bifurcation near Del Norte, downstream to the Rio Grande – Alamosa county line. The 2011-2012 investigation thus has confirmed the hypothesis proposed in the 2009 hydrogeologic study.

Recommendations

1. We recommend that an appropriate range of value for streambed conductance for the Rio Grande in the study area for RGDSS model calibration would be in the range of 0.01 to 10 feet/day, with calibration used to refine the value to attempt to match, as well as can be done, the estimated stream gain / loss in this reach.

2. We also recommend that it is appropriate for RGDSS modeling, and fits the available evidence, that the Rio Grande and an associated near-surface water table is perched above the regional unconfined aquifer water table.

Rio Grande Test Hole Lithologic Logs

GL	7860		Well Name	Miller				Date	5/2/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE NW Sec. 29, T40N, R6E: 2540' fnl, 2600' fwl				job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	1.9 ft.	moderate	SR-SA	sand	volcanic	Top 0.4 ft.: very fine to fine grained, dark brown, slightly clayey			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.5 ft.: fine to coarse grained and gravel, dark brown,			
							slight layering			
5	10	3.2 ft.	poor	SR-SA	sand & grav.	volcanic	Top 1.9 ft.: fine to coarse grained, gravel layers, dark brown			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.3 ft.: as above, slightly clayey, layered			
10	15	5.0 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 2.5 ft.: fine to coarse grained, gravel, dark brown			
			very poor	SR-SA	sand & grav.	volcanic	Middle 1.6 ft.: as above, clayey			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.9 ft.: as above, no clay			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7845		Well Name	Off Kane-Callen Ditch Headgate West Hole				Date	5/2/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SW NW Sec. 28, T40N, R6E: 1550' fnl, 1110' fwl				job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	1.4 ft.	N/A	N/A	soil	soil	Top 0.5 ft.: organic rich			
			poor	SR-SA	gravel	volcanic	Next 0.3 ft.: dark brown clay and silt matrix			
			moderate	SR-SA	sand	volcanic	Next 0.3 ft.: fine grained, silty, gray, clayey			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.3 ft.: fine to coarse grained, gravel, dark brown, silty			
5	10	3.2 ft.	moderate	SR-SA	sand	volcanic	Top 0.5 ft.: fine grained, silty, gray, clayey			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.7 ft.: fine to coarse grained, gravel, dark brown, silty			
10	15	4.9 ft.	very poor	SR-SA	sand & grav.	volcanic	as above			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7845	Well Name	Off Kane-Callen Ditch Headgate Center Hole	Date	5/2/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	SW NW Sec. 28, T40N, R6E: 1560' fnl, 1310' fwl	job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	1.7 ft.	N/A	N/A	clay	clay	Top 0.6 ft.: brown, very sandy to clayey sand - fine grained,
							organic
			very poor	SR-SA	sand & grav.	volcanic	Bottom: 1.1 ft.: fine to coarse grained, gravel, dark brown,
							clayey matrix in part
5	10	2.8 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, slight layering,
							clayey matrix in part
10	15	4.4 ft.	very poor	SR-SA	sand & grav.	volcanic	as above, clayey at base
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7845	Well Name	Off Kane-Callen Ditch Headgate East Hole	Date	5/2/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	SE NW Sec. 28, T40N, R6E: 1560' fnl, 1510' fwl	job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	0.9 ft.	N/A	N/A	clay	clay	Top 0.6 ft.: slightly reddish brown, silty to sandy - fine grained,
							organic at top
			poor	SR-SA	sand & grav.	volcanic	Bottom 0.3 ft.: fine to coarse grained, gravel, dark gray,
							slight clay matrix in part
5	10	0.8 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, slight clay matrix in
							part
10	15	3.4 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, slight clay matrix in
							part, slight layering, more apparent clay matrix in finer lenses
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7800		Well Name	Off Bridge East Hole			Date	5/2/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources			by	GES	1
TD	14 feet		Location	SW NE Sec. 35, T40N, R6E: 1430' fnl, 1910' fel			job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push			permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description		
From	To								
0	5	1.0 ft.	poor	SR-SA	sand	volcanic	Top 0.2 ft.: fine to coarse grained, fine gravel, rusty, clayey		
			poor	SR-SA	sand	volcanic	Bottom 0.8 ft.: fine to medium grained, gravel at base, rusty at top		
							to gray below , slightly clayey		
5	10	3.0 ft.	moderate	SR-SA	sand	volcanic	Top 0.4 ft.: fine to medium grained, trace gravel, dark brow n,		
							clayey, fill?		
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.6 ft.: fine to coarse grained, gravel, dark brow n,		
							layered, clayey in part		
10	14	2.0 ft.	very poor	SR-SA	sand & grav.	volcanic	same as 5 - 10 ft., hit refusal at 14 ft. due to large cobble		
							Note: Gravel generally rounded and sand generally subrounded		
							to subangular		
							Note: The largest gravel recovered is the diameter of the		
							sample tube, larger gravel penetrated by drilling		

GL	7800		Well Name	Off Bridge West Hole			Date	5/2/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources			by	GES	1
TD	15 feet		Location	SW NE Sec. 35, T40N, R6E: 1550' fnl, 2120' fel			job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push			permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description		
From	To								
0	5	2.0 ft.	moderate	SR-SA	sand	volcanic	Top 1.5 ft.: very fine to fine grained, gray, organic, slightly		
							clayey, gravel at top w ith roots		
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.5 ft.: fine to coarse grained, gravel, gray to dark brow n,		
							organic lenses		
5	10	2.4 ft.	moderate	SR-SA	sand	volcanic	Top 0.2 ft.: fine to very fine grained, dark brow n, fill?		
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.2 ft.: fine to coarse grained, gravel, dark brow n,		
							slight layering, slightly clayey in part		
10	15	3.4 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 1.7 ft.: fine to coarse grained, gravel, dark brow n,		
							clayey in part		
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.7 ft.: same as top, less clay matrix & fines		
							Note: Gravel generally rounded and sand generally subrounded		
							to subangular		
							Note: The largest gravel recovered is the diameter of the		
							sample tube, larger gravel penetrated by drilling		

GL	7745		Well Name	County Rd. 5W East Hole				Date	5/1/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE SE Sec. 6, T39N, R7E: 140' fsl, 80' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	2.0 ft.	moderate	SR-SA	sand	volcanic	Top 0.7 ft.: fine grained, gravel in part, dark brown, very clayey			
			N/A	N/A	clay	clay	Bottom 1.3 ft.: gray, semi firm, silty, fine grained sandy lenses,			
							gravelly at base			
5	10	3.5 ft.	moderate	SR-SA	sand	volcanic	Top 0.8 ft.: fine to medium grained, some gravel, brown,			
							clayey in part			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.7 ft.: fine to coarse grained, gravel, dark brown,			
							slightly to very clayey lenses			
10	15	5.0 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 1.7 ft.: fine to coarse grained, gravel, dark brown			
			N/A	N/A	clay	clay	Middle 1.6 ft.: brown, sandy - fine grained, thin gravel lens			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.4 ft.: same as top, clayey			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7745		Well Name	County Rd. 5W West Hole				Date	5/1/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE SE Sec. 6, T39N, R7E: 160' fsl, 220' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	2.3 ft.	poor	SR-SA	sand	volcanic	Top 0.9 ft.: fine to coarse grained, tan, organic material			
			very poor	SR-SA	sand & grav.	volcanic	Middle 0.6 ft.: fine to coarse grained, gravel, dark brown,			
							very clayey with thin brown sandy clay lenses			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.8 ft.: same as middle, slightly clayey			
5	10	3.5 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, layered,			
							slightly to very clayey in part			
10	15	4.9 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 3.4 ft.: fine to coarse grained, gravel, dark brown, layered,			
							slightly clayey in part			
			very poor	SR-SA	sand & grav.	volcanic	Middle 0.1 ft.: as above, very clayey			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.4 ft.: fine to coarse grained, gravel, dark tan, very			
							clayey to very sandy gravelly clay			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7705		Well Name	CR 3W West Side North Hole				Date	5/1/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	NE SE Sec. 16, T39N, R7E: 1470' fsl, 20' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.3 ft.	N/A	N/A	N/A	N/A	Top 0.6 ft.: road base
			poor	SR-SA	sand	volcanic	Next 0.8 ft.: fine to medium grained, brown, very clayey
			poor	SR-SA	sand	volcanic	Next 0.4 ft.: fine to medium grained, brown, slightly clayey
			N/A	N/A	clay	clay	Next 0.1 ft.: gray, soft, silty to fine sand
			very poor	SR-SA	sand & garv.	volcanic	Bottom 0.4 ft.: fine to coarse grained, dark gray, slightly clayey
5	10	2.5 ft.	very poor	SR-SA	sand & garv.	volcanic	Top 0.8 ft.: fine to coarse grained, dark brown, clayey
			very poor	SR-SA	sand & garv.	volcanic	Bottom 1.7 ft.: as above, slightly clayey in part
10	15	2.2 ft.	very poor	SR-SA	sand & garv.	volcanic	Top 0.5 ft.: fine to coarse grained, dark brown
			poor	SR-SA	sand	volcanic	Middle 1.2 ft.: fine to medium grained, dark brown, trace gravel,
							clayey in part
			very poor	SR-SA	sand & garv.	volcanic	Bottom 0.5 ft.: same as top
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7705		Well Name	CR 3W West Side South Hole				Date	5/1/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	NE SE Sec. 16, T39N, R7E: 1230' fsl, 20' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	1.0 ft.	poor	SR-SA	sand & grav.	volcanic	Top 0.7 ft.: road base and soil
			N/A	N/A	clay	clay	Bottom 0.3 ft.: gray to rusty, soft, very sandy - fine grained
5	10	1.0 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey
10	15	3.0 ft.	moderate	SR-SA	sand	volcanic	Top 0.7 ft.: fine to medium grained, dark brown, trace of clay
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.3 ft.: fine to coarse grained, dark brown, clayey at
							top to slightly clayey at base
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7705	Well Name	CR 3W East Side South Hole	Date	5/1/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	NW NW Sec. 22, T39N, R7E: 10' fnl, 20' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.5 ft.	N/A	N/A	clay	clay	Top 1.1 ft.: brown, sandy with some gravel
			very poor	SR-SA	sand & garv.	volcanic	Bottom 1.4 ft.: fine to coarse grained, dark brown, slightly
							clayey in part, slight layering
5	10	2.1 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, clayey
10	15	2.4 ft.	very poor	SR-SA	sand & grav.	volcanic	as above, very clayey in part
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7705	Well Name	CR 3W East Side South Hole	Date	5/1/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	NW NW Sec. 22, T39N, R7E: 210' fnl, 20' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.4 ft.	N/A	N/A	clay	clay	Top 1.0 ft.: brown, very sandy - fine to medium grained, gravelly
			poor	SR-SA	sand & grav.	volcanic	Bottom 1.4 ft.: fine to coarse grained, dark brown, slightly clayey,
							slight layering
5	10	1.9 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey to clayey in
							part, 0.2 ft. very clayey lens 0.6 ft. above base
10	15	3.0 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 2.1 ft.: fine to coarse grained, dark brown
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.9 ft.: as above, slightly clayey
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7650	Well Name	Cotten East Hole	Date	5/1/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	SE SE Sec. 19, T39N, R8E: 300' fsl, 880' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval From	To	Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
0	5	1.8 ft.	N/A	N/A	clay	soil	Top 0.1 ft.: dark brown, clayey to sandy
			poor	SR-SA	sand	volcanic	Middle 1.4 ft.: fine to medium grained, some coarse grained,
							some gravel, slightly clayey
			poor	SR-SA	sand & grav.	volcanic	Bottom 0.3 ft.: fine to coarse grained, gravel, dark brown, trace
							clay matrix
5	10	2.8 ft.	poor	SR-SA	sand	volcanic	Top 0.3 ft.: fine to medium grained, dark brown, very clayey,
							trace gravel
			very poor	SR-SA	sand & garv.	volcanic	Middle 1.4 ft.: gravel with sand as above, slightly clayey
			poor	SR-SA	sand	volcanic	Bottom 1.1 ft.: medium to fine grained, dark brown, increase in
							gravel downward, slightly clayey
10	15	5.0 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, clayey in part
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7650	Well Name	Cotten West Hole	Date	5/1/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	SE SE Sec. 19, T39N, R8E: 380' fsl, 1060' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Macro Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval From	To	Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
0	5	2.7 ft.	poor	SR-SA	sand	volcanic	Top 1.0 ft.: fine to medium grained, dark brown, clayey, silty
							in part
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.7 ft.: fine to coarse grained, gravel, dark brown,
							slightly clayey
5	10	2.4 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, slightly clayey
10	15	5.0 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, gravel, dark brown, slightly clayey
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7620		Well Name	SWA CR 3E NW				Date	4/30/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE NE Sec. 33, T39N, R8E: 2370' fnl, 120' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	2.8 ft.	N/A	N/A	clay	clay	Top 1.4 ft.: brown, sandy - fine to medium grained, semi firm,			
							trace gravel			
			N/A	N/A	clay	clay	Middle 0.8 ft.: brown, soft, silty to very fine sand			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.6 ft.: fine to coarse grained, brown, slightly clayey			
5	10	2.4 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 1.2 ft.: as above, clayey			
			poor	SR-SA	sand	volcanic	Middle 0.7 ft.: fine to coarse grained, dark brown			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.5 ft.: same as top			
10	15	2.3 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 0.8 ft.: as above			
			very poor	SR-SA	sand & grav.	volcanic	Middle 0.7 ft.: as above, increase in clay, slightly layered			
			very poor	SR-SA	sand & grav.	volcanic	Bottom 0.8 ft.: fine to coarse grained, dark gray, no clay			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7620		Well Name	SWA CR 3E NE				Date	4/30/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE NE Sec. 33, T39N, R8E: 2370' fnl, 20' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1
Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description			
From	To									
0	5	2.8 ft.	N/A	N/A	clay	clay	Top 2.0 ft.: brown, very sandy - fine to medium grained, soft			
							this fine grained sand lens near base			
			poor	SR-SA	sand	volcanic	Bottom 0.8 ft.: fine to medium grained, brown with thin rusty			
							layers, slightly clayey			
5	10	2.3 ft.	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey			
10	15	2.4 ft.	very poor	SR-SA	sand & grav.	volcanic	same as 5 to 10 ft.			
							Note: Gravel generally rounded and sand generally subrounded			
							to subangular			
							Note: The largest gravel recovered is the diameter of the			
							sample tube, larger gravel penetrated by drilling			

GL	7595	Well Name	CR 6E North Lot SW	Date	4/30/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	NE NE Sec. 1, T38N, R8E: 1300' fnl, 210' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.7 ft.	N/A	N/A	clay	clay	Top 2.0 ft.: dark brown, firm, sandy -fine grain, transitions
							downward to clayey fine grained sand - SR-Sa, moderate
							sorting
			poor	SR-SA	sand & grav.	volcanic	Bottom 0.7 ft.: fine to coarse grained, dark brown, slightly clayey
5	10	2.3 ft.	poor	SR-SA	sand	volcanic	fine to coarse grained, reddish at top to dark brown downward,
							some gravel, slightly clayey in part
10	15	2.8 ft.	poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey to clayey
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7595	Well Name	CR 6E North Lot SE	Date	4/30/12	page
Datum	ground level	Owner	State of Colorado Division of Water Resources	by	GES	1
TD	15 feet	Location	NE NE Sec. 1, T38N, R8E: 1300' fnl, 100' fel	job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)	Rig/Bit/Mud	Site Services Direct Push	permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	none					very soft material per driller
5	10	1.0 ft.	N/A	N/A	clay	clay	Top 0.1 ft.: dark brown, very organic, some sand and gravel
			moderate	SR-SA	sand	volcanic	Bottom 0.9 ft.: fine to medium grained, dark brown, scattered
							gravel, slightly clayey
10	15	1.3 ft.	moderate	SR-SA	sand	volcanic	as above
			very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7595		Well Name	CR 6E South Lot NW				Date	4/30/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE SE Sec. 1, T38N, R8E: 1300' fsl, 220' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
0	5	2.0 ft.	N/A	N/A	clay	clay	Top 0.6 ft.: dark brown, sandy - fine grained, firm
			poor	SR-SA	sand	volcanic	Bottom 1.4 ft.: fine to coarse grained, gravelly, dark brown,
							slightly clayey
5	10	2.3 ft.	poor	SR-SA	sand	volcanic	Top 0.8 ft.: as above
			very poor	SR-SA	sand & grav.	volcanic	Middle 0.4 ft.: fine to coarse grained, reddish brown, very clayey
			very poor	SR-SA	sand & grav.	volcanic	Bottom 1.1 ft.: fine to coarse grained, gray, slightly clayey
10	15	4.3 ft.	very poor	SR-SA	sand & grav.	volcanic	Top 1.4 ft.: fine to coarse grained, dark brown, slightly clayey
							to clayey
			very poor	SR-SA	sand & grav.	volcanic	Middle 1.3 ft.: fine to coarse grained, gray, slightly clayey to
							clayey at base
			poor	SR-SA	sand	volcanic	Bottom 1.6 ft.: fine to coarse grained, trace fine gravel, slightly
							clayey
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

GL	7595		Well Name	CR 6E South Lot NE				Date	4/30/12	page
Datum	ground level		Owner	State of Colorado Division of Water Resources				by	GES	1
TD	15 feet		Location	SE SE Sec. 1, T38N, R8E: 1300' fsl, 150' fel				job no.	99001-59	of
BH Dia.	2.25-inches (Dual Tube)		Rig/Bit/Mud	Site Services Direct Push				permit	N/A	1

Depth Interval		Direct Push recovery	Sorting	Rounding	Avg Gr Size	Primary Lithology	Lithologic Description
From	To						
First Hole refusal at 10 ft.							
0	5	0.0 ft. (1st hole)					very soft
5	10	2.0 ft. (1st hole)	very poor	SR-SA	sand & grav.	volcanic	fine to coarse grained, dark brown, slightly clayey to clayey
Second Hole 2 ft. from first							
0	10	3.7 ft.	N/A	N/A	clay	clay	Top 0.2 ft.: brown, sandy, soil
			moderate	SR-SA	sand	volcanic	Next 0.3 ft.: fine to medium grained, trace gravel, dark brown
			N/A	N/A	clay	clay	Next 1.2 ft.: dark brown, firm to soft, sandy - fine grained,
							trace gravel, organic
			very poor	SR-SA	sand & grav.	volcanic	Bottom 2.0 ft.: fine to coarse grained, dark brown, layered,
							clayey in part to very clayey at top
10	15	0.0 ft					tube smashed
							Note: Gravel generally rounded and sand generally subrounded
							to subangular
							Note: The largest gravel recovered is the diameter of the
							sample tube, larger gravel penetrated by drilling

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	13-14.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Cotton East	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	118.85
Wt. Dry Soil & Pan (g)	116.32
Wt. Lost Moisture (g)	2.53
Wt. of Pan Only (g)	4.40
Wt. of Dry Soil (g)	111.92
Moisture Content %	2.3
Wt. Hydrom. Sample Wet (g)	69.43
Wt. Hydrom. Sample Dry (g)	67.89

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	871.34
Weight of + #10 Before Washing (g)	172.53
Weight of + #10 After Washing (g)	164.14
Weight of - #10 Wet (g)	698.81
Weight of - #10 Dry (g)	691.57
Wt. Total Sample Dry (g)	855.71
Calc. Wt. "W" (g)	84.01
Calc. Mass + #10	16.11

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	46.90	46.90	46.90	5.5	94.5
3/8"	0.00	36.23	36.23	83.13	9.7	90.3
#4	0.00	43.98	43.98	127.11	14.9	85.1
#10	0.00	37.03	37.03	164.14	19.2	80.8
#20	3.10	11.35	8.25	8.25	29.0	71.0
#40	3.06	34.63	31.57	39.81	66.6	33.4
#60	3.10	18.73	15.64	55.45	85.2	14.8
#100	3.00	8.73	5.74	61.19	92.0	8.0
#200	3.05	5.00	1.95	63.14	94.3	5.7

Data entered by: DAW Date: 06/06/2012
Data checked by: Date: 6/6/12
FileName: HRH013CE

ADVANCED TERRA TESTING, Inc. ATT

HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	13-14.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Cotton East	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

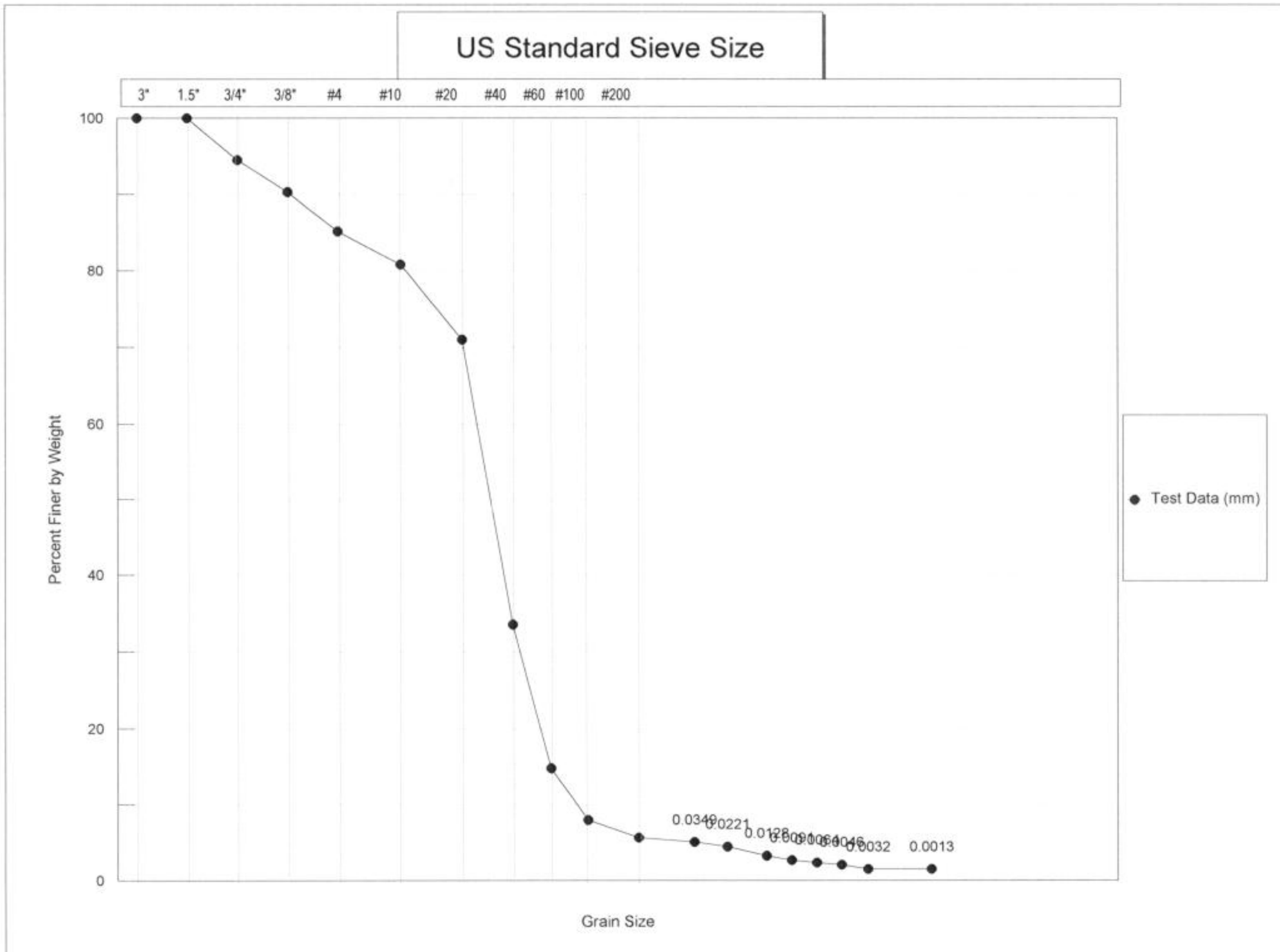
Hydrometer #	ASTM 152 H	Temp., Deg. C	25.1
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01285
Value of "alpha"	1.00	Wt. Dry Sample "W"	84.007
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	--	--	--	--	--	--
1.0	--	--	--	--	--	--
2.0	9.50	4.25	5.1	5.1	14.73	0.0349
5.0	9.00	3.75	4.5	4.5	14.81	0.0221
15.0	8.00	2.75	3.3	3.3	14.98	0.0128
30.0	7.50	2.25	2.7	2.7	15.06	0.0091
60.0	7.25	2.00	2.4	2.4	15.10	0.0064
120.0	7.00	1.75	2.1	2.1	15.14	0.0046
250.0	6.50	1.25	1.5	1.5	15.22	0.0032
1440.0	6.50	1.25	1.5	1.5	15.22	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/06/2012
Data checked by: Date: 6/6/12
FileName: HRH013CE

ADVANCED TERRA TESTING, INC. ATT



COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)	
	COARSE	FINE	CRS	MEDIUM	FINE		USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY	
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE			WENTWORTH

Client: HRS Water Consultants Boring No.: Sample No.: Cotton East
Job Number: 2852-01 Depth: 13-14.5'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants

JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	12.5-14'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR5W East	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes	
NATURAL	No	
Wt. Wet Soil & Pan (g)		79.90
Wt. Dry Soil & Pan (g)		78.94
Wt. Lost Moisture (g)		0.96
Wt. of Pan Only (g)		6.55
Wt. of Dry Soil (g)		72.39
Moisture Content %		1.3
Wt. Hydrom. Sample Wet (g)		86.56
Wt. Hydrom. Sample Dry (g)		85.43

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	981.13
Weight of + #10 Before Washing (g)	109.25
Weight of + #10 After Washing (g)	105.25
Weight of - #10 Wet (g)	871.88
Weight of - #10 Dry (g)	864.42
Wt. Total Sample Dry (g)	969.67
Calc. Wt. "W" (g)	95.83
Calc. Mass + #10	10.40

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	21.86	21.86	21.86	2.3	97.7
3/8"	0.00	18.14	18.14	40.00	4.1	95.9
#4	0.00	26.78	26.78	66.78	6.9	93.1
#10	0.00	38.47	38.47	105.25	10.9	89.1
#20	3.19	8.10	4.91	4.91	16.0	84.0
#40	3.00	17.95	14.95	19.87	31.6	68.4
#60	3.03	14.24	11.21	31.07	43.3	56.7
#100	3.04	13.51	10.47	41.54	54.2	45.8
#200	3.13	14.09	10.95	52.49	65.6	34.4

Data entered by: DAW   Date: 06/06/2012
Data checked by: SLL   Date: 6/6/12
FileName: HRH01251

ADVANCED TERRA TESTING, INC. ATT

HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	12.5-14'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR5W East	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

Hydrometer #	ASTM 152 H	Temp., Deg. C	25.0
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01286
Value of "alpha"	1.00	Wt. Dry Sample "W"	95.830
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	35.00	29.75	31.0	31.0	10.55	0.0591
1.0	29.00	23.75	24.8	24.8	11.53	0.0437
2.0	26.00	20.75	21.7	21.7	12.03	0.0315
5.0	23.00	17.75	18.5	18.5	12.52	0.0203
15.0	20.50	15.25	15.9	15.9	12.93	0.0119
30.0	19.25	14.00	14.6	14.6	13.13	0.0085
60.0	18.50	13.25	13.8	13.8	13.26	0.0060
120.0	17.00	11.75	12.3	12.3	13.50	0.0043
250.0	15.00	9.75	10.2	10.2	13.83	0.0030
1440.0	13.50	8.25	8.6	8.6	14.08	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/06/2012
Data checked by: [signature] Date: 6/6/12
FileName: HRH01251

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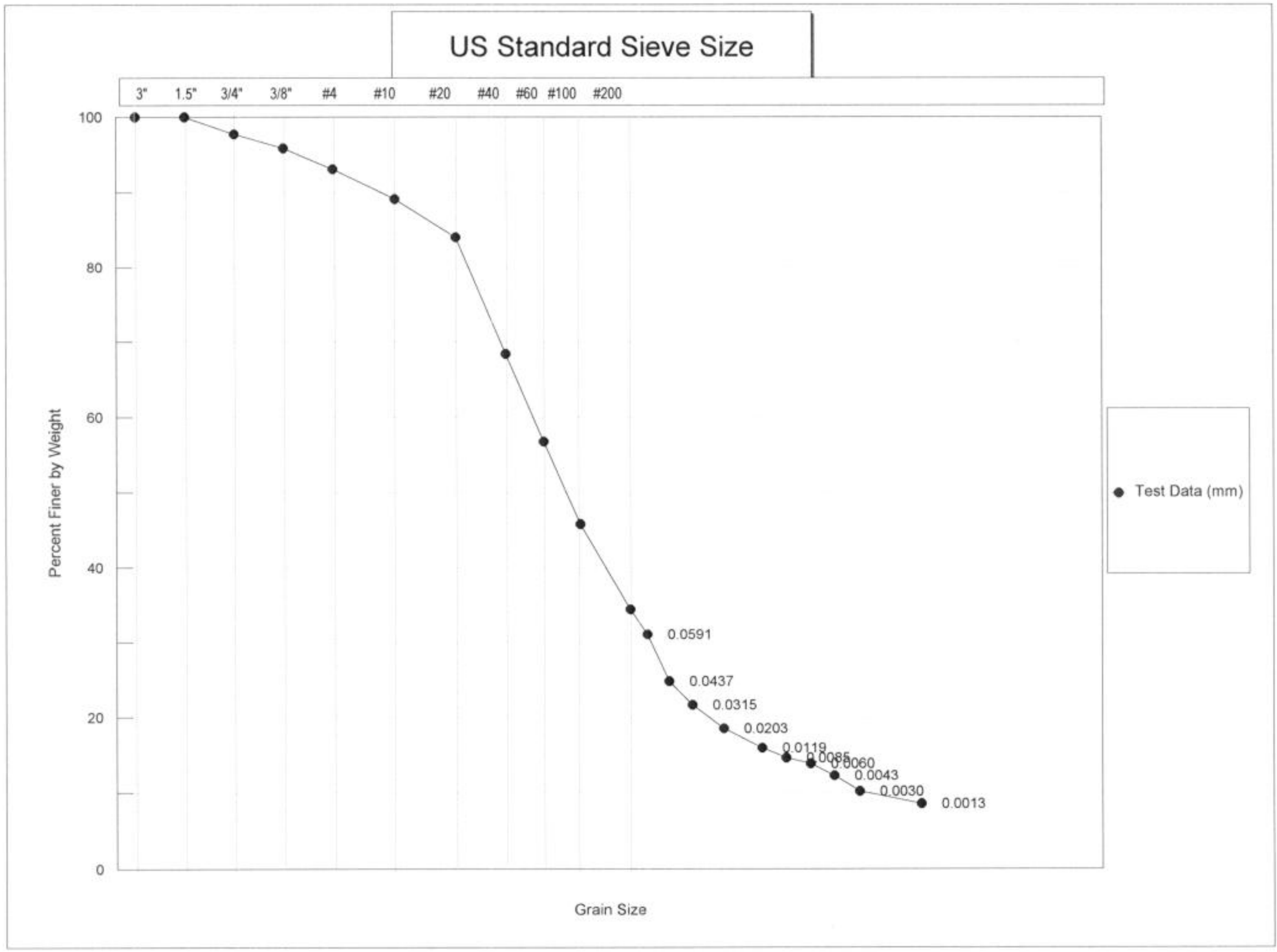

COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)	
	COARSE	FINE	CRS	MEDIUM	FINE		USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY	
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE			WENTWORTH

Client: HRS Water Consultants Boring No.: Sample No.: CR5W East
Job Number: 2852-01 Depth: 12.5-14'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants

JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	12.2-13.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Off Kane - Callen West	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes	
NATURAL	No	
Wt. Wet Soil & Pan (g)		69.71
Wt. Dry Soil & Pan (g)		69.01
Wt. Lost Moisture (g)		0.70
Wt. of Pan Only (g)		3.02
Wt. of Dry Soil (g)		65.99
Moisture Content %		1.1
Wt. Hydrom. Sample Wet (g)		73.10
Wt. Hydrom. Sample Dry (g)		72.34

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	1075.95
Weight of + #10 Before Washing (g)	780.40
Weight of + #10 After Washing (g)	763.91
Weight of - #10 Wet (g)	295.55
Weight of - #10 Dry (g)	308.76
Wt. Total Sample Dry (g)	1072.67
Calc. Wt. "W" (g)	251.30
Calc. Mass + #10	178.97

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	325.27	325.27	325.27	30.3	69.7
3/8"	0.00	180.97	180.97	506.24	47.2	52.8
#4	0.00	135.88	135.88	642.12	59.9	40.1
#10	0.00	121.79	121.79	763.91	71.2	28.8
#20	3.02	32.72	29.70	29.70	83.0	17.0
#40	3.28	16.84	13.57	43.26	88.4	11.6
#60	3.04	10.21	7.17	50.43	91.3	8.7
#100	3.02	8.05	5.02	55.45	93.3	6.7
#200	3.13	7.16	4.03	59.48	94.9	5.1

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FileName: HRH012OK

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HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	12.2-13.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Off Kane - Callen West	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

Hydrometer #	ASTM 152 H	Temp., Deg. C	25.0
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01286
Value of "alpha"	1.00	Wt. Dry Sample "W"	251.304
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	--	--	--	--	--	--
1.0	16.00	10.75	4.3	4.3	13.67	0.0475
2.0	15.00	9.75	3.9	3.9	13.83	0.0338
5.0	13.50	8.25	3.3	3.3	14.08	0.0216
15.0	12.00	6.75	2.7	2.7	14.32	0.0126
30.0	11.00	5.75	2.3	2.3	14.49	0.0089
60.0	10.00	4.75	1.9	1.9	14.65	0.0064
120.0	9.00	3.75	1.5	1.5	14.81	0.0045
250.0	8.00	2.75	1.1	1.1	14.98	0.0031
1440.0	8.00	2.75	1.1	1.1	14.98	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/06/2012
Data checked by: Date: 6/6/12
FileName: HRH012OK

ADVANCED TERRA TESTING, INC.
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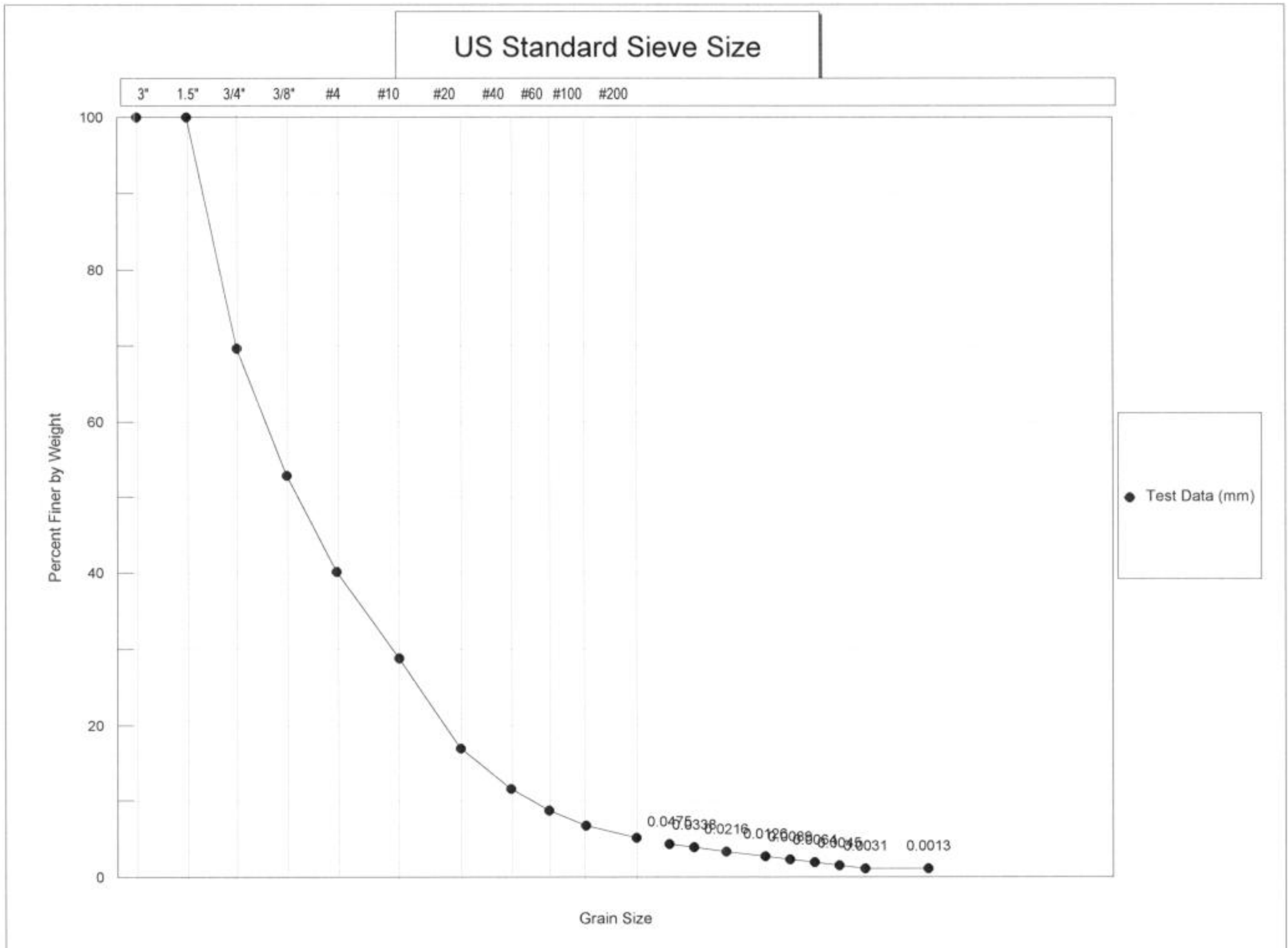


COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: HRS Water Consultants Boring No.: Sample No.: Off Kane - Callen West
Job Number: 2852-01 Depth: 12.2-13.5'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants | JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	13.3-14.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR3W Westside North	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	147.06
Wt. Dry Soil & Pan (g)	145.52
Wt. Lost Moisture (g)	1.54
Wt. of Pan Only (g)	4.40
Wt. of Dry Soil (g)	141.12
Moisture Content %	1.1
Wt. Hydrom. Sample Wet (g)	71.26
Wt. Hydrom. Sample Dry (g)	70.49

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	461.07
Weight of + #10 Before Washing (g)	247.10
Weight of + #10 After Washing (g)	236.66
Weight of - #10 Wet (g)	213.97
Weight of - #10 Dry (g)	221.99
Wt. Total Sample Dry (g)	458.65
Calc. Wt. "W" (g)	145.64
Calc. Mass + #10	75.15

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	61.41	61.41	61.41	13.4	86.6
3/8"	0.00	80.75	80.75	142.16	31.0	69.0
#4	0.00	51.22	51.22	193.38	42.2	57.8
#10	0.00	43.28	43.28	236.66	51.6	48.4
#20	3.26	15.92	12.66	12.66	60.3	39.7
#40	3.06	27.58	24.52	37.18	77.1	22.9
#60	3.07	21.13	18.06	55.24	89.5	10.5
#100	3.03	8.29	5.26	60.50	93.1	6.9
#200	3.13	6.10	2.98	63.48	95.2	4.8

Data entered by: DAW Date: 06/06/2012
Data checked by: SM Date: 6/6/12
FileName: HRH0133C

ADVANCED TERRA TESTING, INC. ATT

HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	13.3-14.5'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR3W Westside North	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

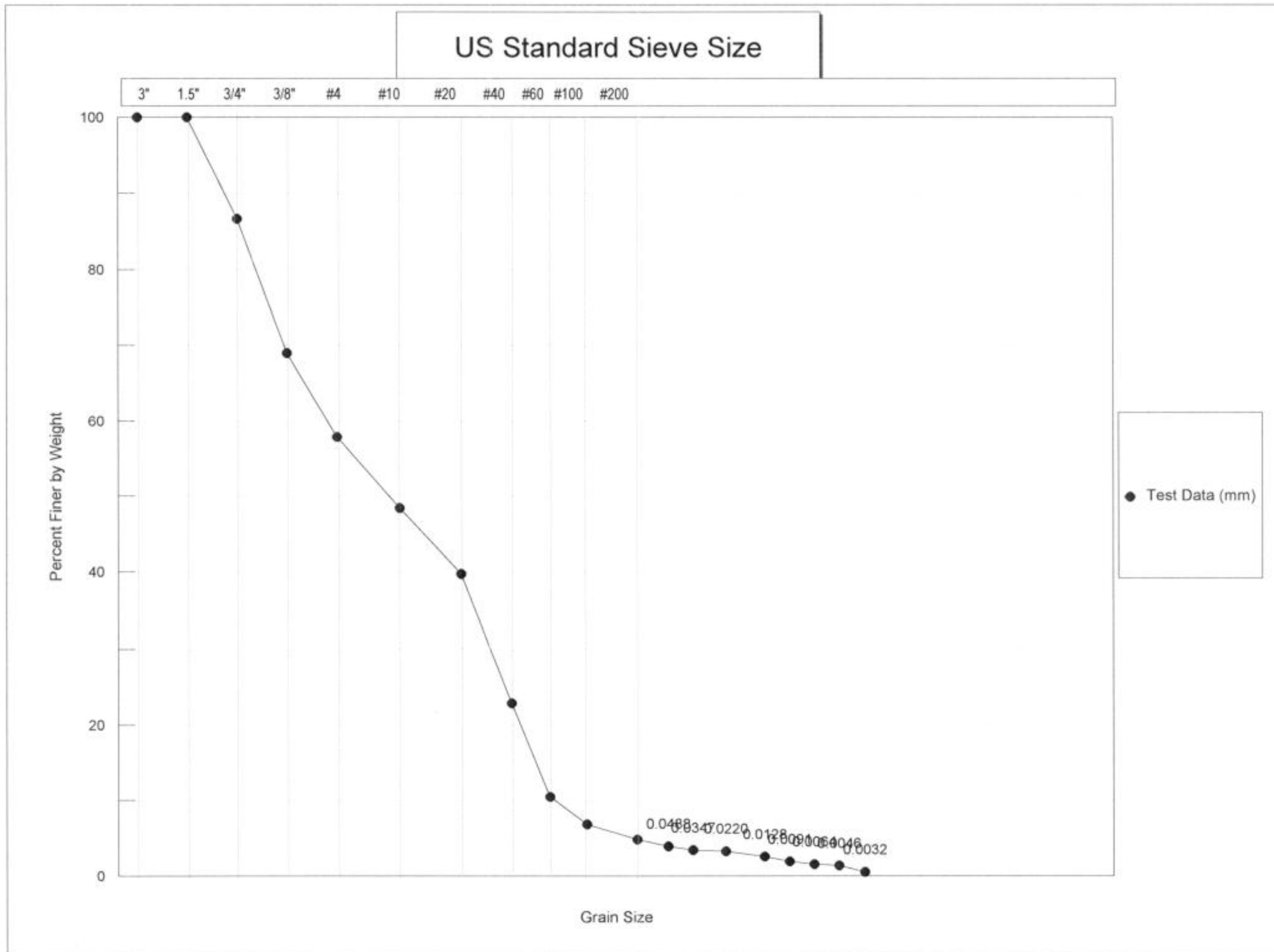
Hydrometer #	ASTM 152 H	Temp., Deg. C	25.2
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01283
Value of "alpha"	1.00	Wt. Dry Sample "W"	145.637
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	--	--	--	--	--	--
1.0	11.00	5.75	3.9	3.9	14.49	0.0488
2.0	10.25	5.00	3.4	3.4	14.61	0.0347
5.0	10.00	4.75	3.3	3.3	14.65	0.0220
15.0	9.00	3.75	2.6	2.6	14.81	0.0128
30.0	8.00	2.75	1.9	1.9	14.98	0.0091
60.0	7.50	2.25	1.5	1.5	15.06	0.0064
120.0	7.25	2.00	1.4	1.4	15.10	0.0046
250.0	6.00	0.75	0.5	0.5	15.31	0.0032

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/06/2012
Data checked by: SM Date: 6/6/12
FileName: HRH0133C

ADVANCED TERRA TESTING, INC. ATT



COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)	
	COARSE	FINE	CRS	MEDIUM	FINE		USCS

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY	
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE			WENTWORTH

Client: HRS Water Consultants Boring No.: Sample No.: CR3W Westside North
Job Number: 2852-01 Depth: 13.3-14.5'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants

JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	13.7-14.1'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Miller	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes
NATURAL	No
Wt. Wet Soil & Pan (g)	57.42
Wt. Dry Soil & Pan (g)	56.94
Wt. Lost Moisture (g)	0.48
Wt. of Pan Only (g)	3.01
Wt. of Dry Soil (g)	53.93
Moisture Content %	0.9
Wt. Hydrom. Sample Wet (g)	87.86
Wt. Hydrom. Sample Dry (g)	87.08

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	918.87
Weight of + #10 Before Washing (g)	686.23
Weight of + #10 After Washing (g)	673.21
Weight of - #10 Wet (g)	232.64
Weight of - #10 Dry (g)	243.49
Wt. Total Sample Dry (g)	916.70
Calc. Wt. "W" (g)	327.85
Calc. Mass + #10	240.77

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	305.39	305.39	305.39	33.3	66.7
3/8"	0.00	158.15	158.15	463.54	50.6	49.4
#4	0.00	113.04	113.04	576.58	62.9	37.1
#10	0.00	96.63	96.63	673.21	73.4	26.6
#20	2.98	31.39	28.41	28.41	82.1	17.9
#40	3.01	19.11	16.10	44.51	87.0	13.0
#60	3.04	12.88	9.84	54.35	90.0	10.0
#100	3.00	10.04	7.04	61.39	92.2	7.8
#200	3.06	9.68	6.61	68.00	94.2	5.8

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Data checked by: [signature] Date: 6/5/12
FileName: HRH0137M

ADVANCED TERRA TESTING, INC. ATT

HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	13.7-14.1'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Miller	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

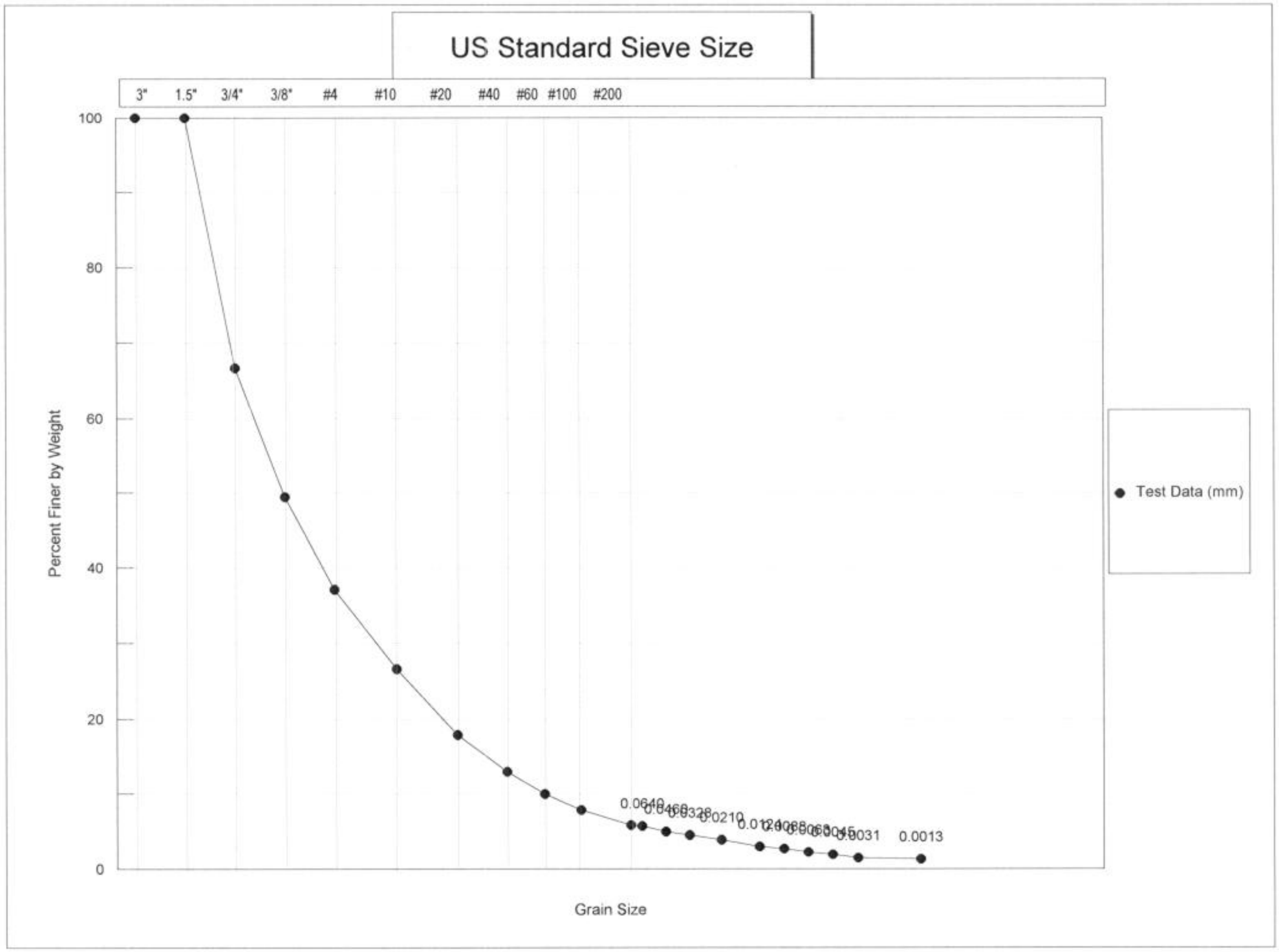
Hydrometer #	ASTM 152 H	Temp., Deg. C	24.9
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01288
Value of "alpha"	1.00	Wt. Dry Sample "W"	327.850
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	24.00	18.75	5.7	5.7	12.35	0.0640
1.0	21.50	16.25	5.0	5.0	12.76	0.0460
2.0	20.00	14.75	4.5	4.5	13.01	0.0328
5.0	18.00	12.75	3.9	3.9	13.34	0.0210
15.0	15.00	9.75	3.0	3.0	13.83	0.0124
30.0	14.00	8.75	2.7	2.7	13.99	0.0088
60.0	12.50	7.25	2.2	2.2	14.24	0.0063
120.0	11.50	6.25	1.9	1.9	14.40	0.0045
250.0	10.00	4.75	1.4	1.4	14.65	0.0031
1440.0	9.50	4.25	1.3	1.3	14.73	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW　　Date: 06/05/2012
Data checked by: [signature]　　Date: 6/5/12
FileName: HRH0137M

ADVANCED TERRA TESTING, Inc. ATT



COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)
	COARSE	FINE	CRS	MEDIUM	FINE	

USCS

COBBLES TO BOULDERS	PEBBLE GRAVEL				SAND			SILT	CLAY
	COARSE	MED	FINE	GRAN	COARSE	MED	FINE		

WENTWORTH

Client: HRS Water Consultants Boring No.: Sample No.: Miller
Job Number: 2852-01 Depth: 13.7-14.1'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants | JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	13.5-15'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR3W East Side South	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes	
NATURAL	No	
Wt. Wet Soil & Pan (g)		92.22
Wt. Dry Soil & Pan (g)		90.59
Wt. Lost Moisture (g)		1.63
Wt. of Pan Only (g)		3.97
Wt. of Dry Soil (g)		86.62
Moisture Content %		1.9
Wt. Hydrom. Sample Wet (g)		71.76
Wt. Hydrom. Sample Dry (g)		70.43

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	604.98
Weight of + #10 Before Washing (g)	444.59
Weight of + #10 After Washing (g)	426.24
Weight of - #10 Wet (g)	160.39
Weight of - #10 Dry (g)	175.44
Wt. Total Sample Dry (g)	601.68
Calc. Wt. "W" (g)	241.55
Calc. Mass + #10	171.12

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	97.53	97.53	97.53	16.2	83.8
3/8"	0.00	143.33	143.33	240.86	40.0	60.0
#4	0.00	109.34	109.34	350.20	58.2	41.8
#10	0.00	76.04	76.04	426.24	70.8	29.2
#20	2.97	21.47	18.50	18.50	78.5	21.5
#40	3.03	14.90	11.87	30.37	83.4	16.6
#60	3.06	14.22	11.16	41.53	88.0	12.0
#100	3.13	11.21	8.08	49.60	91.4	8.6
#200	3.26	9.18	5.92	55.52	93.8	6.2

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Data checked by: Date: 6/5/12
FileName: HRH01351

ADVANCED TERRA TESTING, INC. ATT

HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT	HRS Water Consultants	JOB NO.	2852-01
BORING NO.		SAMPLED	
DEPTH	13.5-15'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	CR3W East Side South	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

Hydrometer #	ASTM 152 H	Temp., Deg. C	25.0
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01286
Value of "alpha"	1.00	Wt. Dry Sample "W"	241.547
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	20.00	14.75	6.1	6.1	13.01	0.0656
1.0	17.50	12.25	5.1	5.1	13.42	0.0471
2.0	16.50	11.25	4.7	4.7	13.58	0.0335
5.0	14.25	9.00	3.7	3.7	13.95	0.0215
15.0	13.00	7.75	3.2	3.2	14.16	0.0125
30.0	12.00	6.75	2.8	2.8	14.32	0.0089
60.0	11.00	5.75	2.4	2.4	14.49	0.0063
120.0	10.00	4.75	2.0	2.0	14.65	0.0045
250.0	9.00	3.75	1.6	1.6	14.81	0.0031
1440.0	9.00	3.75	1.6	1.6	14.81	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/05/2012
Data checked by: Date: 6/5/12
FileName: HRH01351

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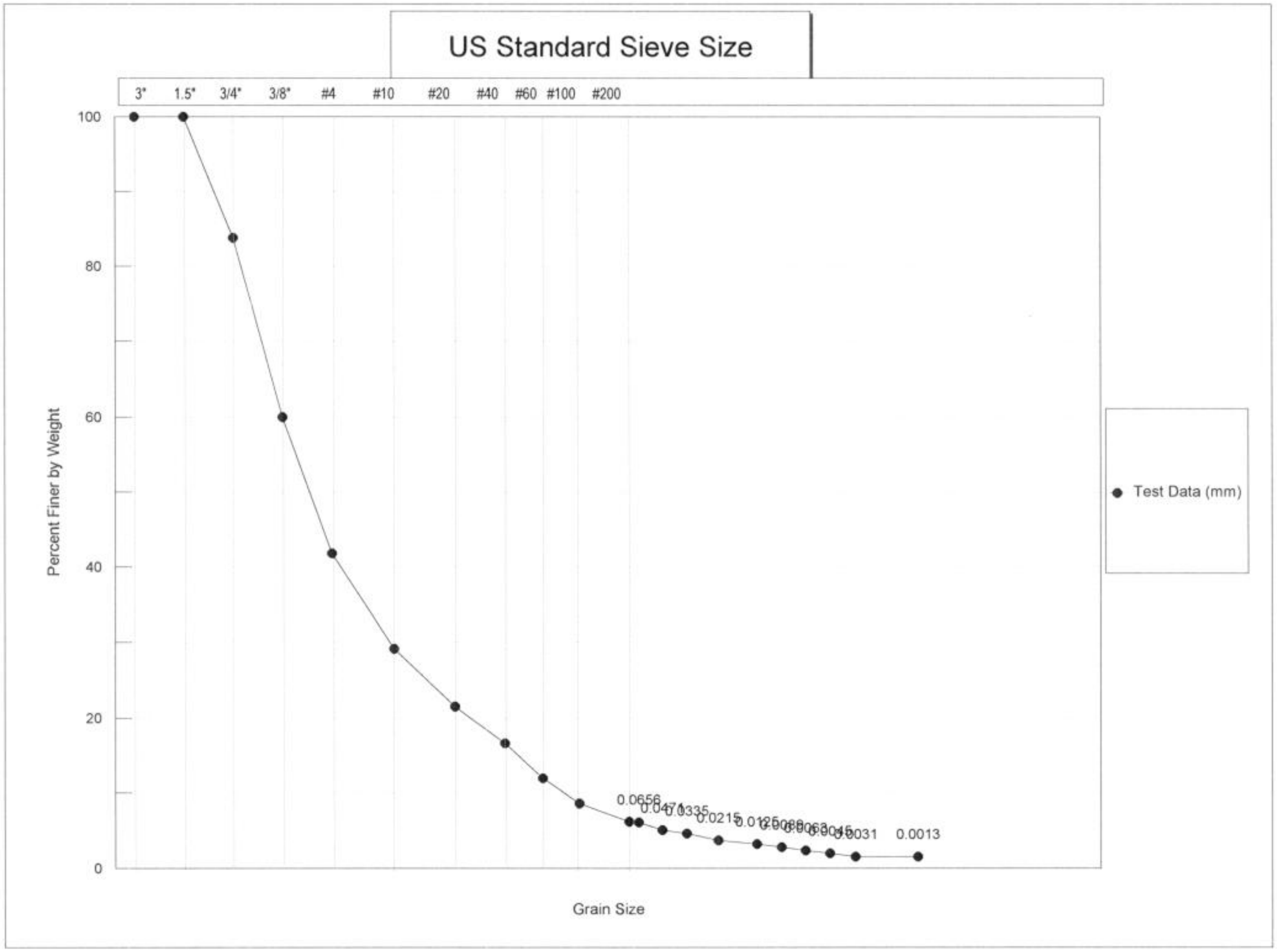

COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)	USCS
	COARSE	FINE	CRS	MEDIUM	FINE		

COBBLES TO BOULDERS	PEBBLE GRAVEL				SAND			SILT	CLAY	WENTWORTH
	COARSE	MED	FINE	GRAN	COARSE	MED	FINE			

Client: HRS Water Consultants Boring No.: Sample No.: CR3W East Side South
Job Number: 2852-01 Depth: 13.5-15'
Classification: **Classification Not Performed**

MECHANICAL ANALYSIS - SIEVE TEST DATA
ASTM D 422

CLIENT HRS Water Consultants

JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	12.5-14'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Off Bridge West	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

MOISTURE DATA

HYGROSCOPIC	Yes	
NATURAL	No	
Wt. Wet Soil & Pan (g)		105.08
Wt. Dry Soil & Pan (g)		103.80
Wt. Lost Moisture (g)		1.28
Wt. of Pan Only (g)		4.45
Wt. of Dry Soil (g)		99.35
Moisture Content %		1.3
Wt. Hydrom. Sample Wet (g)		69.98
Wt. Hydrom. Sample Dry (g)		69.09

WASH SIEVE ANALYSIS

Wt. Total Sample Wet (g)	854.35
Weight of + #10 Before Washing (g)	545.83
Weight of + #10 After Washing (g)	526.25
Weight of - #10 Wet (g)	308.52
Weight of - #10 Dry (g)	323.93
Wt. Total Sample Dry (g)	850.18
Calc. Wt. "W" (g)	181.34
Calc. Mass + #10	112.25

Sieve Number (Size)	Pan Weight (g)	Indiv. Wt. + Pan (g)	Indiv. Wt. Retain.	Cum. Wt. Retain.	Cum. % Retain.	% Finer By Wt.
3"	0.00	0.00	0.00	0.00	0.0	100.0
1 1/2"	0.00	0.00	0.00	0.00	0.0	100.0
3/4"	0.00	118.65	118.65	118.65	14.0	86.0
3/8"	0.00	159.54	159.54	278.19	32.7	67.3
#4	0.00	107.52	107.52	385.71	45.4	54.6
#10	0.00	140.54	140.54	526.25	61.9	38.1
#20	3.01	26.78	23.77	23.77	75.0	25.0
#40	3.03	16.74	13.70	37.48	82.6	17.4
#60	3.04	12.39	9.35	46.83	87.7	12.3
#100	3.05	9.88	6.83	53.66	91.5	8.5
#200	3.04	8.13	5.09	58.75	94.3	5.7

Data entered by: DAW Date: 06/05/2012
Data checked by: Date: 6/5/12
FileName: HRH012OB

ADVANCED TERRA TESTING, INC.
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HYDROMETER ANALYSIS - SEDIMENTATION DATA
ASTM D 422

CLIENT HRS Water Consultants JOB NO. 2852-01

BORING NO.		SAMPLED	
DEPTH	12.5-14'	DATE TESTED	06/01/12 DPM
SAMPLE NO.	Off Bridge West	WASH SIEVE	Yes
SOIL DESCR.	99001-59	DRY SIEVE	No
LOCATION	RGDSS Rio Grande River Direct Push		

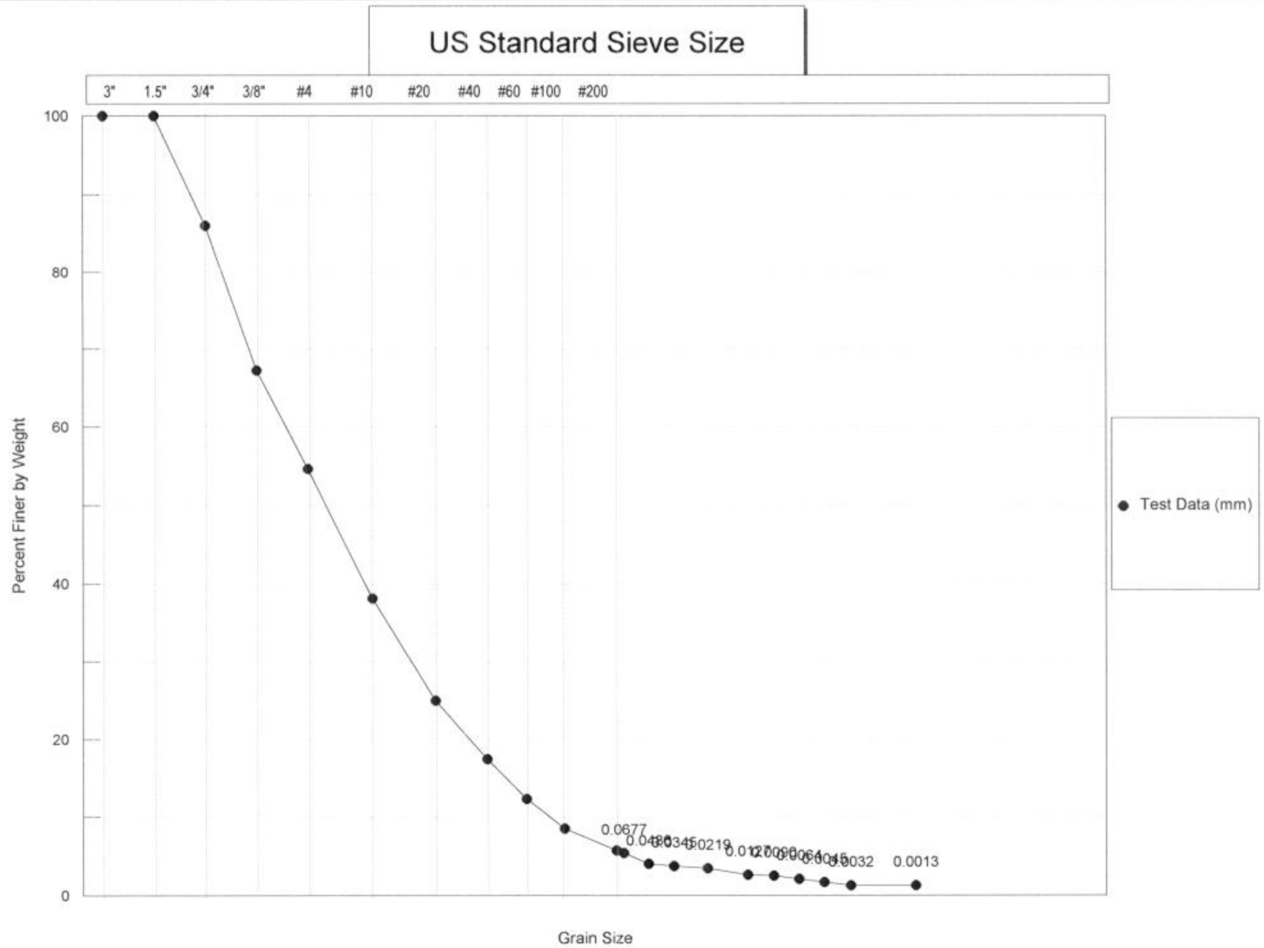
Hydrometer #	ASTM 152 H	Temp., Deg. C	24.9
Sp. Gr. of Soil	2.65	Temp. Coef. K	0.01288
Value of "alpha"	1.00	Wt. Dry Sample "W"	181.343
Deflocculant	Sodium Hexametaphosphate	% of Total Sample	100.0
Defloc. Corr'n	5.3		
Meniscus Corr'n	0.0		

T Elapsed Time (min)	Hydrometer Reading Original	Corrected "R"	100Ra/W	% Total Sample	Effective Depth L	Grain Diameter (mm)
0.0	--	--	--	--	--	--
0.5	15.00	9.75	5.4	5.4	13.83	0.0677
1.0	12.50	7.25	4.0	4.0	14.24	0.0486
2.0	12.00	6.75	3.7	3.7	14.32	0.0345
5.0	11.50	6.25	3.4	3.4	14.40	0.0219
15.0	10.00	4.75	2.6	2.6	14.65	0.0127
30.0	9.75	4.50	2.5	2.5	14.69	0.0090
60.0	9.00	3.75	2.1	2.1	14.81	0.0064
120.0	8.25	3.00	1.7	1.7	14.94	0.0045
250.0	7.50	2.25	1.2	1.2	15.06	0.0032
1440.0	7.50	2.25	1.2	1.2	15.06	0.0013

Grain Diameter = K*(SQRT(L/T))

Data entered by: DAW Date: 06/05/2012
Data checked by: [signature] Date: 6/5/12
FileName: HRH012OB

ADVANCED TERRA TESTING, INC. ATT



COBBLES	GRAVEL		SAND			SILT OR CLAY (mm)	USCS
	COARSE	FINE	CRS	MEDIUM	FINE		

COBBLES	PEBBLE GRAVEL				SAND			SILT	CLAY	WENTWORTH
TO BOULDERS	COARSE	MED	FINE	GRAN	COARSE	MED	FINE			

Client: HRS Water Consultants Boring No.: Sample No.: Off Bridge West
Job Number: 2852-01 Depth: 12.5-14'
Classification: **Classification Not Performed**