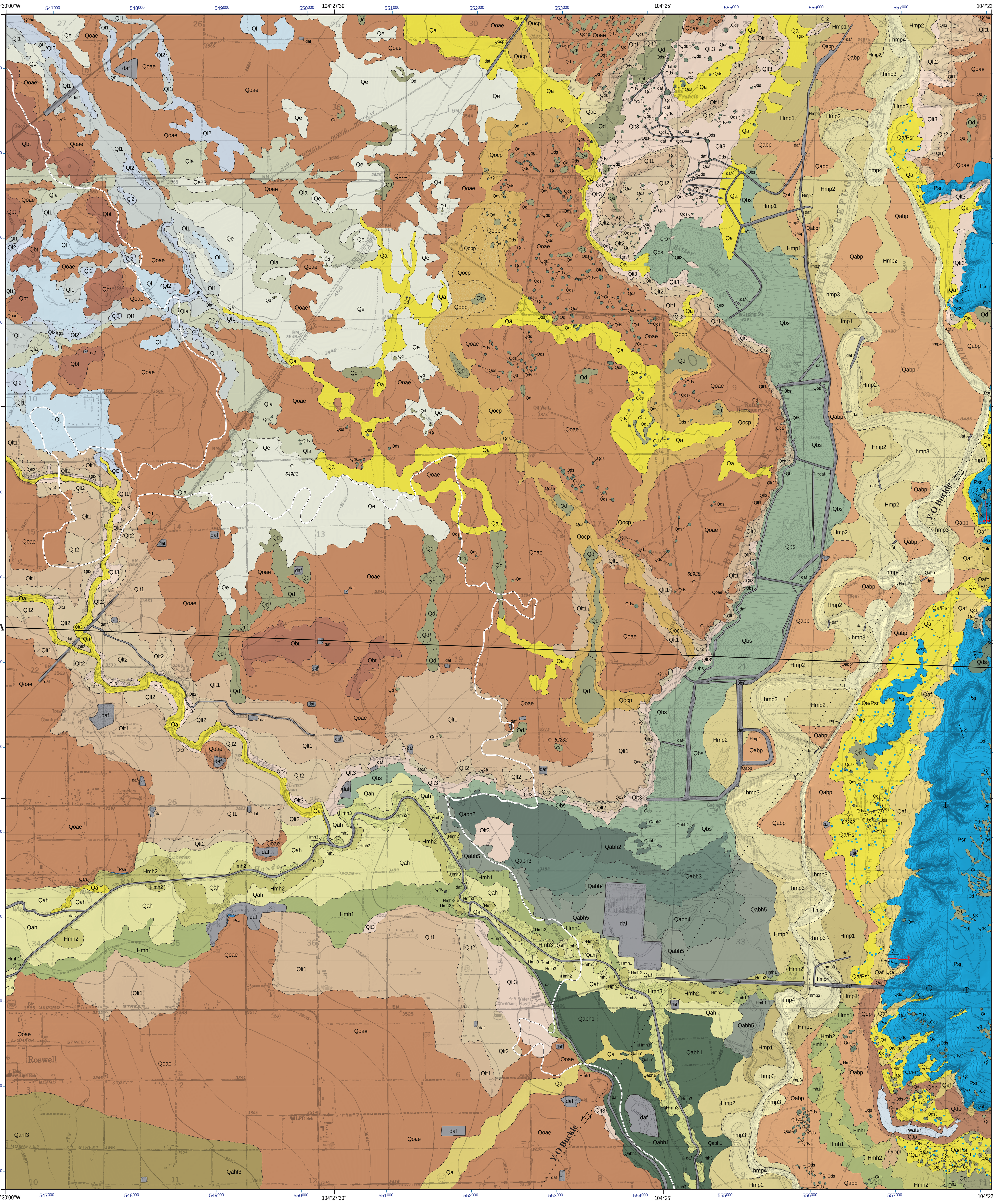
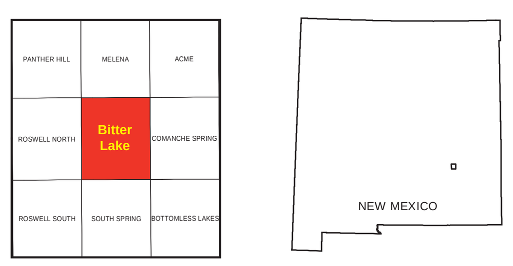
NMBGMR Open-file Geologic Map 151
Last Modified April 2010



Base map from U.S. Geological Survey1962, from photographs taken 1961.1927 North American datum, UTM projection -- zone 13N
1000-meter Universal Transverse Mercator grid, zone 13, shown in red



QUADRANGLE LOCATION

Magnetic Declination
April 2006
8º 41' East
At Map Center

1:24,000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act, administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Dr. Peter A. Scholle, *Director and State Geologist* , Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

Geologic map of the Bitter Lake quadrangle, Chaves County, New Mexico.

May 2007

by
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New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 151

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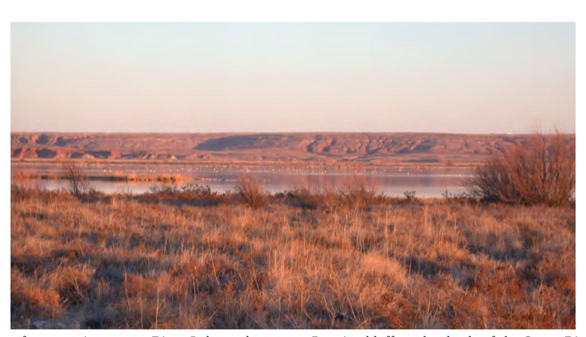
This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu



Late afternoon view across Bitter Lake to the eastern Permian bluffs and uplands of the Seven Rivers formation at the eastern margin of the Pecos floodplain. Numerous snow geese can be seen on the lake. At the base of the bluffs on the left, the Lakewood and Orchard Park terraces are evident.

EXPLANATION OF MAP SYMBOLS

- A——A' Location of geologic cross section.
- Geologic contact. Solid where exposed or known, dashed where approximately known, queried where uncertain, dotted where concealed.
- Trace of syncline axial plane associated with evaporite collapse. Dotted where concealed.
- Westernmost limit of gypsum soils, based upon the Chaves County Soil Survey of 1980.
- Horizontal bedding.
- 11 Inclined bedding showing degrees of dip.
- 00175 Oil well with last five digits of API number from NM Oil Conservation Division database.

COMMENTS TO MAP USERS

A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.

DESCRIPTION OF MAP UNITS

Quaternary/Neogene

Alluvium, colluvium, eolian, and anthropogenic deposits

daf — **Artificial fill (Historic)** — Disturbed areas, dumped fill, and areas affected by other human disturbances. Mapped where deposits or extractions are areally extensive. Includes impoundment levees in the inundated backswamp (*Qbs*) areas within the Bitter Lake National Wildlife Refuge (BLNWR), the channelized Rio Hondo, North Spring River, and the Hagerman Canal, the BNSF railroad right-of-way, raised roadways along U.S. Highways 380 and 70, the old Desalinization Plant Brine Field, the Roswell Country Club lake, and borrow or gravel pits.

Qa — **Quaternary tributary alluvium and valley-fill alluvium, undifferentiated** — Brown (7.5YR4/2) (*Rio Hondo tributaries*), pinkish gray (7.5YR6/2) to light reddish-brown (5YR 6/4) to reddish brown (2.5YR4/6) (*Pecos floodplain*), unconsolidated, moderately sorted, pebbly sand, silt, and clay, gypsiferous in Orchard Park terrace and Pecos floodplain areas. Varies considerably in thickness from <1 m to 10-12 m.

Qae — **Valley-slope alluvium with eolian sand (Holocene to upper Pleistocene)** — White (2.5Y8/1) to light gray (2.5Y7/1), unconsolidated to partly consolidated, well-sorted, fine-grained gypsiferous sand, silty sand, and clay along the northeast slope of Lost River. Forms a relatively thin mantle of alluvial slope deposits shed off of the Orchard Park terrace uplands combined with a large eolian component blown out of the Lost River floodplain, which is about 0.5 km wide here. Thicknesses varies from <1 m immediately adjacent to Lost River to 2.5 m downslope of the alluvial terrace (*Qoae*).

Qaf, Qafo — **Alluvial-fan deposits (Historic to upper Pleistocene)** — Predominantly quartzite, chert, and carbonate cobbles to gravel, often in stringers, in a light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, poorly sorted, and coarse- to fine-grained sand to silty sand. These fans are built along the base of the Seven Rivers formation (*Psr*) eastern bluffs and interfinger with and/or spread out onto Pecos floodplain deposits. Subdividing the unit into an upper (*Qaf*) and lower, older (*Qafo*) deposit was only clearly mappable for one fan. Thickness <1 m at their distal margins to 8 (?) m.

Qca — **Colluvium and/or valley-slope alluvium, undifferentiated (Holocene – uppermost Pleistocene)** — Light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6) (eastern *Psr* bluffs), light gray (2.5Y7/1) to pale brown (10YR6/3) (Orchard Park terrace and oldest Lakewood terrace margins), unconsolidated to poorly consolidated, poorly to moderately sorted sand and silty sand, with rubble blocks of gypsum, sandstone, siltstone, and mudstone, and minor limestone (eastern *Psr* bluffs), and blocks of indurated gypsite along the terrace bluffs. Deposits range from less than 1 m to about 3 m in thickness.

Qe — **Eolian sand, undivided (Holocene – uppermost Pleistocene)** — Very pale brown (10YR8/2) to light brown (7.5YR6/4), unconsolidated, moderately to well-sorted sand, silty sand, and sandy clay. Forms extensive thin sheets and low dunes along the top of the Orchard Park terrace (*Qoae*). Thickness commonly <1 m to about 3 m.

Pecos River alluvial valley floor

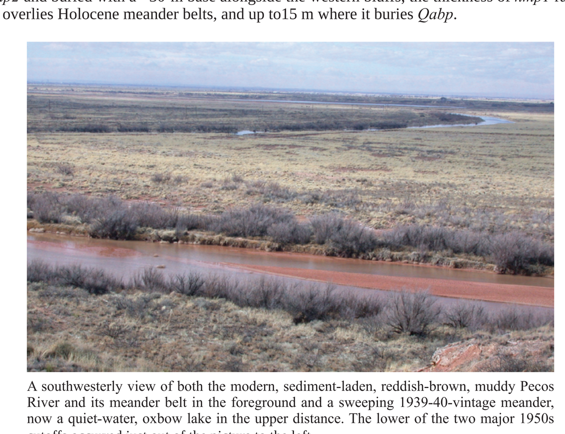
Qa/Psr — **Quaternary valley-fill alluvium over Seven Rivers formation, undivided** — Light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, moderately sorted, pebbly, fine-grained, gypsiferous sand, silty sand, and clay, thinly draped over gypsum, siltstone, and sandstone of *Psr*. Alluvium is <1 m (often <60 cm) in thickness.

Pecos River meander belt alluvial deposits (Historic to lower (?) Holocene) — During the Holocene, the Pecos River built four distinguishable meander belts on top of an upper Pleistocene Pecos River braided alluvial valley-fill deposit (*Qabp*), which is the basal unit of the floodplain. Consisting of channel, channel bar, and point bar deposits, undivided, these meander belt deposits are differentiated based upon aerial photographic work into two older Holocene units and two Historic units: 1) the modern meander belt was mapped from both 2005 digital 1-m resolution, color orthophotography and 1981-vintage color aerial photography produced for the U.S.D.I. – Bureau of Land Management, and 2) a 1939-1940 meander belt was mapped using vintage U.S.D.A. – Soil Conservation Service black and white aerial photography. The 1939-40 meander belt, in places, also incorporates areas where meander migration clearly continued up at least until around 1962, the issue date of the Bitter Lake topographic quadrangle (before photo-revision). The historic units are differentiated from the Holocene units by using a lower case "h" on the unit labels.

hmp4 — **Modern meander belt deposits (Historic)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well-sorted, occasionally pebbly, coarse- to fine-grained sand in the modern channel and adjacent bar crests, grading to silty sand and sandy clay with distance from the channel. In the early 1950s, two major meander cutoffs (along with other minor channel adjustments) were carried out by the U.S. Bureau of Reclamation to create oxbow lakes out of the large 1940s-era meanders in the BLNWR, thereby increasing open water and wetlands for waterfowl, aquatic plants, and fish. As a result, the majority of the modern channel through its Bitter Lake reach has since been confined into old *Qadp* channels, and meandering has been hampered. Modern meander amplitudes are only approximately 0.2-0.6 km in width. This has greatly reduced overbank deposition, thus the majority of modern meander belt deposits are <1 m thick, but reach about 1.5 m thick.

The modern Pecos River, here occupying an older braided *Qadp* channel, is incised into Seven Rivers formation gypsum in the northeastern part of the quadrangle. Dormant salt cedar (*Tamarix pentandra*), growing along the shore on the right, are approximately 1.5 m in height. Note that the alluvium on top of the gypsum is <1 m in thickness.

hmp3 — **1939-1940 meander belt deposits (Historic)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well sorted, coarse- to fine-grained gypsiferous sand in the Historic channel and adjacent bar crests, grading to silty sand and sandy clay with distance from these older channels. Throughout the upper Holocene, extensive point bar development has taken place, resulting in a series of meanders, with meander amplitudes >1 km in width common, the largest reaching about 1.8 km in width. In terms of estimating thicknesses of this meander belt, the Holocene meander belts, and the braided Pleistocene deposits, we consider a valley-fill thickness map based upon interpretations of data from numerous wells throughout the Roswell artesian basin by Lyford (1973). This map depicts the valley fill thickness dropping from approximately 30 m at the base of the western Orchard Park terrace bluffs to < 1 m just west of the modern channel. Based upon this fact that the meander belts are built on a wedge of Pleistocene braided alluvial valley fill, present at the surface aside *hmp2* and buried with a ~30-m base alongside the western bluffs, the thickness of *hmp1* ranges from <1 m to 3-10 m where it overlies Holocene meander belts, and up to15 m where it buries *Qabp*.



A southwesterly view of both the modern, sediment-laden, reddish-brown, muddy Pecos River and its meander belt in the foreground and a sweeping 1939-40-vintage meander, now a quiet-water, oxbow lake in the upper distance. The lower of the two major 1950s cutoffs occurred just out of the picture to the left.

Hmp2 — **Younger Holocene meander belt deposits (Historic to upper Holocene)** — Very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, moderately to well sorted, occasionally pebbly, coarse- to fine-grained sand, silty sand, and sandy clay. Meander geometries are similar to *hmp1*, and while much of this is obscured by more recent meander belt deposition and/or agriculture, amplitudes are estimated to average about 1 km in width with one amplitude of about 2 km in width. Thickness 3-10 m.

Hmp1 — **Older Holocene meander belt deposits (upper Holocene to lower (?) Holocene)** — White (2.5Y8/1) to light gray (2.5Y7/1) in the northern part of the quad, very pale brown (10YR7/4) to reddish brown (2.5YR4/6) in the south, unconsolidated, well sorted, fine-grained, gypsiferous (especially in the north) sand, silty sand, and sandy clay. Meander geometries are significantly smaller with meander amplitudes averaging only 0.5 km in width. It appears that this meander belt was first to develop, switching the river from flowing in a braided, coarser-grained *Qabp* floodplain into a small meandering stream, which probably co-existed with active *Qabp* channels throughout much of the lower Holocene. The northern segment is older than those deposits located at the mouth of the Rio Hondo, whose timing is constrained to the middle Holocene, as discussed below. Nevertheless, the northern segment is also younger as it has been active throughout much of the Holocene, acting as a yazoo stream flowing into the backswamp (*Qbs*) of and surrounding Bitter Lake. Thickness <1-3 m.

Qdp — **Pecos River channel alluvium occupying coalescing depressions (middle Holocene to uppermost Pleistocene)** — Light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, well sorted, fine-grained, gypsiferous sand, silty sand, and clay thinly draped over the floor of depressions developed primarily in gypsum. Forms the lowest inset fluvial deposit of the Pecos floodplain. The timing of the collapse or subsidence of the depressions is unknown, but their capture of the Pecos River is constrained to lower Holocene – uppermost Pleistocene prior to or at the onset of *Hmp1* development and probably in the waning phases of active *Qabp* deposition. This is clear because the tributary Rio Hondo built two lower to middle Holocene meander belts (*Hmh1* and *Hmh2*) across both upper Pleistocene Rio Hondo braided alluvial "deltaic" deposits (*Qabh1* and *Qabh5*) and *Qabp*, into which *Qabh1-5* drained. *Hmh1* and *Hmh2* are clearly distinguished from any meandering Pecos River deposit by differing lithologies, sediment chararacteristics, and especially meander geometries (Rio Hondo meanders are an order of magnitude smaller than those of the Pecos), and are clearly visible in aerial photos completely crossing the Pecos floodplain to the eastern margin, where it joined the Pecos in its *Qdp* channel on the Bottomless Lakes quadrangle southeast of the Bitter Lake quad (Rawling and McCraw, 2010). While *Qdp* flows could have occurred concurrently in the depression channel(s) and parts of *Hmp1*, it was not until an avulsion occurred upstream during the middle Holocene, which caused *Hmp1* to build out across *Hmh1* and *Hmh2* in the vicinity of the historic meander belts, thereby cutting these lower belts off and causing the Rio Hondo to develop *Hmh3* to the south and west. Pecos River alluvium is very thin in these channels (<1-2 m thick) and very little bank or bar formation occurred while *Qdp* was active. The shallow, saline Chain Lakes now occupy *Qdp* on the Bitter Lake quad.

Qabp — **Pecos River braided alluvial deposits (lower Holocene to upper Pleistocene)** — Light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, poorly to moderately sorted, pebbly coarse- to fine-grained sand, silty sand, sandy clay, and clay. Braided channels and bars typify the surface of *Qabp*. As discussed above, the thickness of *Qabp* is greatest on the western margin of the floodplain, although buried, varies from 10 - 20 m. Large areas of *Qabp* are found on the floodplain surface in the center and eastern margins of the valley, here the thickness varies from 3 m to <1 m.

Qbs — **Floodplain alluvial backswamp deposits (Historic to upper Pleistocene)** — *Pecos floodplain:* light gray (2.5Y7/1) to very dark gray (7.5YR3/1), unconsolidated, well-sorted, gypsiferous silty sand, sandy clay, and clay in low-lying, poorly drained areas surrounding Bitter Lake and the impoundments along the western margins. *Rio Hondo floodplain:* light brownish gray (10YR6/2) to dark yellowish brown (10YR3/4), unconsolidated, well-sorted, gypsiferous silty sand, sandy clay, and clay in low-lying, poorly drained areas below the northern bluffs of the oldest Lakewood terrace (*Qlt1*). Both areas commonly only receive fine-grained, slack-water flood deposition, although several springs discharge into the Pecos *Qbs*. The Rio Hondo *Qbs* area occupies the lowest inset area in its floodplain, and is probably the result of scour from a Pleistocene Rio Hondo channel. Thicknesses range from 3-15 (?) m in the Pecos floodplain and are unknown in the Rio Hondo floodplain, but probably 3 m or less.

Rio Hondo alluvial valley floor

Qah — **Quaternary valley-fill alluvium within the Rio Hondo, undivided (Historic to upper Pleistocene)** — Cobbles and gravels of chert, quartzite, gray and green porphyritic igneous rocks, and limestone in brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, poorly to moderately sorted, coarse- to fine- grained sand, silty sand, silt (largely calcareous), sandy clay, and clay. While clasts and coarse-grained sediment are common, these deposits are typically found between meander belts and older Pleistocene channel deposits, and are thus finer-grained. According to Lyford (1973), the valley fill beneath the Hondo valley in the Bitter Lake quadrangle increases from about 30 m in thickness at the mouth to over 45 m quickly upvalley. Thicknesses of *Qah* are estimated to be 10-25 m.

Rio Hondo meander belt alluvial deposits (Historic to lower (?) Holocene) — Cobbles and gravels of chert, quartzite, gray and green porphyritic igneous rocks, and limestone in brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt (largely calcareous), and sandy clay. While meander geometries are essentially identical between all three Hondo meander belts, *Hmh1* certainly exhibited the widest lateral migration.

Hmh3 — **Modern (pre-channelization) meander belt deposits (Historic to upper Holocene)** — Responding to an avulsion of the Pecos River in the middle Holocene which shifted flow back to the west-central part of the floodplain into the *Hmp1* deposit, *Hmh3* after leaving the Hondo floodplain was forced to turn south and build a course over the top of the oldest and lowest Rio Hondo braided alluvial "deltaic" deposit (*Qabh1*). Upstream of this southerly diversion, *Hmh3* basically built up on top of *Hmh2*. It was abandoned in the early 20th Century with the construction of the Hagerman Canal and the channelized Rio Hondo. Thickness 1-3 m.

Hmh2 — **Young meander belt deposits (middle Holocene)** — As described above, the two oldest Hondo meander belts (*Hmh1* and *Hmh2*) built up on top of both upper Pleistocene Rio Hondo braided alluvium (*Qabh*) and upper Pleistocene Pecos braided alluvium. In the Pecos floodplain, *Hmh2* built on top of *Hmh1*, but in the Hondo floodplain, it built a new meander belt north of *Hmh1* until it reached the vicinity of the present-day Hagerman Canal diversion, where it crossed over *Hmh1* and flowed to the south, over *Qabh1*. Thickness 1-3 m.

Hmh1 — **Older Holocene meander belt deposits (middle Holocene to lower (?) Holocene)** — In the Hondo floodplain, *Hmh1* flowed primarily along the southern margin (mapped where not totally obscured by agriculture), probably in upper Pleistocene channels. At the mouth of the floodplain, its course was clearly influenced by the youngest upper Pleistocene channels within *Qabh5*. Thickness 1-3 m.

Rio Hondo braided alluvial deposits (lower Holocene to upper Pleistocene) — Cobbles and gravels of chert, quartzite, gray and green porphyritic igneous rocks, and limestone in brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, poorly to moderately sorted, coarse- to fine- grained sand, silty sand, silt (largely calcareous), sandy clay, and clay. From the mouth of the Hondo floodplain westward up the valley, these braided deposits are either all buried or undiscernable due to agriculture. They undoubtedly fill the entire base of the inset valley and are probably 15-30 m thick. As these upper Pleistocene braided stream channels carrying glacial outwash from the Sacramento Mountains discharged out into the Pecos floodplain, they built a series of "deltaic" valley-mouth fans, each comprised of braided distributaries and overbank deposits. These "deltas" can be differentiated based upon height above the Pecos floodplain, degree of channel preservation, degree of deflation, and relative gypsite crust development into five distinct braided alluvial deposits. With the exception *Qabh1*, the southernmost unit, units *Qabh2-5* progressively shift from a northern position adjacent to the Hondo floodplain *Qbs* deposits, southward approximately to the location of the Holocene Rio Hondo meander belts.

Qabh5 — **Youngest braided valley-mouth alluvial-fan deposits (uppermost Pleistocene)** — Clearly defined channels are seen on the second-lowest *Qabh* surface, including a large (i.e., very high meander wavelengths and amplitudes compared to the Holocene Rio Hondo) channel, overridden in places by *Hmh1-2*. Bar and swale deposits exhibit minor gypsite crust development. *Qabh5* spreads out laterally both north and south at the margin of Pecos alluvial deposits (both braided and meandering) due to the fact that it accommodates Holocene to modern flows from older *Qabh* valley-mouth fan channels. Thickness <1 to about 15 m.

Qabh4 — **Younger braided valley-mouth alluvial-fan deposits (upper Pleistocene)** — Surface slightly higher, channels less defined and more braided (multiple, smaller channels) with more extensive gypsite at the surface than *Qabh5*. The 2005 orthoimagery shows approximately the eastern quarter of this deposit with a distinctly redder surface, in a semi-arcuate shape, suggesting a possible short-lived *Hmp2* occupation of this lowland. Thickness <1 to about 15 m.

Qabh3 — **Young braided valley-mouth alluvial-fan deposits (upper Pleistocene)** — Highest *Qabh* deposit suggesting formation during periods of massive outwash deposition. Large areas choked with gypsite crust, minor channel remnants remain. Thickness about 3-20 m.

Qabh2 — **Older braided valley-mouth alluvial-fan deposits (upper Pleistocene)** — Lower, northernmost *Qabh* deposit exhibiting large areas choked with gypsite crust, few channel scars remaining, and wide areas of extensive deflation. Often undergoes modern flooding. Thickness about 2-10 m.

Qabh1 — **Oldest braided valley-mouth alluvial-fan deposits (upper to middle (?) Pleistocene)** — Lowest-lying, yet most extensive braided alluvial-fan deposit. Greatly modified by agriculture on it eastern margin adjacent to and within the Pecos floodplain. Only an occasional channel remnant remains. Overriden by *Qabh5*, *Hmh3*, and *Hmp2*. Thickness about 2-30 m.

Alluvial terrace deposits

Lakewood terrace alluvial deposits (upper to middle Pleistocene) — Alluvial terraces of the Pecos River and its tributaries were first described in the classic study of Fiedler and Nye (1933). They recognized 3 terraces: (from lowest to highest) the Lakewood, the Orchard Park, and the Blackdom. The Lakewood terrace, with an elevation of 6 to 9 m above the floodplain, flanked the inset Pecos floodplain and extended up many of its western tributaries. We now recognize three distinct low-lying (upper to uppermost middle(?) Pleistocene) "Lakewood terraces," the highest and oldest of which would be Fiedler and Nye's original. Surface tread elevations above the floodplain for these three are: <1-1 m, 1.2-6 m, and 6-9 m, respectively. These terraces are differentiated by their location either in the Pecos valley or in the tributary valleys of the Rio Hondo and Borrendo Creek, and its tributaries. The Pecos valley west side terraces are comprised of light gray (2.5Y7/1) to very pale brown (10YR7/4) to reddish brown (2.5YR4/6), unconsolidated, well-sorted, medium- to fine-grained gypsiferous sand, silt, and sandy clay, while the east side terraces are made up of light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, moderately sorted, pebbly, fine-grained, gypsiferous sand, silty sand, and clay. The tributary Lakewood terrace alluvial deposits are comprised of occasional gravels and pebbles, brown (10YR5/3) to dark yellowish brown (10YR3/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt and sandy clay. These sediments are mostly non-gypsiferous.

Qlt3 — **Youngest Lakewood terrace alluvial deposits (upper Pleistocene)** — Thickness <1-1 m.

Qlt2 — **Young Lakewood terrace alluvial deposits (upper Pleistocene)** —Thickness 1.5-5 m.

Qlt1 — **Older Lakewood terrace alluvial deposits (upper to middle Pleistocene)** —Thickness about 2-9 m.

Orchard Park terrace alluvial deposits (upper to middle Pleistocene) — According to Fiedler and Nye (1933), the Orchard Park terrace rises 1.5-3 m above the Lakewood terrace and 6-10.5 m above the Pecos floodplain. On the Bitter Lake quadrangle, it consists of an alluvial-eolian complex (*Qoae*), with many subsidence-related depressions (*Qd*) and collapse-related sinkholes (*Qds*) pitting its surface. Furthermore, many of these depressions are artesian-spring fed, and supported shallow lakes (*Ql*, *Ql2* ,and *Ql1*) prior to 20th Century pumping of the artesian aquifer. Given their shallow nature, water often flowed from basin to basin, giving rise to an unusual "hybrid" lacustrine-alluvium map unit (*Qla*).

On the Bitter Lake quadrangle, the Orchard Park terrace comprises the majority of the surface area, in three distinct locations: the northeast corner of the quad, the western two-thirds of the quad north of the Hondo Valley, and the agricultural lands south of the Hondo valley, west of the Pecos floodplain. The northeastern deposit is distinctly different from the other Orchard Park deposits as its largely non-gypsiferous, made up of light reddish-brown (5YR6/4) to reddish brown (2.5YR4/6), unconsolidated, moderately sorted, pebbly, medium- to fine-grained sand, and silty sand. This deposit could actually be an outcrop of the Gatuña Formation (Kelley, 1980; Powers and Holt, 1993) as the lithologic characteristics are essentially identical, but given its proximity to the Pecos floodplain, is mapped as *Qoae*.

The remaining two areas of Orchard Park terrace are separated by the Hondo valley. The southern area lies west of the gypsiferous soils and saline ground-waters, and again, supports extensive agriculture. It is comprised of very pale brown (10YR7/4) to reddish brown (5YR4/4), unconsolidated, moderately sorted, coarse- to fine- grained sand, silty sand, silt, and sandy clay. The northern area, however, is predominantly gypsiferous with saline ground-waters. It is comprised of white (2.5Y8/1) to light gray (2.5Y7/1) to very pale brown (10YR7/4), unconsolidated, well sorted, fine-grained, gypsiferous sand, silty sand, and sandy clay. In general, the gypsum content of the soils decreases from the western bluffs above the Pecos valley westward. At and near the bluffs, *Qoae* is so choked with gypsum it forms gypsite, an indurated hyper-concentration of gypsum in the soil (Watson, 1983). This material develops from a combination of in-situ weathering of gypsum bedrock, as well as eolian and alluvial depositional input of gypsum into the solum (Eswaran and Zi-Tong, 1991).

On this northwestern surface of *Qoae*, in addition to the depression and lacustrine deposits discussed below, two distinct middle (?) Pleistocene Pecos River channels (*Qocp*) traverse from north to south-southwest. Alluvial channel and point bar deposits associated with these Pecos channels (*Qobp*) are present in places. There is some suggestion of fluvial interaction between the channels via *Qa* deposits, and depressions greatly influenced where these channels developed.

Qoae — **Orchard Park terrace alluvial and eolian deposits, undivided (upper to middle Pleistocene)** — Thickness 15-45 m.

Qocp — **Orchard Park terrace ancestral Pecos River alluvial channel deposits (upper to middle Pleistocene)** — Thickness about 2-15 m.

Qobp — **Orchard Park terrace ancestral Pecos River alluvial point and channel bar deposits (upper to middle Pleistocene)** — Thickness 1-2 m.

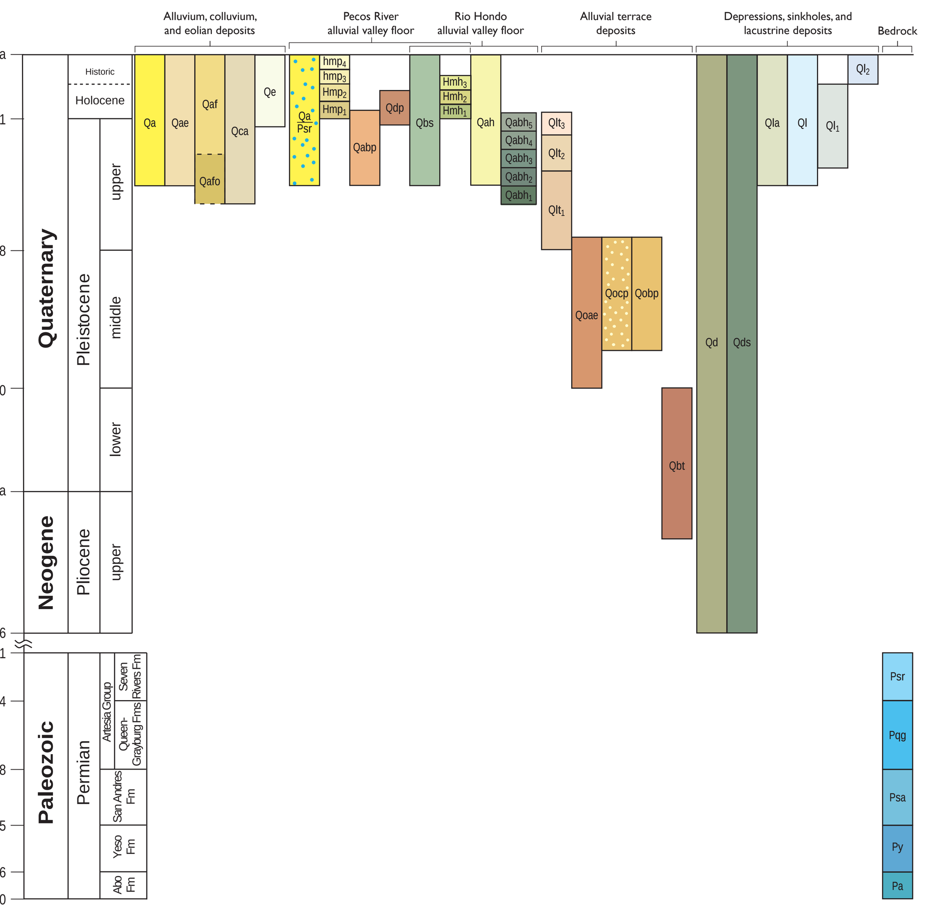
Qbt — **Blackdom Terrace alluvial deposits (lower Pleistocene to upper Pliocene)** — Fiedler and Nye (1933) describe the Blackdom terrace in northern Chaves County as isolated erosional terrace remnants 9-15.5 m above the Orchard Park terrace. This perfectly describes the isolated high hills we map as Blackdom terrace on the Bitter Lake quadrangle. They are comprised predominantly of chert and quartzite gravel in yellowish brown (10YR5/4) to reddish brown (5YR5/4), unconsolidated, moderately sorted, coarse- to fine-grained, occasionally gypsiferous, sand and silty sand. Thickness 15-30(?) m.

Depression, sinkhole, and lacustrine deposits

Qd — **Quaternary depression fill, primarily caused by subsidence (Historic to middle Pleistocene)** — Unconsolidated, well-sorted, fine-grained (fine sands to clay) complexes of alluvial, colluvial, eolian, and occasional lacustrine deposits within closed depressions created by either gradual subsidence or sudden collapse followed by gradual subsidence of underlying gypsiferous carbonate terrane. These complexes are often significantly modified by stream erosion and deposition, playa deposition, deflation, and mass wasting. Depression fills have been active since the middle Pleistocene and are usually 1-3 m thick but can reach thicknesses in excess of 30 m.

Qds — **Quaternary sinkhole deposits, primarily caused by collapse (Historic to middle Pleistocene)** — Eastern bluffs: boulders, slump blocks, gravel, sand, silt, and clay filling dry sinkholes derived from local collapse of *Psr*. Thickness unknown, probably 1-5 m for smaller sinks, quite likely several tens of meters for the larger ones (predominantly on the Commanche Spring quad to the east). Western terraces: occasional cobbles, gravel, and slumped gypsite blocks in a fine-grained sandy clay matrix. Most are submerged beneath the water table. Thickness <1-5 (?) m.

CORRELATION OF MAP UNITS



View of a small sinkhole and several depressions in the distance developed on the Orchard Park terrace, just west of Bitter Creek in the BLNWR. More than 40 cm of gypsite is exposed in the sinkhole wall.

Ql — **Quaternary lacustrine deposits, undivided (lower Holocene (?) to upper Pleistocene)** — Unconsolidated, well-sorted, fine-grained silty sands, silt, and clay deposited primarily by pluvial lakes fed by artesian springs. These deposits surround the lower Holocene lacustrine units, and may have a significant alluvial component in their composition. Thickness 1-2 m.

Ql2 — **Young Quaternary lacustrine deposits (predominantly Historic to lower (?) Holocene)** — Greenish gray (Gley1, 5/5GY) to greenish black (Gley1, 2.5/5GY), unconsolidated, well-sorted, fine-grained silty sands, silt, and clay deposited by lakes fed by artesian springs. Occupies lowest, wettest landscape positions. Thickness 1-3 m.

Ql1 — **Older Quaternary lacustrine deposits (Historic to upper Pleistocene)** — Greenish gray (Gley1, 5/10Y) to gray (5YR5/1), unconsolidated, well-sorted, fine-grained silty sands, silt, and clay deposited by lakes fed by artesian springs. Occupies area surrounding *Ql2*, and is inundated less frequently. Thickness 1-3 m.

Qla — **Quaternary lacustrine and alluvial deposits, undivided (Historic to upper Pleistocene)** — Pinkish gray (5YR6/2) to gray (5YR5/1), unconsolidated, well-sorted, fine-grained silty sands, silt, and clay. Usually lacustrine, but when water levels are sufficiently high, fluvial action occurs depositing alluvium, especially along the margins of this unit. Thickness 1-3 m.

PALEOZOIC SEDIMENTARY ROCKS

Pemian Artesia Group

Psr — **Seven Rivers Formation (Guadelupian - upper Permian) —** White to pale gray gypsum, brick red, pale red, to orange very fine sandstone, siltstone, and mudstone, and minor limestone. Exposed in bluffs along the east bank of the Pecos River. Gypsum comprises up to 75% of the unit in the southern two thirds of the quadrangle. Gypsum content decreases gradually northward, with concomitant increase in clastic interbeds. North of the latitude of the wildlife refuge headquarters, gypsum comprises only about 25% of the unit. Gypsum beds are thin- to thick- to very thick-bedded, and massive to thin-bedded to laminated internally. Red outcrop color is due to surface wash from the clastic interbeds. These clastic layers often have veins of gypsum. Bedding is irregular and highly variable where gypsum content is high. As gypsum content decreases, bedding becomes thinner and more planar, with less development of collapse features and slumping. Top of the bluff is often capped by or covered with rubble of medium gray thin- to medium-bedded, crinkly laminated limestone. The top is not exposed, but thickness is at least 75 m, based on the cross section.

Pqg — **Queen and Grayburg Formations, undivided (Guadelupian - upper Permian) —** Cross section only. Completely covered by terrace deposits or stripped.

Other Pemian Sedimentary Rocks

Psa — **San Andres Formation (middle to upper Permian) —** Light to dark gray and bluish gray limestone and dolomite. Limestones and dolomites range from thin- to very thick-bedded, and are carbonate mudstones, wackestones, and grainstones. Freshly broken surfaces are darker gray than weathered surfaces and often fetid. Silty and sandy beds are common. Presumably the upper Bonney Canyon member of Kelley (1971). Thickness unknown.

Py — **Yeso Formation, undivided (lower to middle Permian) —** Cross section only.

Pa — **Abo Formation, undivided (lower to middle Permian) —** Cross section only.

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GEOLOGIC CROSS SECTION