

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

All colors are designated from soil color charts (Globe, 2005).

HUMAN-MADE DEPOSITS

af

**Artificial fill (Uppermost Holocene)** — Mostly fill material, refuse, and riprap placed during construction of roads, railroads, buildings, dams and landfills. Fill material and refuse generally consists of unsorted clay, silt, sand, and rock fragments, whereas riprap commonly consists of boulder sized rock fragments. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted and/or placed on steep slopes. Fill deposits are usually less than 1.5 m thick and are difficult to delineate.

ALLUVIAL DEPOSITS

Qa<sub>1</sub>

**Alluvium one (Upper Holocene)** — Pinkish-gray, pink, or reddish-yellow (7.5 YR 7/2 and 7.5YR 7/3), moderately to well sorted, poorly consolidated, very fine-grained sand with gravel. In channel deposits of Qa<sub>1</sub>, gravel-sized material ranges from subangular to well rounded and dominantly consists of quartz, quartzite, granitoid rocks and schist. Unit Qa<sub>1</sub> underlies the South Platte River and low-lying terraces up to 1.5 m above the active channel. Low-lying terraces of Qa<sub>1</sub> and adjacent floodplain deposits are typically vegetated and consist chiefly of clay, silt and silty clay. Unit Qa<sub>1</sub> is confined by alluvium two (Qa<sub>2</sub>) and alluvium three (Qa<sub>3</sub>) in most of the Hardin quadrangle except near the eastern boundary of the map area, where colian sand (Qes) bounds Qa<sub>1</sub>. A sample of unit Qa<sub>1</sub> from NW ¼ SE ¼ sec. 35, T. 6 N., R. 67 W. in the nearby Bracewell quadrangle (Palkovic, 2020) contained 39.4 % gravel, 54% sand, 4.2% silt, and 2.4% clay. The Unified Soil Classification System (USCS) (Howard, 1986) designation for this sample is poorly graded sand with silt and gravel (SP-SM). Channel-bar deposits are present adjacent to and within the South Platte River, and are composed chiefly of pinkish-gray (7.5 YR 7/2) sandy gravel with lenses of clay and silt. On the nearby Berthoud quadrangle (Keller and others, 2017), a bulk carbon-14 sample taken from a depth of 1 m below a ~1.5 m-high terrace of the Little Thompson River (a tributary of the South Platte River) yielded a 14C age of at least 1,525 to 1,350 cal yr BP (1,530 ± 30 14C yr BP), indicating the unit is Late Holocene in age where sampled. Unit Qa<sub>1</sub> is generally correlative, by virtue of height above stream level, soil characteristics, and radiometric dates (Keller and others, 2017) on nearby quadrangles with the post-Piney Creek Alluvium (Colton, 1978). Unit Qa<sub>1</sub> is generally correlative with the Federal Emergency Management Agency (FEMA) mapped floodway zone AE (FEMA, 2020), which is prone to flooding, and may have a high seasonal or annual water table due to its proximity to modern streams and low height above stream level. Unit Qa<sub>1</sub> is generally 0.5 to 3 m thick in the quadrangle, as interpreted from the Colorado Division of Water Resources (DWR) borehole drillers logs (Colorado Division of Water Resources, 2021).

Qa<sub>2</sub>

**Alluvium two (Upper Pleistocene)** — Dark-brown (7.5 YR 3/2), poorly to moderately sorted, moderately consolidated, weakly stratified, silty to clayey very fine-grained sand. Unit Qa<sub>2</sub> is bounded by colian sand (Qes) on both sides of the South Platte River. Unit Qa<sub>2</sub> underlies stream-terrace deposits that are approximately 1.5-5 m above the modern South Platte River. In the nearby Bracewell quadrangle, a soil profile approximately 2 m thick formed in unit Qa<sub>2</sub> was described near SW ¼ NW ¼ sec. 32, T. 6 N., R. 66 W. The soil is overlain by 0.0-3 m fill and consisted of the following soil horizons from top to bottom (soil horizon designations are those of Birkeland, 1999): 0-3.0-6 m silt-enriched Bz horizon, dark-brown (7.5 YR 3/1) clay to very fine-grained sand that has a moderate amount of silt and clay; 0.6-1.3 m C horizon, dark-brown (7.5 YR 3/2) clayey silt and sand; 1.3-2 m C horizon, dark-brown (7.5 YR 3/2) clayey silt and sand with orange streaks. Humic organic material is common in the Bz horizon and stage I stringers of calcium carbonate (of Machette, 1985) are locally present in the lower part of the soil (A. Steinhart and M. Moore, Natural Resources Conservation Service, written commun., 2019). Two optically stimulated luminescence (OSL) analyses from samples in the nearby La Salle quadrangle (Palkovic and others, 2019) were taken from unit Qa<sub>2</sub> near NW ¼ sec. 35, T. 5 N., R. 66 W. One sample yielded an OSL age estimate of 3,040 ± 200 years (Central Age Model), whereas the other sample yielded an OSL age estimate of 3,020 ± 260 years (Central Age Model). In the nearby Berthoud quadrangle, Keller and others (2017) reported two carbon-14 ages from unit Qa<sub>2</sub> of 1,350 and 2,490 cal yr BP (1,530 ± 30 and 2,390 ± 30 14C yr BP). Unit Qa<sub>2</sub> is generally correlative, by virtue of height above stream level and radiometric dates, with the upper part of the Piney Creek Alluvium described by Hunt (1954) in the Colorado Piedmont near Denver. Portions of the unit lie within FEMA mapped floodway zone AE (FEMA, 2020), are prone to flooding, and may have a high seasonal or annual water table due to its proximity to modern streams and low height above stream level. Unit Qa<sub>2</sub> ranges from 5 to 10 m thick, on the basis of DWR borehole data (Colorado Division of Water Resources, 2021).

Qa<sub>3</sub>

**Alluvium three (Upper Pleistocene)** — Pinkish-gray (7.5 YR 6/2), poorly sorted, poorly consolidated, medium sand to gravel, with a matrix of fine- to medium-grained sand. Unit Qa<sub>3</sub> underlies terraces approximately 10-21 m above adjacent streams, and occupies a broad, flat terrace on the south side of the South Platte River. Clasts in unit Qa<sub>3</sub> are generally subrounded to well rounded, and range in size from 1-10 cm. Clast types include granitoid rocks (dominantly granite and granodiorite), gneiss, schist, quartzite, and vein quartz. Unit Qa<sub>3</sub> is bordered by Qa<sub>1</sub> and Qa<sub>2</sub> to the south, and bordered to the north by Qa<sub>1</sub> and Qa<sub>2</sub>. The southern contact with Qe is defined by the occurrence of NW-SE trending linear sand dunes that are visible on lidar imagery. Two OSL samples were collected on the nearby Bracewell quadrangle (Palkovic, 2020) from SW ¼ sec. 30, T. 6 N., R. 66 W (Plate 2, Table 1). BW06a, collected 2 m below ground surface, yielded an OSL age estimate of 28,225 ± 2350 years (Central/Minimum Model SAR Age), while BW06ab, collected 3.2 m below ground surface, yielded an OSL age estimate of 39,600 ± 1940 years (Central/Minimum Model SAR Age). These ages roughly correspond to the 30-12 ka date range for the Broadway Alluvium commonly provided by previous authors (Madole and Shroba, 1979; Nelson and others, 1979; Madole, 1986; Madole, 1991; Kellogg and others, 2008; Workman and others, 2018). Stage I to stage II (Machette, 1985) pedogenic carbonate is common in the soil profile and locally forms discontinuous rinds on gravel clasts. Locally, finer grained sand is cemented onto the underside of gravel clasts due to abundant secondary carbonate accumulation. Unit Qa<sub>3</sub> is generally correlative, by virtue of height above stream level, soil characteristics, and radiometric dates with the Broadway Alluvium (Colton, 1978) and units T3 and T4 of Schwochow and others (1974). Boreholes registered with the Colorado DWR that terminate in unit Qa indicate the thickness of the unit ranges from 10-25 m in the quadrangle (Colorado Division of Water Resources, 2021).

Qa

**Alluvium, undivided (Holocene and Upper Pleistocene)** — Pale-brown or beige of hue 10 YR, weakly stratified, moderately to loosely consolidated, silty to clayey sand with thin beds and lenses of sand. The lone deposit of this unit on the Hardin quadrangle occurs along Box Elder Creek, in the west-central portion of the mapped area. Unit Qa is used where the identification of a specific alluvial unit was not possible due to poor exposure and a lack of access. In northeastern Colorado, many alluvial channels dominate the lidar imagery, and may be paleochannels of the South Platte River. In present time, these channels are often occupied by both ephemeral and perennial streams that are likely too small to account for the vast alluvial deposition in the channels, and many of these channels can be traced south to the Denver area. Boreholes registered with the Colorado DWR that terminate in unit Qa indicate the thickness of the unit ranges from 10-25 m in the quadrangle (Colorado Division of Water Resources, 2021).

Qg<sub>1</sub>

**Gravel deposit one (Middle Pleistocene)** — Pink (7.5 YR 8/3), poorly sorted, poorly consolidated, matrix-supported gravel with a silty sand matrix that underlies alluvial terraces about 70 m above modern streams. Some clast are subangular but are generally subrounded, and predominantly composed of granitoid rocks, quartzite, vein quartz and schist. Thin, discontinuous stage I to stage II calcium carbonate rinds (of Machette, 1985) coat some gravel clasts. This unit is locally overlain by unit Qe. In many places the only evidence of unit Qg<sub>1</sub> is gravel clasts in a matrix that appears to be colian in origin. Additionally, the downslope edges of Qg<sub>1</sub> deposits locally contain gravelly colluvium derived from the original Qg<sub>1</sub> deposits, and are mapped as Qg<sub>1</sub>. The lone mapped deposit of Qg<sub>1</sub> lies in the central portion of the Hardin quadrangle, south of the South Platte River. Due to poor exposure and lack of access, mapping of this unit relied upon the interpretation of lidar imagery and DWR borehole logs. Unit Qg<sub>1</sub> is generally correlative on the basis of height above stream level with the Verdos Alluvium (Colton, 1978). Unit Qg<sub>1</sub> is a potential source of sand and gravel. One DWR borehole log that penetrates unit Qg<sub>1</sub> in the quadrangle indicates a thickness of 4 m (Colorado Division of Water Resources, 2019); however, the thickness of unit Qg<sub>1</sub> typically ranges from 3 to 15 m in the Greeley area (Palkovic and others, 2018; Palkovic and others, 2019; Keller and Morgan, 2020).

EOLIAN DEPOSITS

Qes

**Eolian sand (Middle Holocene to Upper Pleistocene)** — Reddish-yellow to yellow (5 YR 6/4 to 10 YR 6/4 or 7/4), well-sorted silty quartz sand with a trace amount of lithic fragments. Sand-sized fragments are generally very fine to fine, but locally may range up to medium-grained sand. Quartz grains comprising unit Qes are generally subangular and subrounded. A sample collected in NW ¼ sec. 36, T. 5 N., R. 63 W. contained 96.2% sand, 1.4% silt, and 2.4% clay. The sample is non-plastic; according to the USCS (Howard, 1986), this sample is a 'poorly graded sand' (SP). In the adjacent Barnesville quadrangle (Lindsey and Palkovic, 2021), a sample collected from NE ¼ sec. 21, T. 5 N., R. 63 W. was composed of 96.2% sand, 0.5% silt, and 3.3% clay. The sample is non-plastic and is a 'poorly graded sand' (SP) (Howard, 1986). In the nearby La Salle quadrangle (Palkovic and others, 2019), a sample from NW ¼ SE ¼ sec. 3, T. 4 N., R. 65 W. contained 89.8% sand, 4.6% silt, and 5.6% clay (Palkovic and others, 2019), is non-plastic and a 'poorly graded sand with silt' (SP-SM) (Howard, 1986). Despite the high sand content of these samples, the unit locally may contain great amounts of fines (silt and clay). Unit Qes is well exposed in secs. 25-26, and secs. 35-36, T. 5 N., R. 63 W. On the La Salle quadrangle (Palkovic and others, 2019), two bulk 14C samples (LS035a and LS035b) were taken from the same stratigraphic interval in NW ¼ sec. 33, T. 4 N., R. 66 W. Sample LS035b, taken 2.7 m below ground surface yielded a carbon 14 age of 9,523 to 9,431 cal yr BP (8440 ± 30 14C yr BP) and sample LS035a, taken 2.75 m below ground surface, yielded a 14C age of 10,691 to 10,488 cal yr BP (9,350 ± 40 14C yr BP). Other authors (Scott and Lindvall, 1970; Muhs and others, 1996; Kellogg and others, 2008) cite three episodes of windblown sand deposition in northeastern Colorado: 27 to 11 ka, 11 to 4 ka, and 1.5 ka to present. Reworked deposits derived from colian sand locally form colluvial or sheetwash deposits that are not mapped. Extensive colian sand dunes are present north and south of the South Platte River, and many eolian features were identified in the field and on lidar imagery. Throughout the mapped area, deposits of loess (windblown sediment that is composed of >60% silt; Muhs and others, 2014) may be locally present. Previous authors (Forman and others, 1995; Muhs and others, 1999; Kellogg and others, 2008; Workman and others, 2018) report two episodes of loess deposition in northeastern Colorado from 20 to 14 ka and 13 to 10 ka. The exact boundaries of the loess deposits are difficult to delineate due chiefly to the subdued geomorphologic signature of loess deposits on lidar imagery. Additionally, unmapped deposits of Qg<sub>1</sub> and colluvium and/or sheetwash may be locally present in unit Qes. Unit Qes may be subject to deflation and wind erosion in areas that are poorly vegetated and may be prone to hydrocompaction when saturated and under load. Locally, the unit may be a source of industrial sand. In the southern part of the quadrangle, Qes ranges in thickness from 3 to 15 m, and is thicker in the southern part of the quadrangle. In the northern part of the quadrangle, thickness ranges from 4-17 m. Thicknesses in both parts of the quadrangle were estimated from interpretation of DWR borehole data (Colorado Division of Water Resources, 2019).

BEDROCK GEOLOGY

Klf

**Laramie Formation and Fox Hills Sandstone, undivided (Upper Cretaceous)** — Unit consists chiefly of sandstone, shale, and interbedded coal (Laramie Formation). Shown in cross section only. Approximately 90-180 m thick.

Kp

**Pierre Shale (Upper Cretaceous)** — Unit consists chiefly of shale with interbedded sandstone. Shown in cross section only. Total thickness approximately 1,800-2,100 m.

Kn

**Niobrara Formation (Upper Cretaceous)** — Unit consists chiefly of shale, marl, chalk and limestone. Shown in cross section only. Approximately 60-100 m thick.

MAP SYMBOLS

Contact — Approximately located

18-6 LIGGETT

Oil and gas well (Well name shown on map)

Permit 162290

Water well (Division of Water Resources permit number shown on map)

V028C14-1

14C age date sample

A A'

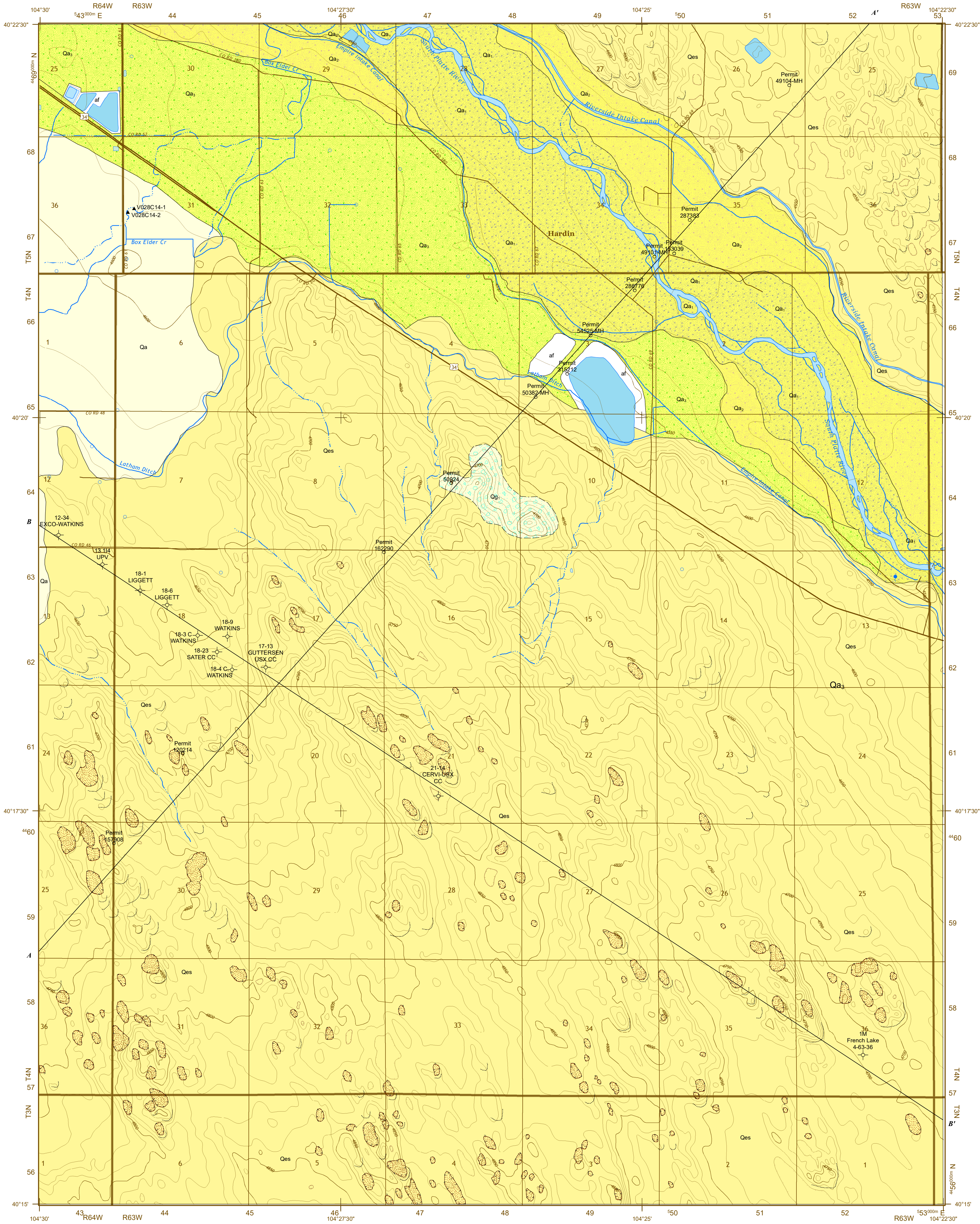
Alignment of cross section

Dune crest

Eolian blowout

ACKNOWLEDGMENTS

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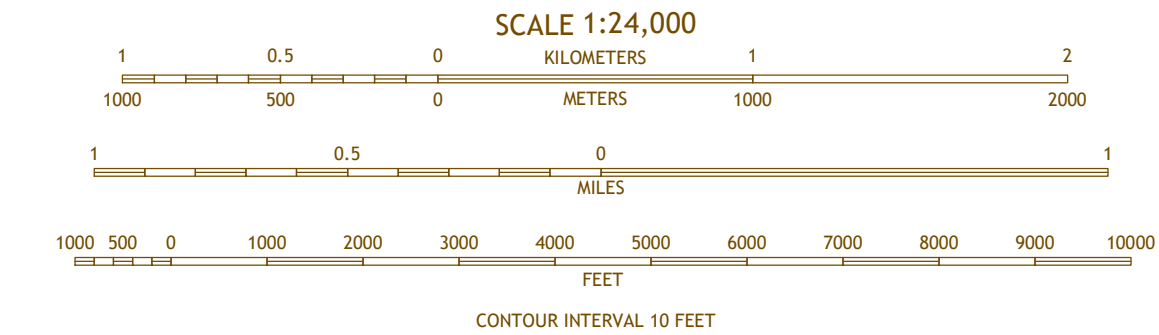


Coordinate System: NAD 1983 UTM Zone 13N  
Projection: Transverse Mercator  
Datum: North American 1983

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Roads.....U.S. Census Bureau, 2016  
Names.....GSI, 1978  
Hydrography.....National Hydrography Dataset, 2004-2019  
Contours.....National Elevation Dataset, 2003-2015  
Boundaries.....Multiple sources; see metadata file, 2017-2018  
Public Land Survey System.....BLM, 2018



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GEOLOGIC MAP OF THE HARDIN QUADRANGLE, WELD COUNTY, COLORADO

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