B2 Setting

Location

The NODOS/Sites Reservoir Project is in the Coast Range foothills and lowlands along the western edge of the northern Sacramento Valley (Figure B.2-1). The United States Geological Survey (USGS) watersheds and subbasins containing the proposed offstream reservoir include Lower Grapevine, Funks, Howard, Upper Grapevine, Antelope, Upper and Lower Hunters Creeks, and McDowell Canyon.

The key feature of the NODOS/Sites Reservoir Project, the proposed Sites Reservoir, is in north-central Colusa County and south-central Glenn County, approximately 10 miles west of the community of Maxwell. Two reservoirs are under consideration at the same site: one with a maximum capacity of 1.8 MAF that would inundate approximately 14,000 acres, the other with a maximum capacity of 1.3 MAF that would inundate an area of approximately 12,500 acres. The proposed reservoir inundation areas include most of Antelope Valley and the small community of Sites. The reservoir is in the Funks Creek and Stone Corral Creek watersheds and includes the eight associated USGS subbasins.

Topography

The physical topography of the watersheds draining the eastern side of the Coast Range toward the Sacramento Valley is diverse. The topography ranges from steep, rugged, mountainous terrain in the upper watersheds to rolling foothills in the project area and relatively flat alluvial terrain as the watersheds enter the Sacramento Valley. Elevations range from less than 40 feet on the valley floor to more than 8,000 feet along the Coast Range divide.

The proposed Sites Reservoir would be situated between the Sacramento Valley to the east and the mountainous portion of the Coast Range on the west. The Coast Range Mountains are a series of rugged, north-south–trending ridges dissected by narrow canyons containing steep gradients and entrenched streams. A relatively narrow band of steep, rolling foothills, approximately 2 to 3 miles wide, separates the proposed reservoir area from the Sacramento Valley. Antelope Valley, the primary inundation area of the proposed Sites Reservoir, lies between this narrow band of foothills and the more mountainous Coast Range. This relatively narrow, north-south–trending valley is approximately 13 miles long, and up to 2 miles wide. The elevation of the Antelope Valley floor ranges from 320 to 400 feet above msl, and the foothills separating the valley from the Sacramento Valley reach a maximum elevation of 1,300 feet. Elevations along the western side of Antelope Valley increase rapidly, with several peaks within 2 miles of the valley margin above 2,000 feet.

Climate

The climate of the watersheds draining into the western Sacramento Valley is typical Mediterranean. Winters are rainy and relatively mild, with only occasional freezing temperatures at the lower elevations; summers are comparatively dry and hot.

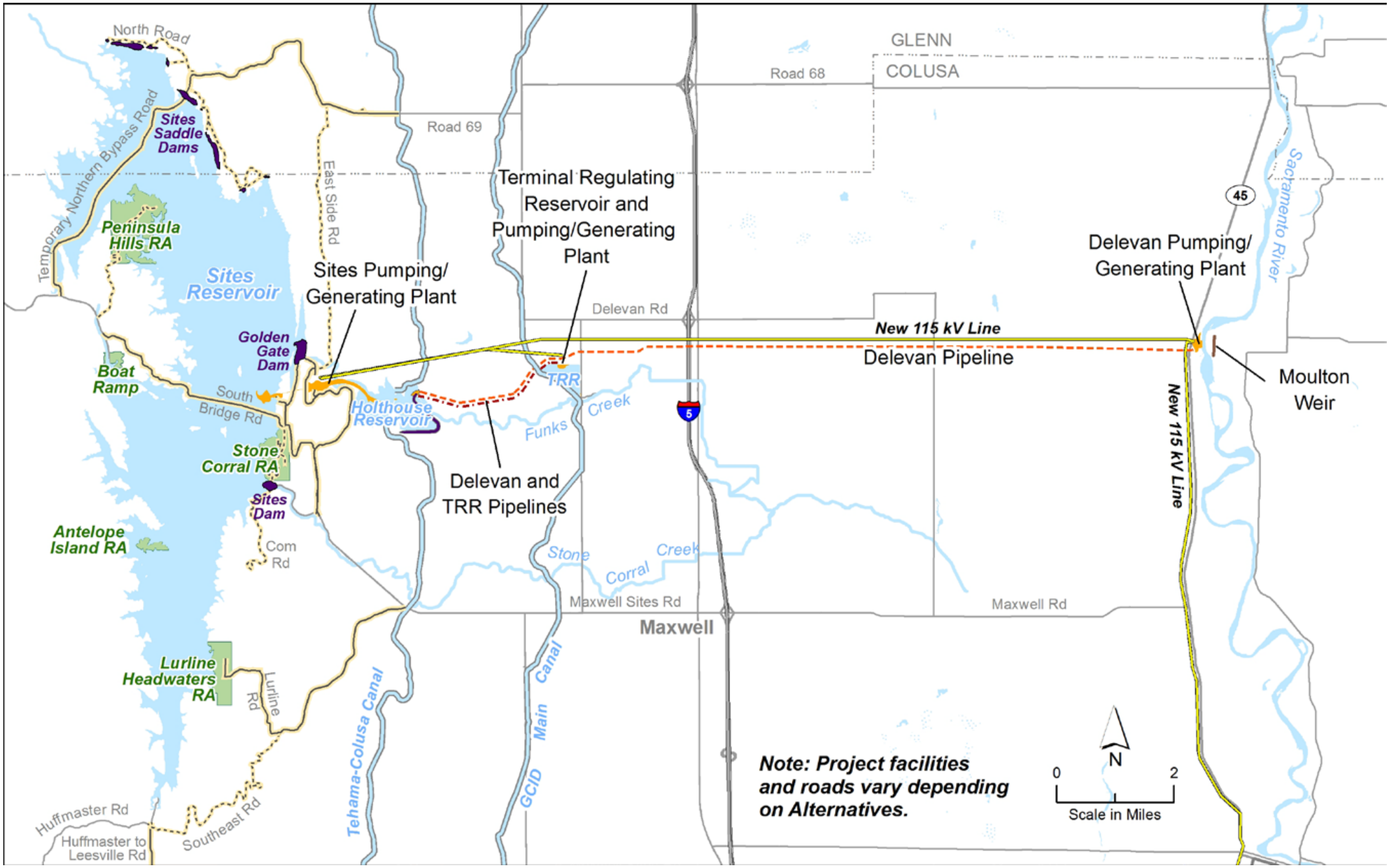


Figure B.2-1. NODOS/Sites Reservoir Project – Location Map

The rainy season normally begins in September and continues through March or April. Rains may continue for several days at a time, but are usually gentle. Summer rains are rare, as are thunderstorms and hailstorms. Thunderstorms occur approximately 10 days per year in the Sacramento Valley, occasionally producing high-intensity rainfall of short duration. Most precipitation is associated with migrant storms that move across the area during winter. Snow is the dominant form of precipitation above 5,000-foot elevations, and persists on north- and east-facing slopes into the early summer.

High temperatures occur during July, August, and September, with temperature readings commonly in excess of 100 degrees Fahrenheit. Fog of varying density and duration is common in the Sacramento Valley during winter. However, due to the physical topography, dense or persistent fog is much less common in the project areas. Winds occur seasonally, with dry, northern winds common during the summer and fall, while winds from the south are frequently associated with winter storm events. Winds in excess of 60 miles per hour (mph) may occur; however, these events are relatively uncommon and of short duration. Average wind speed at Red Bluff is 8.8 mph, with the strongest winds reported during the winter months. Gross evaporation—the depth of water lost to the atmosphere—averages approximately 70 inches per year in the foothill region.

Vegetation

Approximately 92 percent of the proposed Sites Reservoir inundation area is annual grassland community, with the remaining areas dominated by blue oak woodland and small amounts of chaparral, riparian wetlands, cultivated grain, and non-vegetated areas. The blue oak woodland gives way to foothill pines above the crest elevations of the two principal dams, and large chaparral stands emerge on the southern exposures and shallow soils above the dam crest elevations.

Watershed Hydrology

The watershed contributing inflow directly to Sites Reservoir drains approximately 83 square miles. Average annual precipitation in the basin is approximately 19 inches from the Sites Reservoir PMF Analysis (DWR DOE 2004) and occurs almost exclusively in the form of rain. Snowfall is not common below a 5,000-foot elevation. Snow does occur annually at the higher elevations in the coastal range. Some areas in western Glenn County frequently receive between 60 and 75 inches of precipitation per year; primarily in the form of snow.

Streams draining into the proposed reservoir are ephemeral, with little or no flow from July to October. However, these streams tend to respond rapidly to notable rainfall events. Flash flooding with substantial overland flow has been observed. Flow recorded at the stream gauge on Stone Corral Creek near Sites is representative of the flow variability of these small, ephemeral streams. Annual discharge varies from 0 AF in 1972, 1976, and 1977 to 39,930 AF in 1963 and averages 6,500 AF. Monthly volumes in excess of 15,000 AF have been documented.

Funks Creek

Funks Creek has 43 square miles of drainage area. No stream gauge currently exists on Funks Creek, and no accurate estimate of 100-year discharge is available. However, because the topography and soil composition of the watershed are similar to those of Stone Corral Creek, where stream flow records are available, and given the comparable drainage areas of the two watersheds, it may be reasonably assumed that the 100-year discharge into Funks Creek would be similar to that of Stone Corral Creek.

Stone Corral Creek

The drainage area of the Stone Corral Creek watershed is 38.2 square miles. The 100-year discharge was established in a 1987 DWR Colusa Basin flood flow frequency analysis at 7,870 cfs (March 10, 1987, Colusa Basin Flood Flow Frequency Analysis). This value was based on 25 years of discharge measurements collected near the town of Sites, with interruption, from 1958 through 1985.

Flood Hydrology

Flood Inflows and Volumes

At the request of DWR's Division of Planning and Local Assistance (DPLA), the DWR DOE performed a Probable Maximum Flood (PMF analysis for the Sites Reservoir watershed. (DWR DOE 2004) The goal of the study was to determine the performance of the reservoir in response to inflows from the Probable Maximum Precipitation (PMP) event. The study focused on the 1.8 MAF reservoir size, and the assumptions of the study included a completely full reservoir with a WSE of 520 feet at the start of the storm, a dam crest elevation of 540 feet, and a reservoir inundation area of 14,000 acres. The results of this analysis are also applicable to the 1.3 MAF reservoir, which is in the same location as the larger reservoir and has similar drainage areas.

The PMF analysis for the 1.8 MAF reservoir determined that the PMP the watershed would experience during a 3-day event was 20.63 inches. The total volume of inflow into the reservoir would be 78,422 AF, with a peak inflow of 68,500 cfs during the storm. Storing the full runoff in the reservoir above the normal maximum water level would raise the WSE by approximately 5.2 feet. After the PMP event, the freeboard left in the 1.8MAF reservoir would be approximately 14.8 feet (from the Sites Reservoir PMF Analysis [DWR DOE 2004]).

As mentioned above, the storm inflow volume for the 1.3 MAF reservoir would be approximately the same for the 1.8 MAF reservoir. The 1.3 MAF reservoir would have a maximum normal operating elevation of 480 feet (based on the available area capacity curve for the reservoir site) and a dam crest elevation of 500 feet. Storing the full runoff in the reservoir above the normal maximum water level would raise the WSE by approximately 6.25 feet. After the PMF event, the freeboard left in the 1.3 MAF reservoir would be approximately 13.75 feet.

Emergency Signal Spillway Design Flood

Preliminary design of the Sites Reservoir emergency spillway was performed in accordance with the state-of–the-practice for dam appurtenant structures. The emergency signal spillway design conforms to existing Division of Safety of Dams (DSOD) criteria. The elevation, type, and capacity of the emergency spillway are designed for a highly unusual set of circumstances.

The proposed Sites Reservoir in either the 1.8 MAF or 1.3 MAF configuration would accommodate full storage of the design flood inflow with adequate residual freeboard to the dam crest. The emergency spillway would be required primarily for the improbable case where the pumping plant would continue pumping into the reservoir despite the reservoir being at maximum pool. The emergency spillway selected for the Feasibility Report would consist of one 7-foot-diameter reinforced-concrete pipe, which would be at Saddle Dam 6 for both reservoir alternatives. However, the spillway configuration would be different for the two reservoirs, as discussed further in Section B.3, Design Considerations. The pipe size selection is based on maintenance and inspection considerations.

Geology

General

This section summarizes the geology and geotechnical conditions of the features under consideration for the proposed NODOS/Sites Reservoir Project. The information in this section was summarized from the July 2003 *Project Geology Report No. 94-30-02, Geologic Feasibility Report, Sites Reservoir Project, Appendix to Engineering Feasibility Report*. Project Geology Report No. 94-30-02, in turn, provided a general summary of the detailed geologic reports prepared by the DOE and the DPLA, Northern District, Geology Section (Northern District). Discussions include the preliminary geologic investigations, which were conducted mostly by the Northern District for the proposed project features (DWR DOE 1999a, 1999b, 2000, 2002a, 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2008a).

Geologic conditions at the two main dam sites (Golden Gate and Sites Dam), the saddle dam sites, and all other project facilities provide good-quality rock for their respective foundations. Three important geology-related issues associated with the Feasibility Report were:

- Determining that geologic foundation conditions for the proposed project facilities are adequate
- Determining seismic sources for the project and fault activity at the Golden Gate and Sites Dam sites
- Evaluating sources for sand and gravel for construction materials

The data and analyses presented in this summary were used in developing preliminary design criteria for the NODOS/Sites Reservoir Project.

Geologic Setting

The NODOS/Sites Reservoir Project would be located in the foothills of the northwestern edge of the Sacramento Valley, within the border area of the Great Valley and Coast Range geomorphic provinces (Figure B.2-2). The project area is underlain by Upper Cretaceous sedimentary rocks of the Cortina and Boxer Formations and alluvial deposits of the Sacramento Valley. Surficial geologic units in the project area include Pliocene- to Pleistocene-age deposits of the Tehama Formation, Quaternary older alluvial terrace deposits, and Holocene (Recent) alluvium, colluvium, and landslide deposits (Figure B.2-3). Structurally, the reservoir site is bounded by the Green Valley thrust and Stony Creek faults to the west and the Corning and Willows faults to the east. Passing beneath the proposed reservoir are westerly dipping fault planes of the Funks and Bear Valley segments of the Great Valley thrust fault, while the Fruto Syncline, Sites Anticline, and Salt Lake thrust fault pass through the project site in a generally north-south trend.

The proposed Golden Gate Dam site is in a stream-cut water gap on Funks Creek in the Venado sandstone member of the Upper Cretaceous Cortina Formation. The proposed Sites Dam site is in a stream-cut water gap on Stone Corral Creek, within the Boxer and Cortina Formations. At these dam sites, the Cortina and Boxer Formations are part of a series of an east-dipping, Great Valley sequence of rocks exposed in the foothills bordering the eastern Coast Ranges (Figure B.2-3). Directly west of the dam sites, at the saddle dam sites and in the reservoir, these rocks are folded about the axes of the north-trending Sites anticline and Fruto syncline. East of the Golden Gate and Sites Dam sites, the rocks progressively flatten beneath the western Sacramento Valley margin. The two primary rock units in both the Cortina and Boxer Formations are sandstone and mudstone. The sandstones are commonly ridge-formers, and the mudstones are generally expressed as topographic lows.

In addition to the folds, numerous faults offset and deform the bedrock strata in the Study Area. Two primary sets of surface faults were mapped in the vicinity of the dam sites:

Northeast-striking, high-angle faults that obliquely cut the north-striking bedrock units, and consistently displace stratigraphic contacts in a right-lateral strike-slip sense. Specific examples of these structures include the informally named GG-1, GG-2, GG-3, and S-2 faults, all of which pass directly through or near the proposed Golden Gate and Sites Dam (Figure B.2-3).

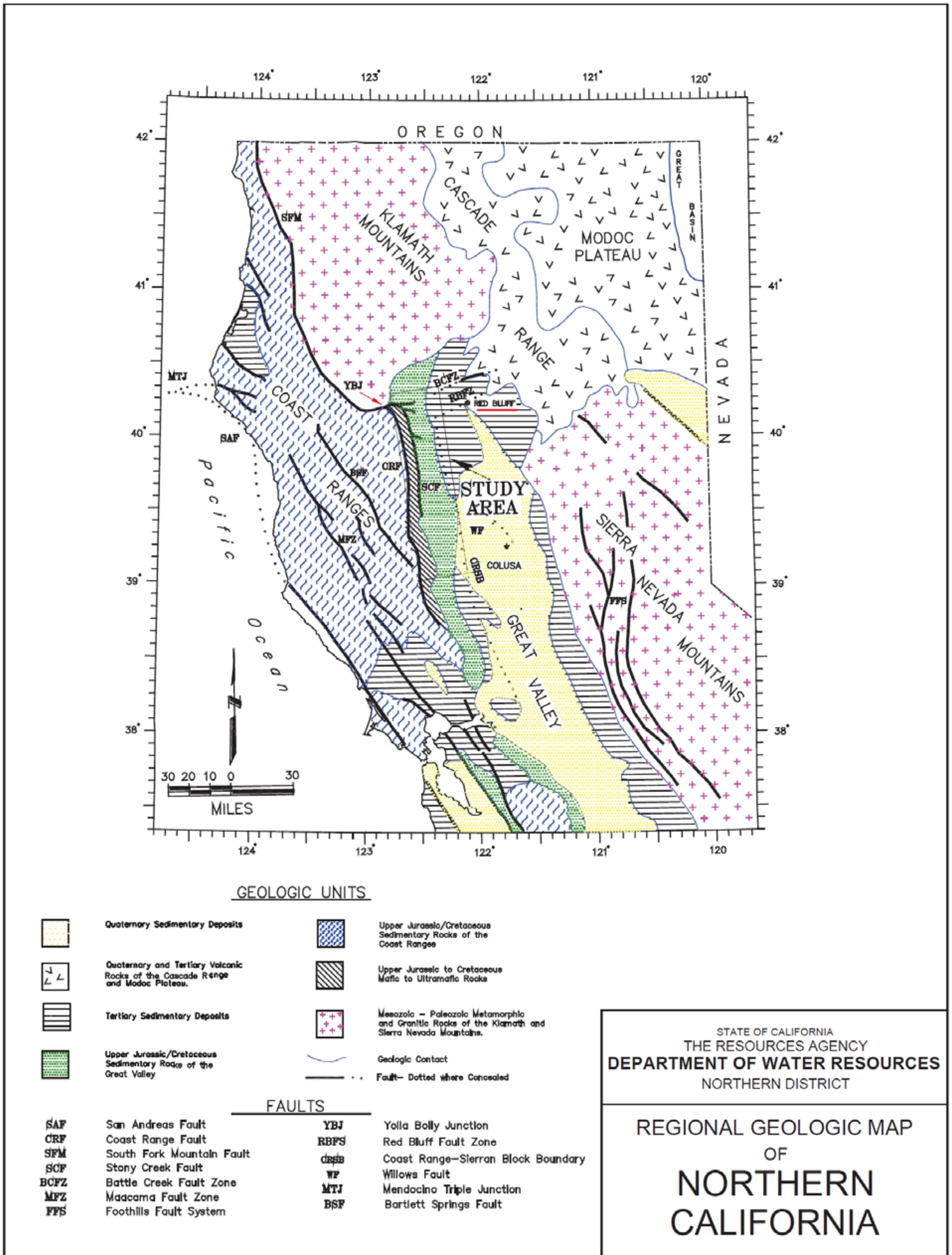
North-striking faults that are generally parallel to bedding. The most laterally continuous example of these structures is the steeply east-dipping Salt Lake thrust fault, which is parallel to, and directly east of, the axis of the Sites anticline in the proposed reservoir area. This fault trends through the middle of the reservoir and through the proposed Saddle Dam 2 site.

Geotechnical Investigations

Geologic exploration for investigation at the various NODOS/Sites Reservoir Project features consisted of geologic mapping, drilling and water pressure testing, seismic refraction surveys, trenching and test pits, and laboratory testing. Individual exploration techniques are discussed below.

- DWR's Division of Land and Right-of-Way produced new topographic maps from a 1:7200 aerial flight in November 1998. Contours were developed at 2-foot intervals. Most of the geologic maps for the project used this topographic base map.

Numerous sources of previous geologic mapping were used in developing site maps for individual features of the project. The first published source of geologic mapping that covers the entire project area is the USGS Oil and Gas Investigations Map OM-210, entitled *Geologic Map of the Lodoga Quadrangle, Glenn and Colusa Counties, California* (USGS 1961). The mapping was performed by R.D. Brown and E.I. Rich in 1961 at a scale of 1:48,000. This detailed regional geologic mapping covers the entire reservoir area and was the geologic base map for all of the studies performed by Reclamation and DWR since 1963.



Filename:N:\NDSharedInfo\typing\geo\Final 1999 Sites Report\Figures\original\Figure 3--Sites Regional Geology--01-19-01--JHM.dwg

Figure B.2-2. Regional Geologic Map of Northern California

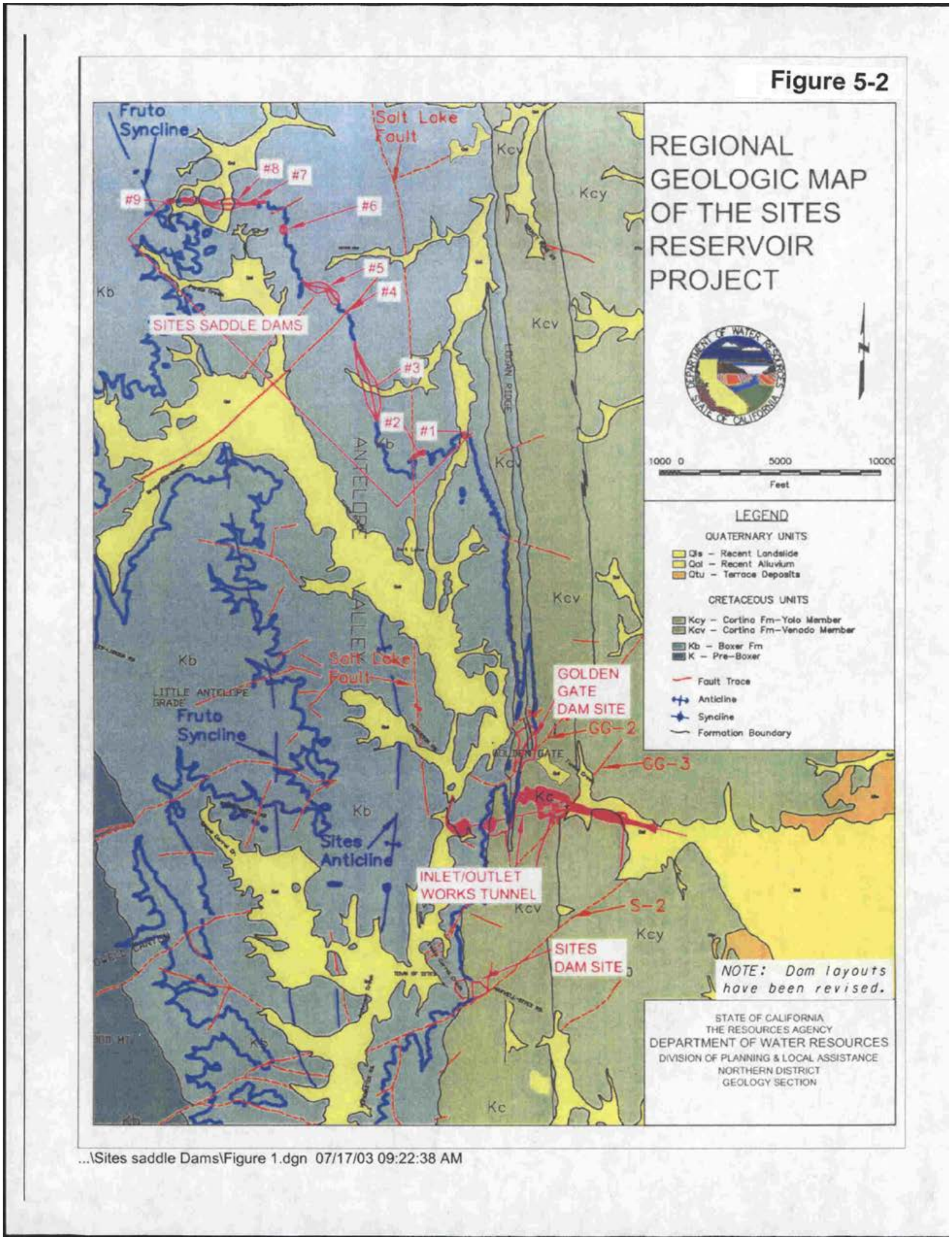


Figure B.2-3. Regional Geologic Map of the NODOS/Sites Reservoir Project

In 1963 and 1969, Reclamation performed feasibility-level geologic mapping at a scale of 1 inch = 200 feet. In addition, in 1979 and 1980, Reclamation performed additional geologic site mapping using metric scales and topography. Geologic mapping and subsurface exploration for the project have been ongoing since 1997, by numerous DWR geologists. Geologic mapping for the reservoir site was primarily conducted by Northern District personnel between 1997 and 2001, with contributions by DOE engineering geologists.

Most of the subsurface exploration to date has been concentrated at the Sites, Golden Gate, and saddle dam sites. However, some reservoir and fault mapping, along with trenching associated with fault studies carried out by William Lettis & Associates Inc. (WLA), were conducted independent of individual dam site studies. Approximately 72 exploration borings were drilled in the project area by Reclamation and DWR, using a combination of rotary coring and hollow-stem auger methods. Standard Penetration Tests (SPTs) and water pressure/packer tests were performed in the boreholes as appropriate, and samples collected for laboratory testing. WLA excavated 31 trenches and test pits at 14 locations for their faulting and seismicity studies, while Reclamation and DWR excavated 10 test pits for construction material evaluations. Ten seismic refraction arrays were surveyed for the project: six at the Golden Gate Dam site and four for the Funks Reservoir enlargement and Delevan Pipeline alignment.

Laboratory testing was performed on rock and soil samples collected from test pits, drill holes, and the nearby Sites Quarry for potential construction materials use. The testing was performed by the United States Army Corps of Engineers (USACE), Reclamation, and DWR over different periods of exploration. Rock testing included specific gravity; absorption; compressive, shear, and tensile strengths; and Los Angeles abrasion losses. Petrographic analyses of weathered and fresh Venado sandstone were performed by the USACE in 1962 and 1972. Soil samples were tested for classification, density, permeability, and shear strength; soil samples from auger holes along the proposed conveyance alignment were also tested for resistivity, sulfates, and chlorides. Results of laboratory testing can be found in *Sites Reservoir Feasibility Study – Materials Investigation, Testing, and Evaluation Program* (DWR DOE 2002c).

Geologic Conditions

Sites Reservoir

The proposed Sites Reservoir would lie on alluvial and colluvial deposits and interbedded mudstone, sandstone, and conglomerate bedrock of the Cretaceous Boxer Formation (Figure B.2-3). However, a comprehensive geologic study of the entire reservoir has not yet been completed. Most of the previous exploration has focused on the Sites, Golden Gate—and to a lesser extent—the saddle dam sites. Figure B.2-4 provides an explanation of symbols for individual dam site geologic maps.

Golden Gate Dam would be founded on sandstone (Kcvs) and mudstone (Kcvsm) of the Cortina Formation that generally strike north-south, and dip 50 degrees downstream to the east (Figures B.2-5, B.2-6, B.2-7, and B.2-8).

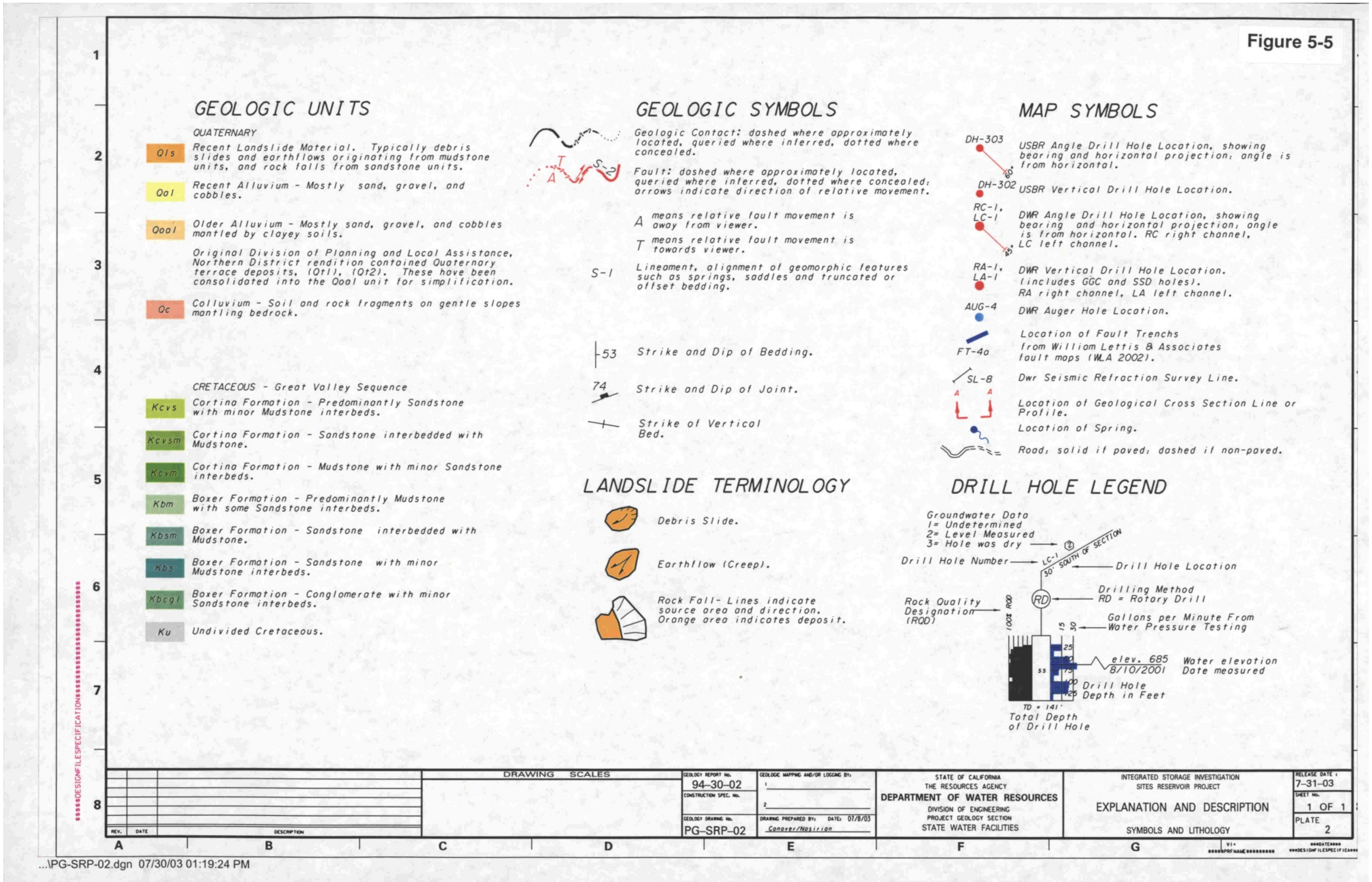


Figure B.2-4. Explanation and Description – Symbols and Lithology

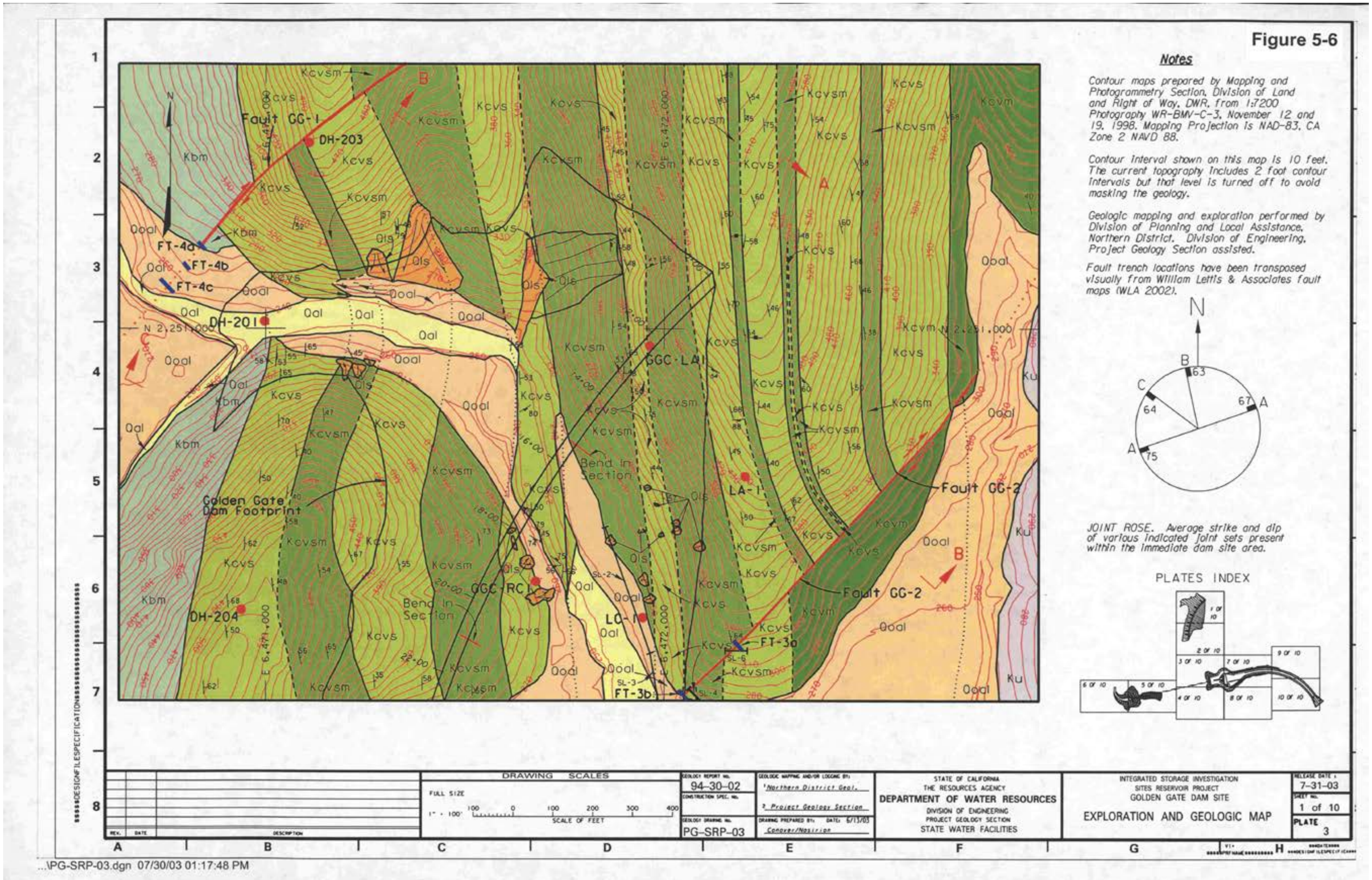


Figure B.2-5. Golden Gate Dam Site – Exploration and Geologic Map (Sheet 1)

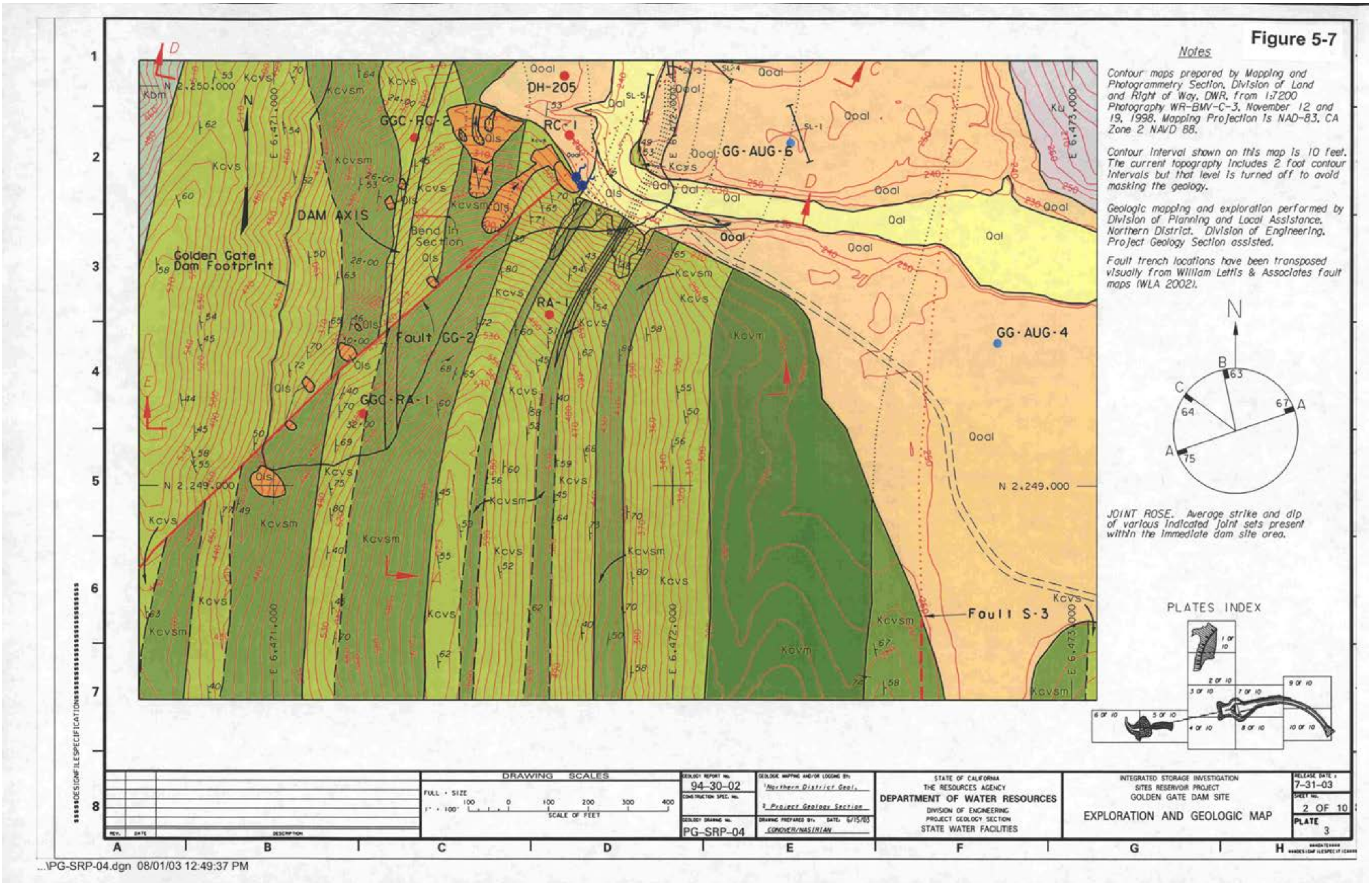


Figure B.2-6. Golden Gate Dam Site – Exploration and Geologic Map (Sheet 2)

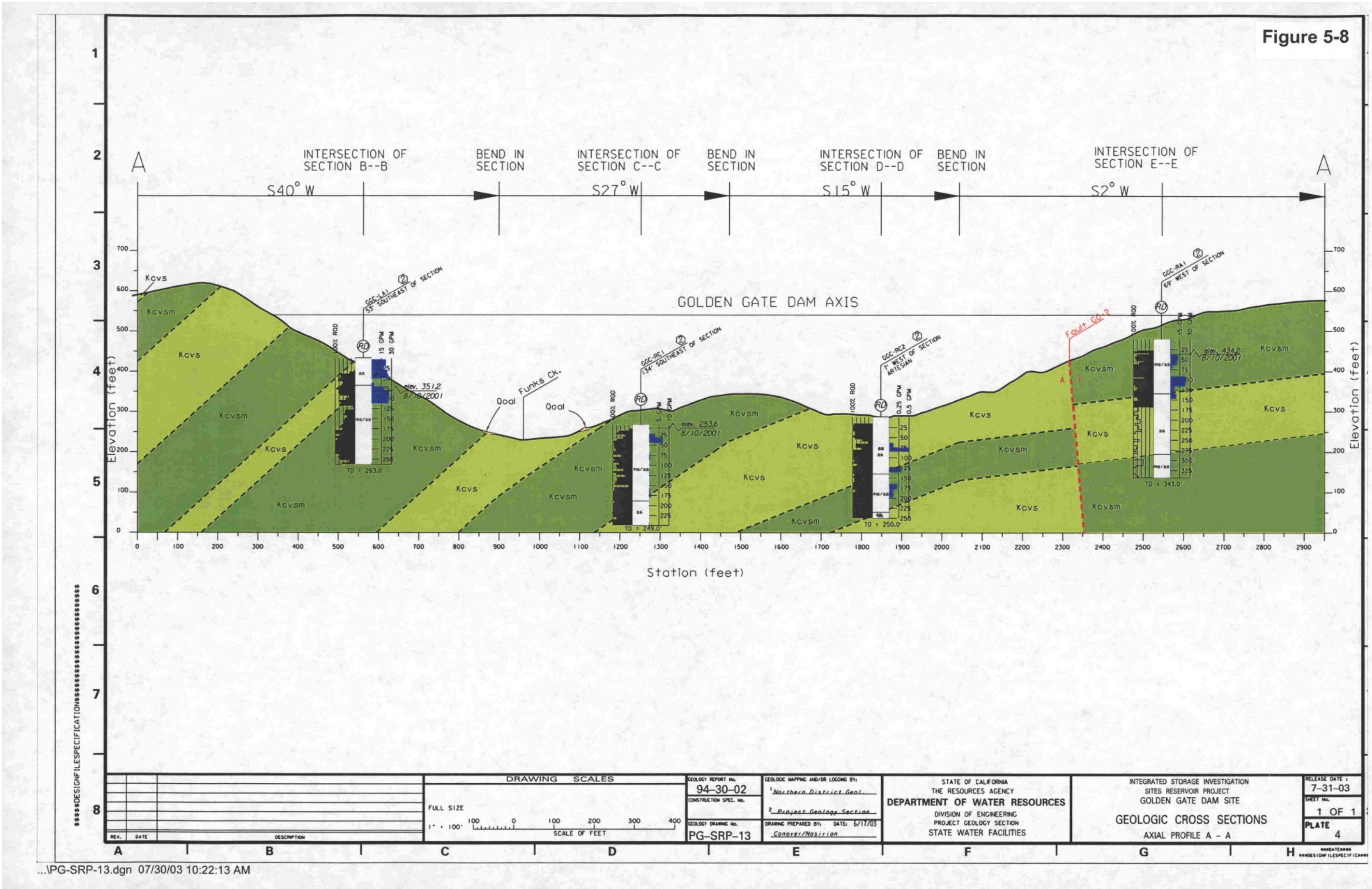


Figure B.2-7. Golden Gate Dam Site – Geologic Cross Sections – Axial Profile A-A

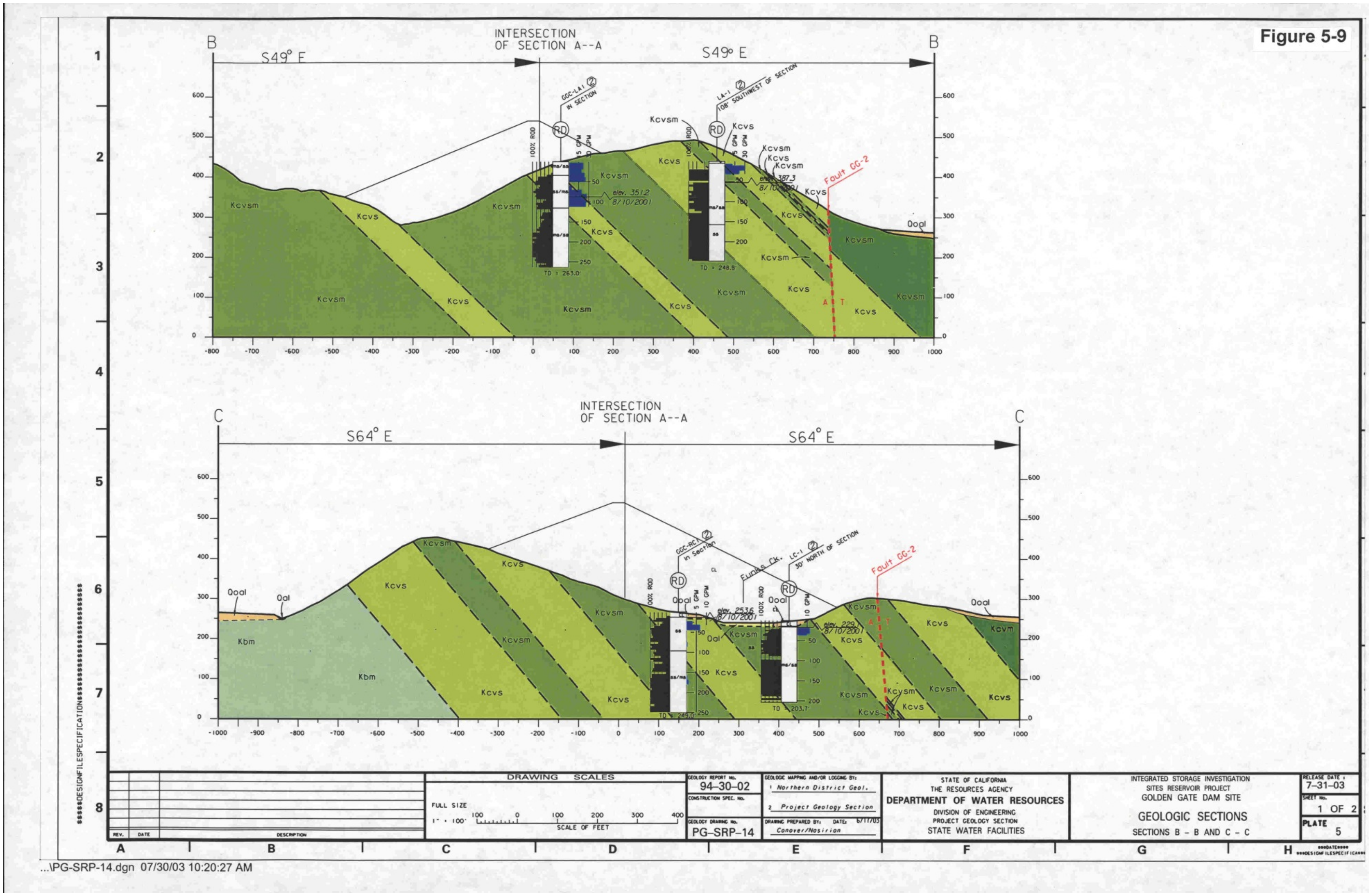


Figure B.2-8. Golden Gate Dam Site – Geologic Cross Sections – Sections B-B and C-C

The sandstone is moderately to well-indurated (hardened), and thin- to thick-bedded, with mudstone interbeds up to 5 feet thick. Near the surface, the sandstone is intensely to moderately weathered, moderately hard, moderately strong, and closely to moderately fractured. At depth, the sandstone improves from slightly weathered to fresh, hard, strong, and moderately to slightly fractured. Fractures are generally associated with jointing, and are mostly healed with calcium carbonate. Overlying the bedrock, in the Funks Creek channel, is recent alluvium (Qal) consisting of silty and poorly graded sand and gravel deposits up to 17 feet thick. There are also up to 25 feet of older, sandy, and lean clay alluvial terrace (Qoal) deposits along the channel banks.

The mudstone unit at the site is moderately indurated, thinly laminated to thinly bedded with thin sandstone interbeds; and not exposed on the surface within the dam footprint. Nearby outcrops show that weathered mudstone is friable to low hardness, weak, closely fractured, brittle, and susceptible to slaking when exposed to air or moisture. At depth, fresh mudstone is moderately hard, moderately strong, and slakes only slightly after prolonged exposure to air. Bedding-plane fractures predominate, while joint fractures are relatively short and discontinuous; mudstone bedding plane fractures commonly exhibit some plastic deformation in the form of slickensides or internal shearing.

Shears associated with bedding were noted in the sandstone and mudstone units, with zones up to 3.7 feet thick. The shears commonly contained up to 10 percent clay gouge, with a variable percentage of calcite healing.

Two primary joint sets were identified from surface mapping at the site (Figures B.2-5 and B.2-6). Set A, trending nearly normal to the ridges and bedding, has a strike ranging from North 68 degrees East to North 86 degrees East, and dips steeply from 67 degrees North to 79 degrees South. Set B is nearly parallel to bedding, and strikes north-south to North 25 degrees West, dipping 53 degrees to 79 degrees East. Analysis of the field mapping also showed a minor joint set, Set C, ranging in strike from North 48 degrees to 58 degrees West, and dipping 54 degrees to 74 degrees South.

Two near-vertical, northeast-trending faults are at the Golden Gate Dam site, GG-1 (Figure B.2-5) and GG-2 (Figure B.2-6). Fault GG-1 is approximately 150 to 400 feet upstream of the left abutment, exhibiting right-lateral displacement of up to 250 feet. The second fault, GG-2, is approximately 650 feet southeast (downstream) of the left abutment, passing under the downstream footprint, and traversing across the upper right abutment. GG-2 trends approximately North 50 degrees East, and displays a maximum right-lateral separation of approximately 1,300 feet.

Some colluvium, minor landslides, rockfalls, and surficial slumps are present within the footprint of the proposed dam (Figures B.2-5 and B.2-6). They do not appear to pose any construction problems, or ultimate dam safety/foundation problems. Current rock falls are associated with older quarry operations. These materials would need to be stripped to reach a suitable foundation.

Water pressure testing in exploration drill holes generally indicated that the slightly weathered and fresh foundation rock would be fairly tight, with some localized zones of potentially high hydraulic conductivity near the surface. Grouting would be required.

Groundwater data were collected from monitoring wells installed during exploration drilling. Water levels in the wells ranged from elevations of 357 to 382 feet in the left abutment, 231 to 254 feet in the channel, and 392 to 437 feet in the right abutment. Based on the groundwater elevations above, dewatering would be required, because some of the dam foundation and cut-off wall excavation would be below the water table.

Sites Dam Site

Sites Dam would be founded on Cretaceous sedimentary rocks of the Cortina and Boxer Formations, which generally trend north-south and dip 50 degrees downstream to the east (Figures B.2-9, B.2-10, B.2-11, and B.2-12). The Cortina Formation consists of sandstone (Kcvs) and interbedded sandstone and mudstone (Kcvsm) of the Venado member, while mudstone (Kbm) with sandstone interbeds (Kbs) make up the Boxer Formation rocks at the site. The Stone Corral Creek channel is composed of up to 10 feet of recent alluvium (Qal) and colluvium consisting of silty and poorly graded sands and gravels. Up to 15 feet of older alluvial (Qoal) deposits of sandy and lean clay and silt with gravel underlying silty and clayey gravels mantle the dam abutments. Some areas have no soil cover, and sandstone bedrock is exposed at the surface. Some landslides and surficial slumps were mapped within the footprint of the proposed dam, with the Boxer Formation more susceptible to instability than the Cortina Formation.

The Cortina Formation sandstone at the site is thinly to very thickly bedded, with thin interbeds of mudstone ranging from laminar to 5 feet thick, and moderately to well-indurated. At and near the surface, the sandstone is intensely to moderately weathered, moderately hard, moderately strong, and closely to moderately fractured. At depth, the sandstone is slightly weathered to fresh, hard to very hard, strong, and closely to slightly fractured to massive. Fractures are mostly associated with jointing, and are commonly healed with calcite.

The Boxer Formation at the site is approximately 60 to 80 percent mudstone, with 20 to 40 percent interbedded sandstone. The Boxer mudstone unit is low to moderately hard, weak to moderately strong, closely to moderately fractured, and very thin to thinly bedded. Fractures in the mudstone are mostly associated with bedding, and commonly exhibit some plastic deformation in the form of slickensides or internal shearing. The mudstone is susceptible to slaking when exposed to air and/or water.

Geologic mapping at the site identified two primary joint sets (Figures B.2-9 and B.2-10). Set A trends nearly normal to the topographic ridges and bedding, striking between North 57 degrees East, to North 80 degrees East, and dipping 69 degrees to 80 degrees North. Joint Set B ranges in strike from North 72 degrees West, to North 86 degrees West, and dips steeply from 78 degrees North, to 83 degrees South. A minor joint set, Set C, was also identified striking approximately North 74 degrees East, and dipping approximately 45 degrees North.

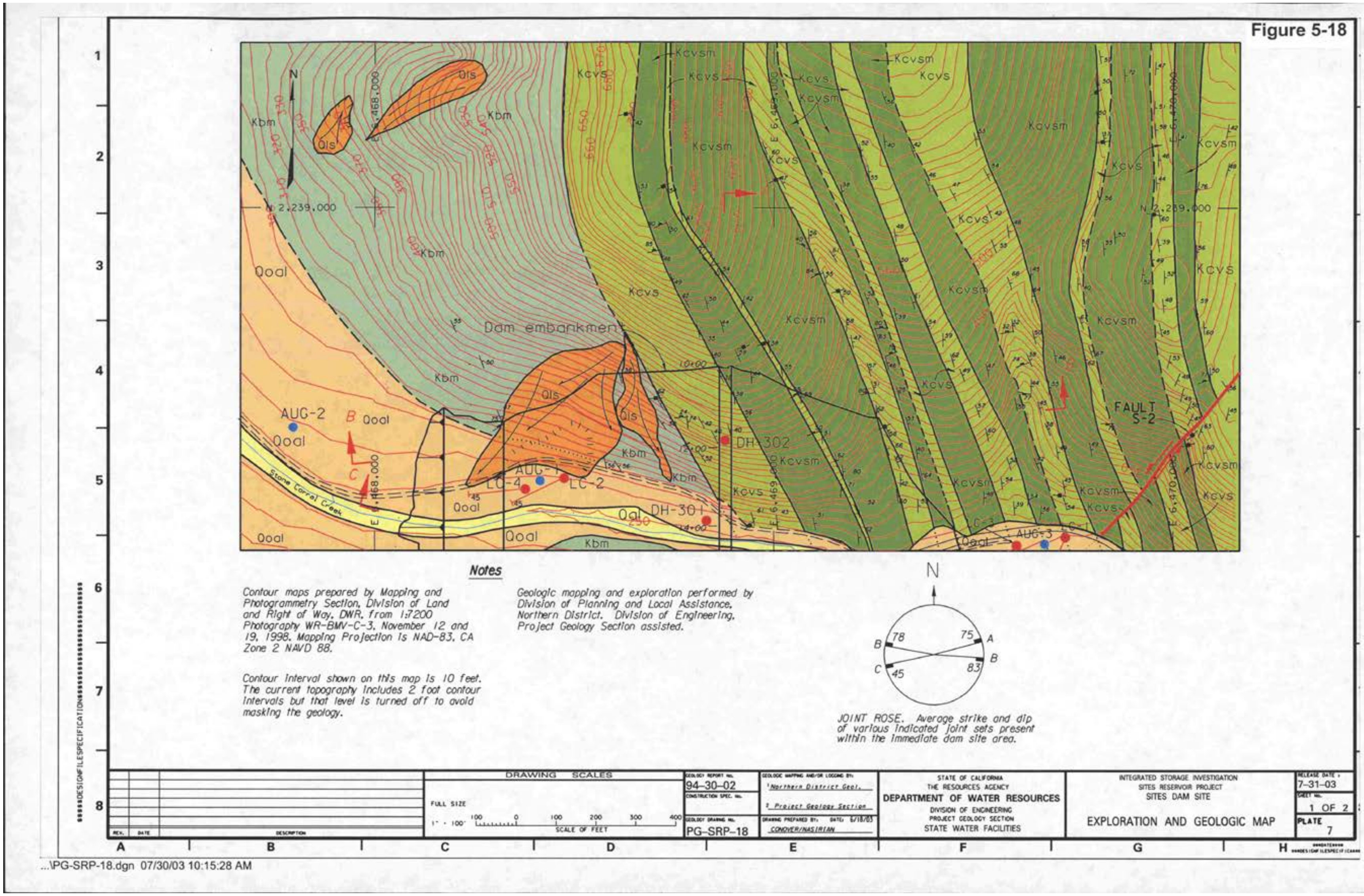


Figure B.2-9. Sites Dam Site – Exploration and Geologic Map (Sheet 1)

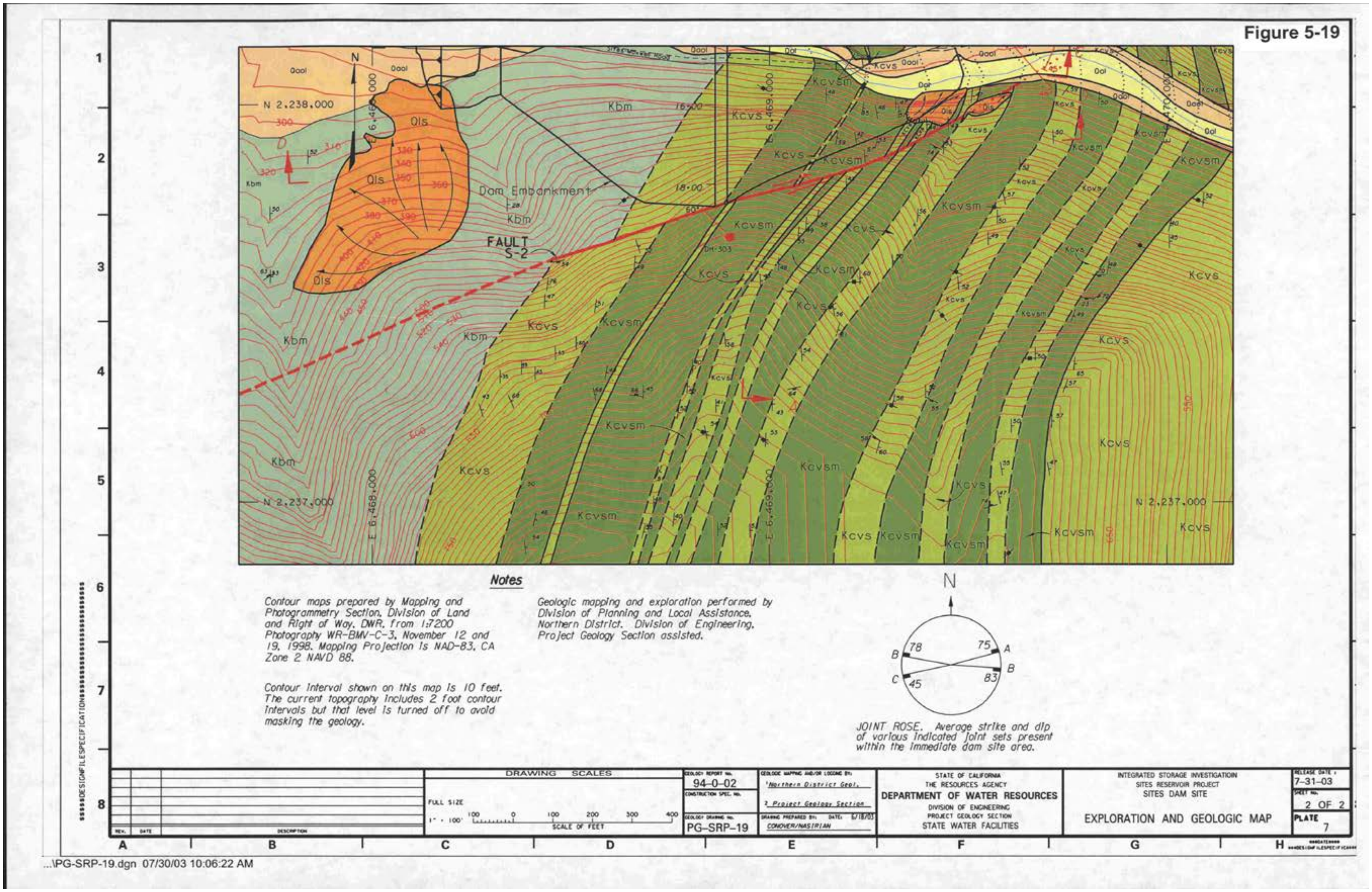


Figure B.2-10. Sites Dam Site – Exploration and Geologic Map (Sheet 2)

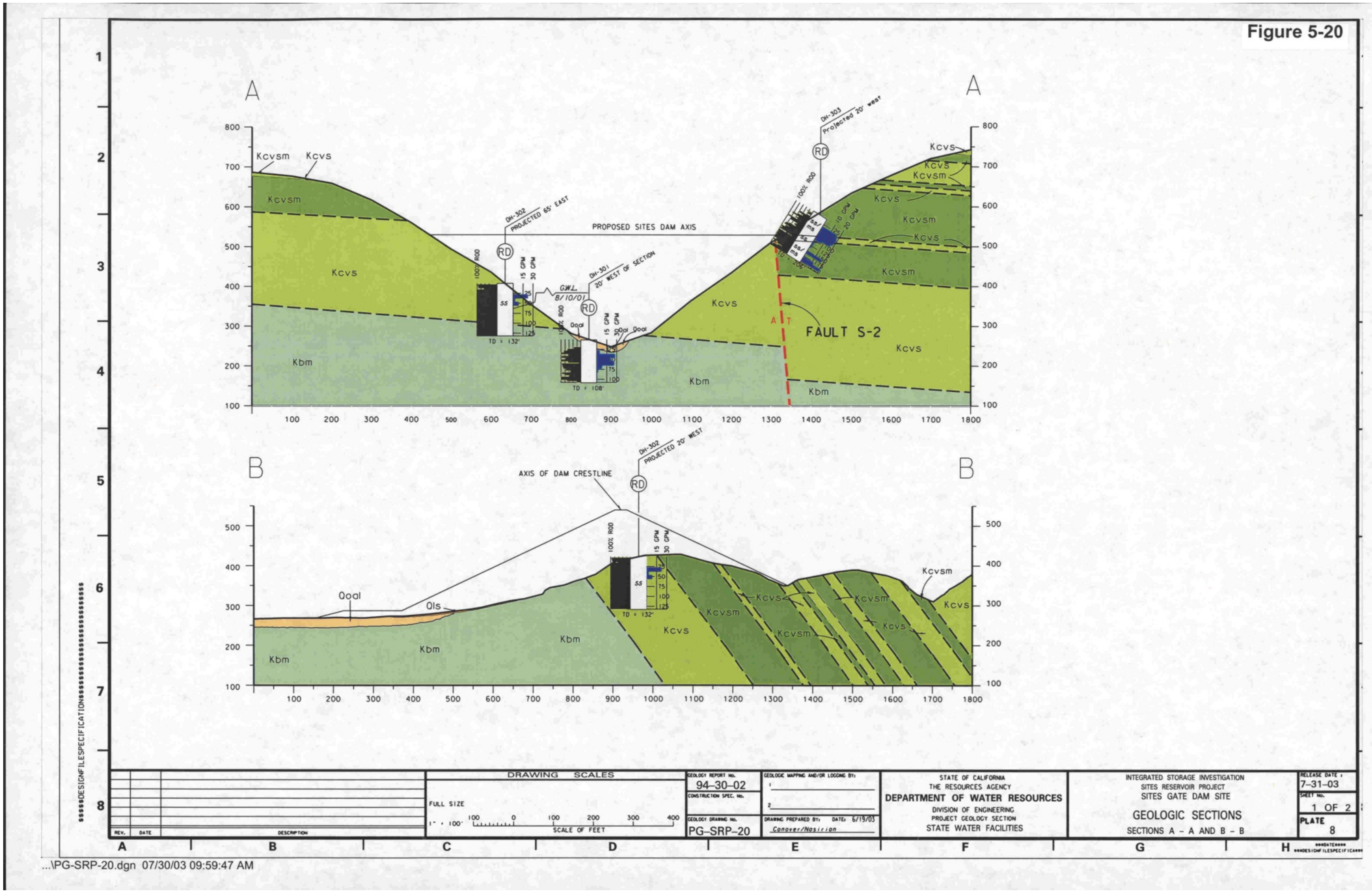


Figure B.2-11. Sites Dam Site – Geologic Sections – Sections A-A and B-B

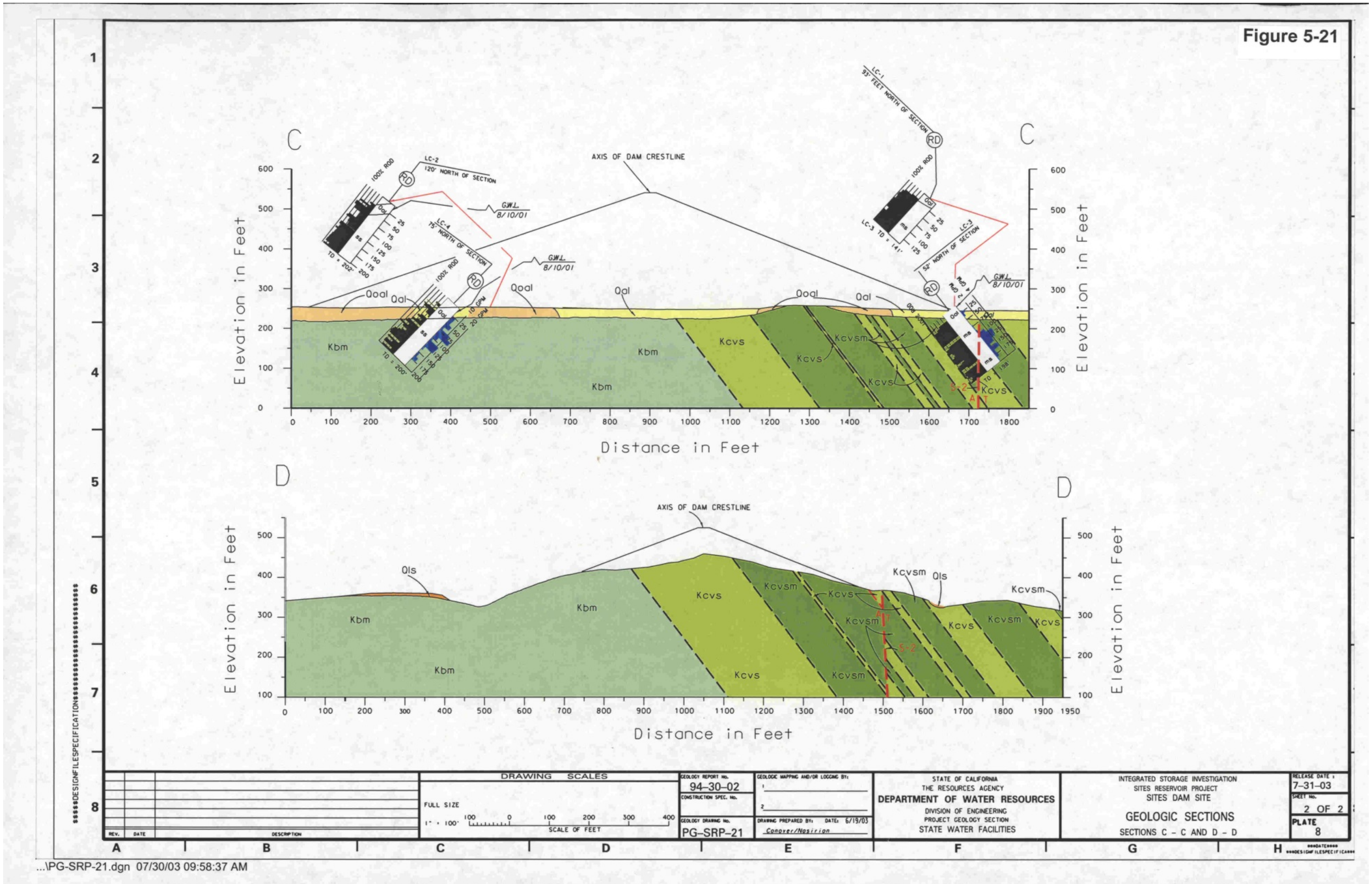


Figure B.2-12. Sites Dam Site – Geologic Sections – Sections C-C and D-D