UTAH GEOLOGICAL AND MINERAL SURVEY

REPORT OF INVESTIGATION

NO. 206

GEOLOGIC EVALUATION OF A PROPOSED REGIONAL WASTEWATER TREATMENT PLANT SITE WASHINGTON COUNTY, UTAH

by
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Site Investigation Section

March 1986

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GEOLOGIC EVALUATION OF A PROPOSED REGIONAL WASTEWATER TREATMENT PLANT SITE WASHINGTON COUNTY, UTAH

PURPOSE AND SCOPE

This report presents the results of a geologic investigation at the site proposed for construction of a regional wastewater treatment plant in southwestern Washington County, Utah. The purpose of the investigation was to determine if geologic conditions exist at the site which might adversely affect the proposed facility. The investigation included a review of available geologic literature, air photo analysis, field reconnaissance and mapping, and excavation of 6 test pits. Mr. Larry Bullock, St. George City Engineer, requested the investigation on behalf of St. George, which is a participant in the project.

SETTING

The proposed wastewater treatment plant site is located about 4 miles southwest of St. George on the west side of the Virgin River (fig. 1). It encompasses approximately 480 acres, and includes the S1/2 sec. 15 and the SE 1/4 sec. 16, T. 43 S., R. 16 W. Salt Lake Base and Meridian. The west edge of the property encroaches on the Virgin River flood plain, and the northern boundary roughly parallels an irregular line of cliffs marking the southern extent of the White Hills. The remainder of the site is flat to moderately rolling and is comprised of stream terraces, alluvial fans, and eolian (sand dune) deposits. Curly Hollow Wash, an ephemeral stream with a drainage area of several square miles, crosses the western third of the site. Two smaller

Base map from USGS 15'
St. George, Utah Quadrangle

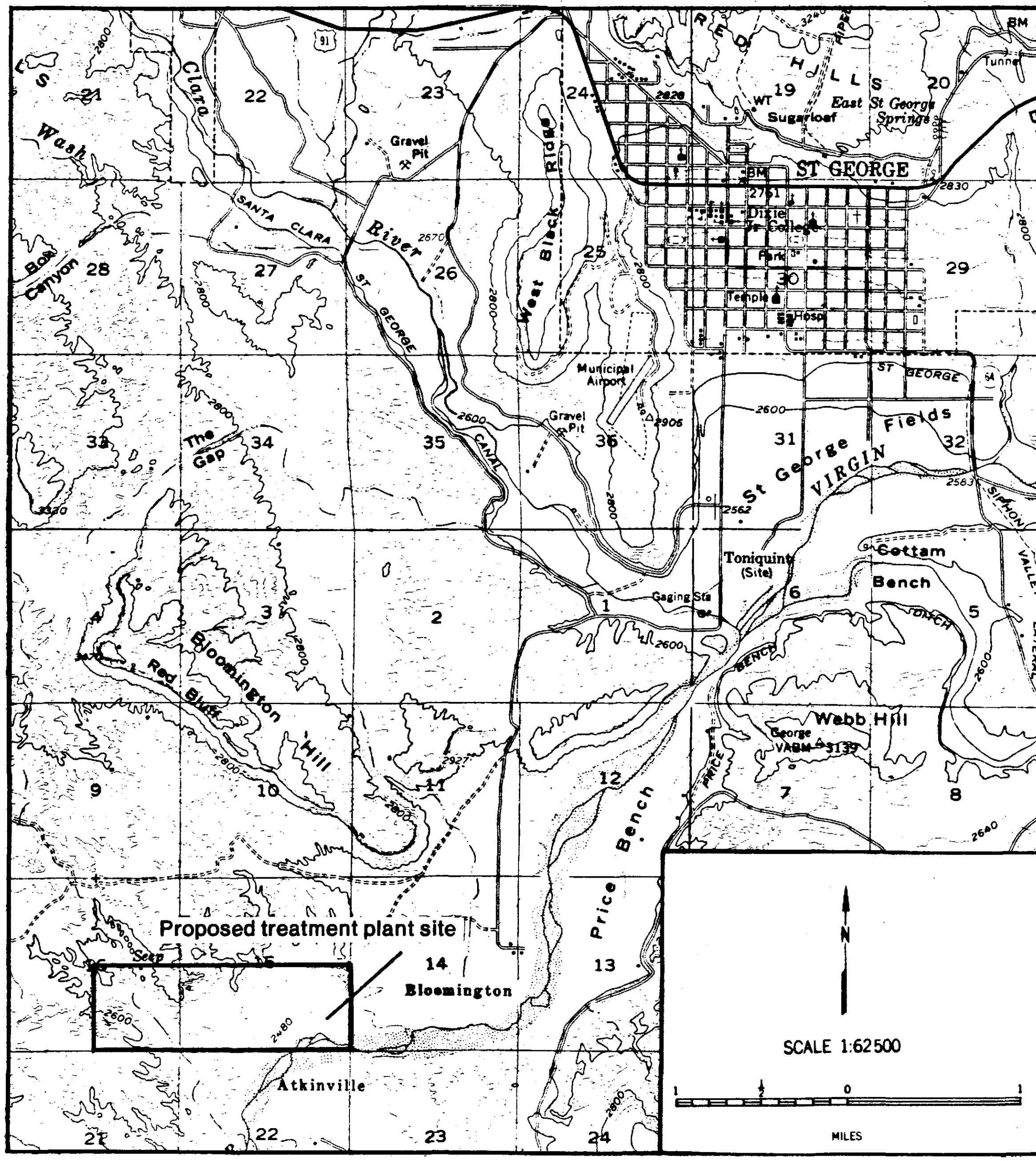


Figure 1 - Location map of proposed wastewater treatment plant southwest of St. George, Utah.

ephemeral streams, draining primarily from the cliffs, cross the central and eastern portions of the property. All three drainages have incised their channels several feet and show evidence of flow in the recent past. The edge of the Virgin River flood plain is marked by a steep scarp more than 10 feet high at the southern property boundary. The scarp height decreases in an upstream direction, and is less than a foot high at the east end of the site. Two long, narrow gullies have been eroded into the scarp just west of the point where the easternmost ephemeral stream joins the Virgin River flood plain.

Salt cedar trees and other phreatophytes are abundant on the Virgin River flood plain. Elsewhere on site, vegetative cover is sparse. Access to the property is by gravel and unimproved dirt roads from Bloomington, Utah.

GEOLOGY AND HYDROLOGY

The Triassic Moenkopi Formation underlies the cliffs and upland areas along the north edge of the site (fig. 2). Five members of the Moenkopi Formation crop out in the St. George area, two of which are present at the site. They are the Middle Red Member and the underlying (older) Virgin Limestone Member. The Middle Red Member consists of gypsiferous brown to red shale and sandstone. It forms the cliffs near the west end of the site. The Virgin Limestone Member is comprised of dense, gray limestone with thin interbeds of yellow-brown shale and sandstone (Christenson and Deen, 1983). It forms moderate to steep slopes, but few cliffs, and crops out in the hills at the east end of the property. Because the Moenkopi Formation is easily eroded, good exposures are rare except on cliffs, and strike and dip measurements are difficult to obtain. However, bedrock in the area generally strikes to the northeast and dips about 25 degrees to the northwest. Where

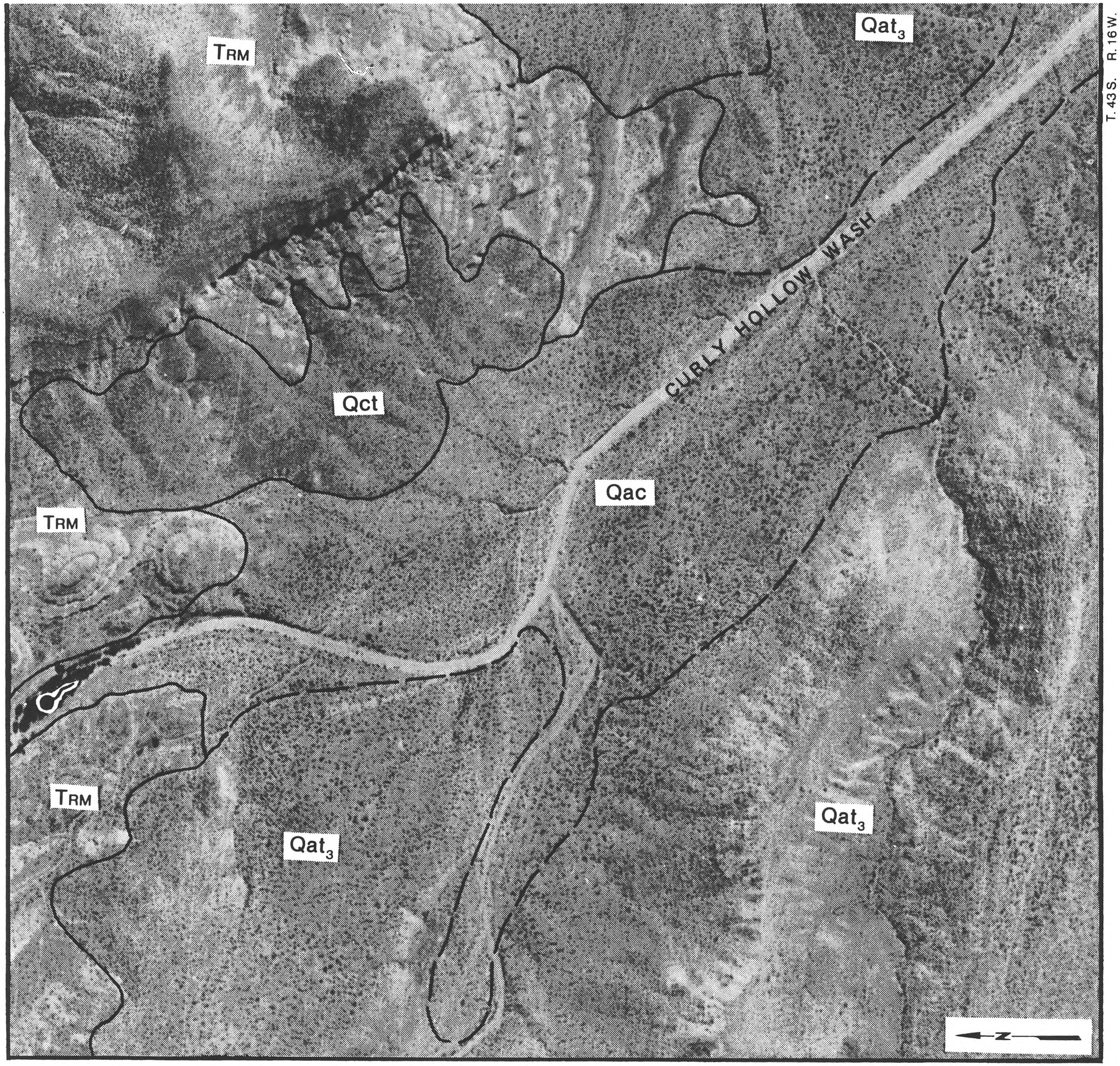
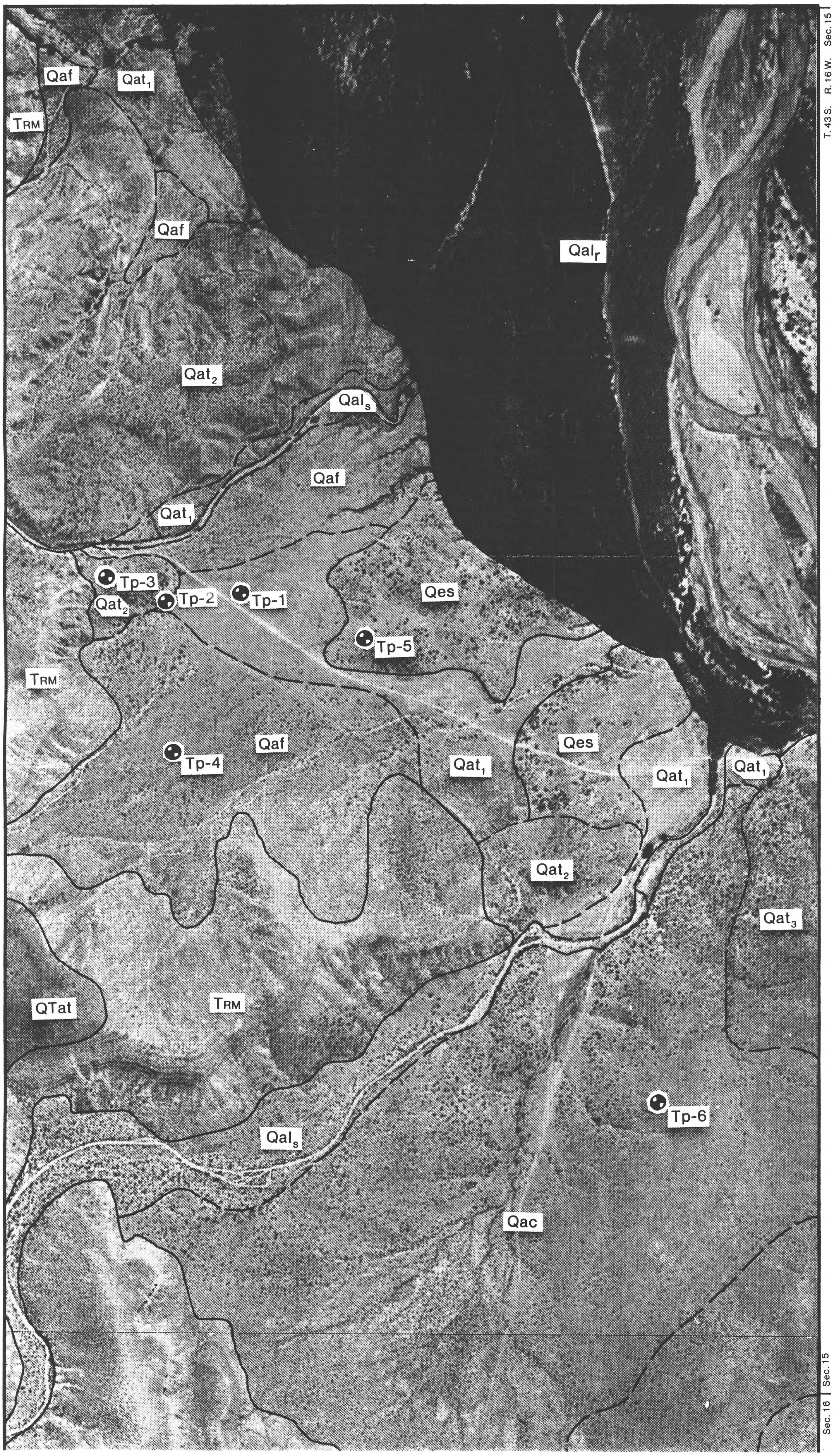


Figure 2. Geologic map of proposed waste-water treatment plant site southwest of St. George, Utah.



EXPLANATION

QUATERNARY

- Qal_r Virgin River alluvium
- Qal_s Intermittent stream alluvium
- Qaf Alluvial-fan deposits
- Qes Eolian deposits
- Qct Talus
- Qac Alluvium with a large colluvial (slopewash) component.
- Qat_1 Lower terrace deposits
- Qat_2 Intermediate terrace deposits
- Qat_3 Upper terrace deposits

QUATERNARY TERTIARY

- QTat Old alluvial gravel deposits

TRIASSIC

- TRM Moenkopi Formation, undifferentiated

Contact
Dashed where approximate

TP-4
Test pit location

Seep

400′

gypsum beds in the formation crop out on steep slopes, they commonly deform under the force of gravity and produce locally intense folding. No major through-going folds or faults in competent bedrock were identified at the site.

Between the cliffs and the flood plain of the Virgin River a series of alluvial deposits have formed from detrital material derived from the Moenkopi Formation (fig. 2). With the exception of an older gravel terrace (QTat) at the top of the cliff, the deposits are believed to be of Quaternary age (0 to 1.6 m.y. B.P.). The older gravel terrace probably dates from the late Tertiary (1.6 to 23.7 m.y. B.P.) or early Quaternary (Hamblin, in press) and gives evidence of active downcutting on the Virgin River. Within the Quaternary deposits at the base of the cliff, three levels (ages) of stream terraces have been identified. The lowest terrace (Qat_1) is closest to the Virgin River flood plain and, with the exception of the gullying at the flood-plain scarp and the incision of the ephemeral stream channels, is flat and undissected. The intermediate terrace (Qat_2) is older, more eroded, and characterized by irregular, rolling topography. The highest terrace (Qat_3) forms a narrow, east-west-trending ridge along the south edge of the property and an upland area at the west end of the site. Alluvial deposits (Qac) along Curly Hollow Wash and the middle unnamed wash may also be stream terraces, although a combination of colluvial slopewash and a thin layer of eolian material give them a relatively smooth surface and mask their true character. However, their elevation and general position relative to the other Quaternary deposits on site implies a probable correlation with the intermediate terrace deposits.

Alluvial fans (Qaf) are found at the mouths of several smaller drainages on site. Most are active, but one on the south side of the northernmost ephemeral stream appears to be cut off from its source by incision of the stream channel. Eolian deposits (Qes) are common across the site but in most areas are too thin and discontinuous to be mapped. Well-developed sand dunes do occur at two locations on lower terraces near the Virgin River flood plain (fig. 2). A talus slope (Qct) has developed at the base of a cliff near the west end of the site. Because of the friable nature of the Moenkopi Formation, the material comprising the slope is mostly sand-sized or finer. Stream alluvium (Qals) consisting of coarse sand with some gravel and considerable silt and clay is found along the ephemeral stream channels.

Depth to ground water at the site varies with elevation above the Virgin River. The water table can be expected within a few feet of the ground surface adjacent to the river, and the depth will increase to several tens or even hundreds of feet to the north and west. Except for the Virgin River flood plain and some low-lying terrace and alluvial-fan deposits in the extreme northeast corner of the site (fig. 2), a depth to ground water of at least 15 feet can be anticipated across the property. Shallow, perched ground water may develop locally along stream drainages and on alluvial fans during periods of heavy precipitation, but such conditions would be of short duration. A small ground-water seep, probably recharged by precipitation, is located in Curly Hollow Wash at the northern site boundary (fig. 2).

TEST PIT EXCAVATIONS AND MATERIAL DESCRIPTIONS

Six test pits were excavated to help characterize the unconsolidated geologic units at the site (fig. 2). Detailed soil logs are presented in the appendix, however, they should be considered only generally representative, because most of the geologic units are extensive and their composition may vary from place to place.

Test pit 1 was excavated in a lower terrace deposit (Qat_1). It encountered a poorly graded, fine, silty sand through its entire depth. The material reacted strongly to dilute hydrochloric acid but was only slightly cemented. Test pits 2 and 3 were in an intermediate terrace (Qat_2). Test pit 3 was on top of the terrace and test pit 2 was on the side at a lower elevation. Together, the two excavations exposed a thickness of about 15 feet of terrace material. Silty sand and silty sand with gravel predominated in test pit 3. Test pit 2 continued with interbedded silty sands and silty gravels until reaching a distinctive red-brown clayey sand horizon. All of the materials in test pit 2 were cemented with gypsum and caliche. Gypsum was also present in test pit 3, but to a lesser degree. Test pit 4 was in an alluvial fan (Qaf) and exposed silty sand and silty sand with gravel. The fan is aggrading, so little or no caliche or gypsum was encountered. The small amount of gravel present consisted chiefly of soft siltstone and sandstone. Test pit 5 was excavated in an area of sand dunes (Qes), but the eolian material proved to be only a few feet thick. It was comprised of poorly graded sand with silt and was a distinctive red color. Beneath the sand and extending to the bottom of the test pit was a horizon of silty gravel with sand that contained well-rounded, purple to dark-brown, quartzite cobbles. Similar cobbles are common at the ground surface on the intermediate terrace elsewhere on site, leading to the conclusion that the material beneath the sand dunes is correlative with the intermediate terrace. Test pit 6 is in an area of alluvial material (Qac) along the ephemeral wash that crosses the central portion of the site. Colluvial slopewash from nearby upper terrace deposits and a thin layer of eolian material mask much of the alluvium. A layer of dense white caliche was encountered in the test pit at a depth of 1.5 feet. The original soil in which the caliche developed could not be identifed, but the horizon did contain gravel to 3 inches in diameter. Below the caliche was a layer approximately 3 feet thick of silty gravel with sand, followed by a red-brown clayey sand/sandy clay horizon to the bottom of the test pit. The clayey sand/sandy clay unit was moderately cemented by gypsum. Because of the similarity in the stratigraphy exposed in test pits 2 and 6, it is felt that the Qac units along the central unnamed wash and Curly Hollow Wash probably correlate with the intermediate terrace deposits.

Test pits were not excavated in the Virgin River or intermittent stream alluvium (Qalr, Qals), the upper terrace deposits (Qat_2), talus (Qct), or the older gravel terrace (QTat). Those units were either in areas difficult to access with the backhoe or were thought unlikely to be involved in construction of the wastewater treatment plant.

ENGINEERING GEOLOGY

The following engineering geologic considerations are of importance to the proposed facility: soil conditions for foundations and waste disposal, flood hazard, erosion, slope stability, and earthquake hazard.

Soils

Site soils are generally coarse grained and, except where plugged by secondary caliche and gypsum, should have moderate to high permeabilty. The fine-grained clayey sands and sandy clays exposed near the bottoms of test pits 2 and 6 probably have moderate to low permeability. Water impounded in unlined lagoons or holding ponds can be expected to infiltrate relatively rapidly, and shallow perched ground-water conditions may develop in areas underlain by clayey sand or sandy clay. In areas selected for sludge disposal, surface drainage should be carefully controlled to prevent ponding and infiltration of water above the disposal beds. The coarse nature of the site soils would allow any leachate that developed to migrate to the water table.

The coarse-grained soils should possess satisfactory compaction and load-bearing characteristics for foundations, but the clayey soils may exhibit some shrink/swell potential. Gypsum is abundant in site soils and may impart unsatisfactory compaction characteristics to foundation materials, as well as have a tendency to dissolve when wetted. Gypsum may also react with certain types of cement, resulting in deterioration of exterior concrete surfaces.

Flood Hazard

The Virgin River and three large ephemeral streams cross the site (fig. 3). The river and its flood plain are subject to overbank flooding during the spring snowmelt or in response to prolonged precipitation at other times of the year. Zone A on figure 3 identifies areas susceptible to flooding along the Virgin River. During the summer months, intense localized thunderstorms are common in the St. George area. Heavy precipitation associated with these storms can result in flash floods along otherwise dry drainages. All three ephemeral streams on site show evidence of flow in the recent (one year) past. Areas subject to flash floods are designated as Zone B on figure 3.

Erosion

The two gullies in the lower terrace deposit at the scarp bordering the flood plain of the Virgin River show evidence of active headward erosion. Both gullies are several tens of feet long and 10 or more feet deep at their intersection with the scarp. Erosion can be expected to continue, resulting in an increase in both length and width of the gullies. The rate of erosion

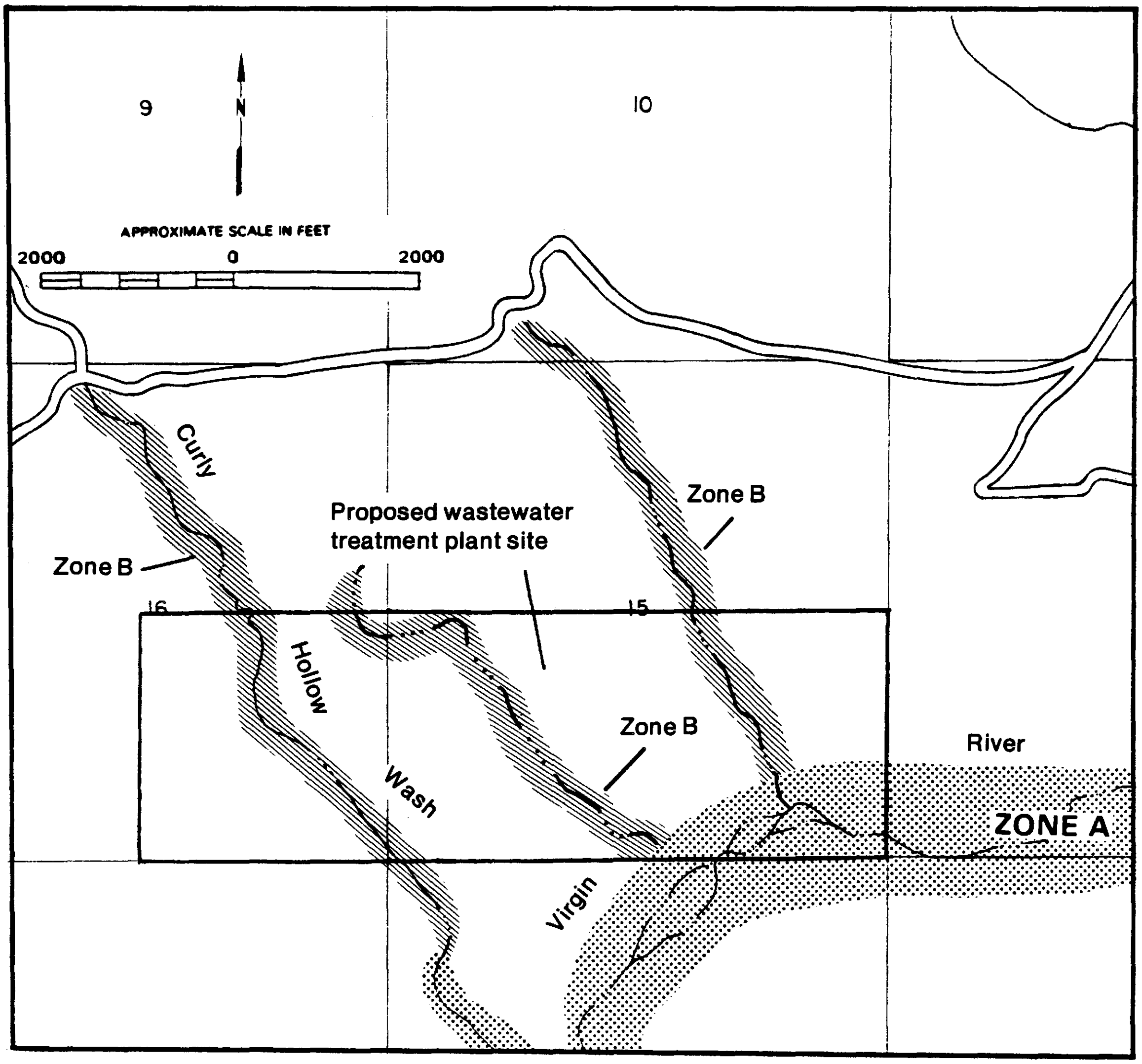


Figure 3.- Map of flood-prone areas in the vicinity of the proposed wastewater treatment plant site (modified from U.S. Dept. of Housing and Urban Development.).

Zone A	Areas susceptible to overbank flooding along the Virgin River.
Zone B	Areas susceptible to flash floods along ephemeral stream channels.

is not known, but the steepness and fresh appearance of the gully slopes indicate that the rate may be measured in feet per year. Structures placed near the gullies, particularly at their northern (headward) end, may be subject to undercutting.

Erosion also occurs along the banks of the ephemeral streams and on the flood plain of the Virgin River during flood events. Evidence does not indicate rates of activity as high as those along the gullies; consequently, the danger to facilities from erosion in these areas is not as great.

Slope Stability

Concerns with slope stability at the site are primarily related to rock-fall hazard at the base of the cliffs along the north and west property boundaries. The Moenkopi Formation in those areas consists chiefly of soft shale and sandstone. Those rock types weather rapidly and normally do not form large cohesive blocks. However, some cobble- and small boulder-size material was observed at the bottom of slopes, particularly in the vicinity of the talus deposit (fig. 2). The run-out distance was not great with most blocks clustered near the cliffs.

Elsewhere on the property, slopes are gentle to moderate and show no evidence of landslides. Small debris falls and topples likely occur along streambanks during flood events, but such failures are of only local extent and easily avoided.

Earthquake Hazard

The St. George area lies at the southern end of the Intermountain seismic belt, a zone of pronounced earthquake activity extending from northwestern Montana to southwestern Utah (Christenson and Deen, 1983). In southern Utah, the zone of seismicity generally follows the north-south-trending Hurricane fault which passes approximately 14 miles east of St. George. The Hurricane fault is suspected to have experienced surface rupture during Quaternary time. Faults that show evidence of movement during the Quaternary are considered active and capable of generating earthquakes. A second major structure suspected, but not proven, active during Quaternary time is the Grand Wash fault located about 6.5 miles west of the site (fig. 4). This fault forms the west edge of the St. George Basin and trends northward from the Grand Wash Cliffs in Arizona to Gunlock, Utah. A third fault in the site vicinity which does show evidence of Quaternary activity (Christenson and Deen, 1983) is the Washington fault. It extends from north of the town of Washington to south of the Utah-Arizona border (fig. 4). The northern segment of the fault has been shown to be active during Holocene time (Earth Science Associates, 1982). At its closest point, the Washington fault is about 7 miles east of the site.

The largest earthquakes to affect the St. George area in historic time occurred near the turn of the century with one estimated Richter magnitude 6.3 and two estimated magnitude 5.0 events (Williams and Trapper,1953). The maximum recorded modified Mercalli intensity (Appendix B) was VIII at St. George for the magnitude 6.3 earthquake which was located about 25 miles north of the site. Surface rupture has not been associated with historic earthquakes in the St. George area, but total offsets on portions of the Hurricane, Grand Wash, and Washington faults, all of which have been active over a period of several millions of years, are measured in thousands of feet.

Several studies have recently been completed in which maximum expected earthquake magnitudes in southwestern Utah have been calculated on the basis of geologic evidence. Thenhaus and Wentworth (1982) calculated magnitudes of

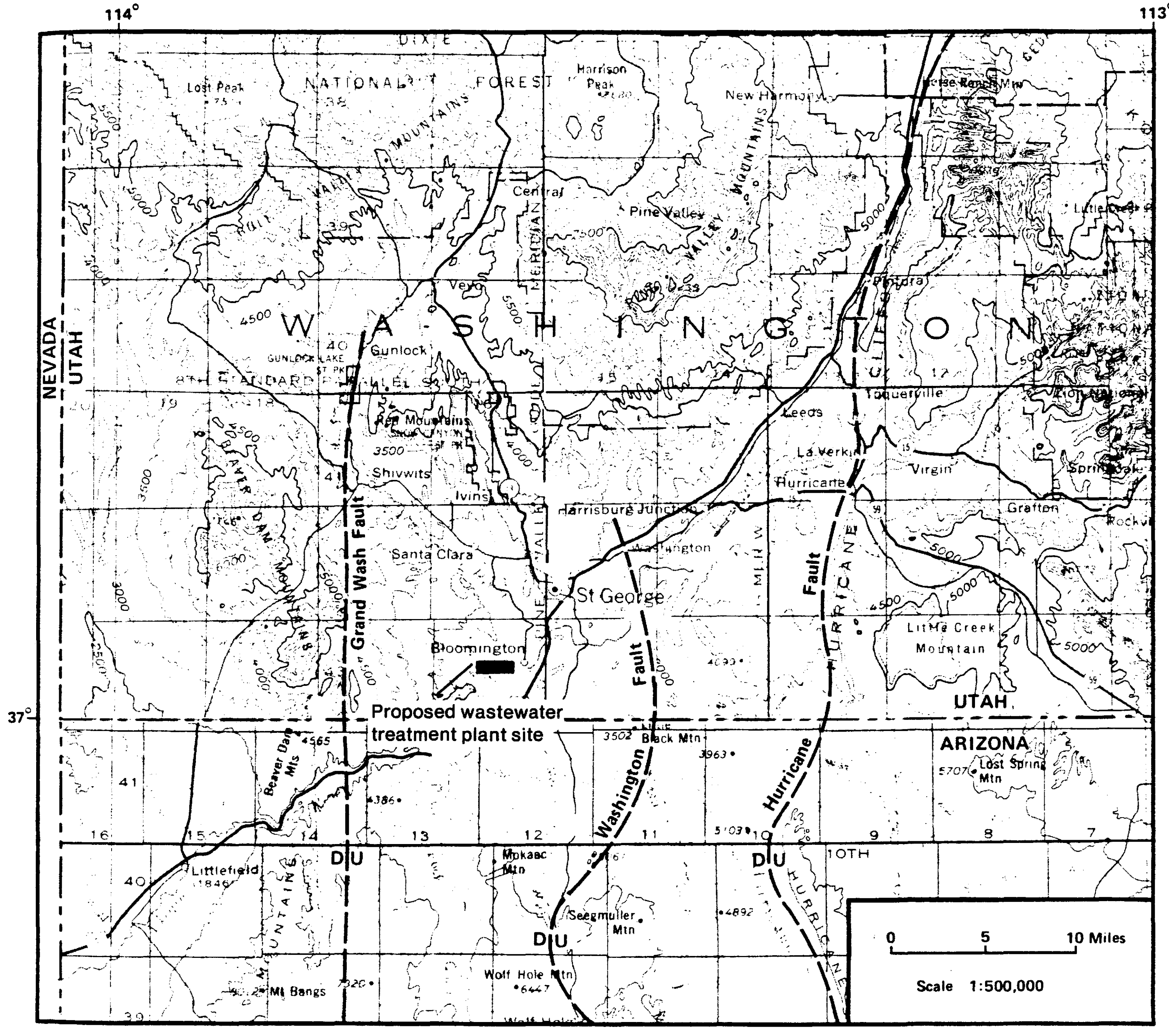


Figure 4.- Map showing the approximate locations of main traces of Quaternary and suspected Quaternary faults in the vicinity of the proposed wastewater treatment plant site.

7.5 for eastern Washington County (Hurricane fault area) to less than 7.5 for western Washington County (St. George area). Earth Science Associates (1982) determined that the maximum credible earthquake that can be generated by either the Grand Wash or Hurricane faults is magnitude 7.5 and that of the Washington fault is 7.0. These large events are thought to have recurrence intervals of 1000 to 10,000 years. Earth Science Associates (1982) concluded that earthquakes of magnitude 6.0 have a recurrence interval of 200-300 years for all three faults. In general, earthquakes of magnitude 7.0 or larger can produce maximum modified Mercalli intensities of IX or greater, whereas magnitude 6.0 events produce intensities of VII-VIII (Christenson, 1984).

Due to the level of seismicity and presence of Quaternary and suspected Quaternary faults in the site vicinity, the property is included within seismic zone 2 of the Uniform Building Code (UBC) and the Utah Seismic Safety Advisory Council (USSAC) statewide seismic zonations. These are zones of moderate earthquake risk, with expected modified Mercalli intensities of VII. However, the UBC and USSAC seismic zones are based on predicted peak ground accelerations with a 90 percent probability of not being exceeded in 50 years (Algermissen and others, 1983). This implies that earthquakes generating these peak ground accelerations will have a 10 percent probability of occurring every 50 years, or a recurrence interval of about 500 years. Therefore, the UBC and USSAC zonations do not reflect maximum events (probable magnitudes 7.0-7.5), but events with a greater probability of occurrence (probable magnitude 6.0).

Because Quaternary faults are not present at the site itself, the principle concern at the property is with ground shaking. Shaking would likely result in rockfall along the cliffs on site during a moderate to large earthquake (Richter magnitude 6.0 or larger), and liquefaction may occur in the saturated flood-plain sediments along the Virgin River.

CONCLUSIONS AND RECOMMENDATIONS

From a geologic standpoint, a wastewater treatment plant can be successfully located within the approximately 480 acres that comprise the proposed site. However, geologic constraints to development do exist and should be considered in the location, planning, and design of the facility. The following recommendations concerning those constraints are general in nature since the exact location of the treatment plant on the site has not been determined. Nevertheless, the recommendations are site-specific, and if the property boundaries change, newly incorporated areas should be carefully investigated.

- The single greatest geologic hazard affecting the site is from flooding. Unless flood-control measures are taken, treatment plant facilities should avoid the flood plain of the Virgin River (Zone A, fig. 3) and the channels of the three ephemeral drainages crossing the site (Zone B, fig. 3). A setback distance of at least 100 feet from the edges of the ephemeral streams is recommended for all treatment plant facilities to avoid both flooding and erosion hazard.

- The UGMS accepts the UBC zone 2 designation and accompanying design specifications as appropriate for most construction in Washington County. However, for critical facilities with relatively long design lives (such as a regional wastewater treatment plant), it is recommended that the more stringent construction specifications for seismic zone 3 be followed to provide an added factor of safety.

- Areas of active erosion should be avoided, and control measures implemented to prevent further gullying. Setback distances of 100 feet normal to the gully walls and 200 feet from the gully head are recommended if control measures are not taken. A 50-foot setback from both the gully walls and head is adequate if erosion is controlled.

- Rock fall is a hazard at the base of the cliffs and steep slopes at the north and west ends of the site. Facilities constructed within 200 feet of those areas should incorporate rock-fall protection measures (berms, angled cuts, wire-mesh fences).

- In general, site soils appear suitable for construction. However, an engineering soil investigation should be conducted for foundation design purposes. The presence of gypsum in the soil should be carefully evaluated, both with regard to its affect on foundation materials and any deleterious effect it may have on concrete.

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APPENDICES

Test Pit Logs
Regional Wastewater Treatment Plant
Washington County, Utah
S1/2 sec. 15 and SE1/4 sec. 16, T. 43 S., R. 16 W.

Test Pit 1 (Qat_1)

0.0' - 11.0'	Silty sand (SM); yellow-brown, medium dense, nonplastic, dry; poorly graded, fine, quartz sand with 10 to 15 percent lithic fragments, strong reaction to HCL acid, slightly cemented.

Test Pit 2 (Qat_2)

0.0' - 1.9'	Silty sand with gravel (SM); mottled red-brown and white, medium dense, slightly plastic, dry; abundant nodules and stringers of caliche and gypsum, approximately 30 percent gravel to 2-inch diameter.
1.9' - 4.0'	Silty gravel with sand (GM); red-brown, medium dense, slightly plastic, dry; gravel to 3-inch diameter, approximately 30 percent sand and 20 percent silt, nodules and coatings of gypsum.
4.0' - 5.8'	Silty sand with gravel (SM); brown; medium dense, nonplastic, dry; coarse, lithic sand with gravel clasts to 2-inch diameter of quartzite and siltstone.
5.8' - 8.3'	Clayey sand (SC); red-brown, medium dense, low to moderate plasticity, dry; medium quartz sand with approximately 20 percent clay, moderately indurated.

Test Pit 3 (Qat_2)

0.0' - 0.9'	Silty sand (SM); yellow-brown, low density, low plasticity, dry; approximately 30 percent silt.
0.9' - 2.2'	Silty sand with gravel (SM); yellow-brown, medium dense, slightly plastic, dry; approximately 25 percent gravel to 2-inch diameter.
2.2' - 6.5'	Silty sand with gravel (SM); red-brown, medium dense, nonplastic, dry; moderately indurated by gypsum, approxiamtely 35 percent gravel to 1-inch diameter.

Test Pit 4 (Qaf)

0.0' - 2.7'	Silty sand with gravel (SM); yellow-brown, medium dense, nonplastic, dry; poorly graded, fine quartz sand with approximately 20 percent gravel to 3-inch diameter.
2.7' - 3.3'	Silty sand (SM); red-brown, medium dense, nonplastic, dry; poorly graded quartz and with approximately 20 percent silt.
3.3' - 8.0'	Silty sand with gravel (SM); yellow brown, medium dense, nonplastic, dry; well-graded quartz sand with approximately 15 percent gravel to 2-inch diameter.

Test Pit 5 (Qes)

0.0' - 2.5'	Poorly graded sand with silt (SP-SM); red, low to medium density, nonplastic, dry; fine, quartz sand with approximately 10 percent silt, caliche development in lower 0.5 feet.
2.5' - 10.0'	Silty gravel with sand (GM); red-brown, medium dense, nonplastic, dry; trace of cobbles to 6-inch diameter.

Test Pit 6 (Qac)

0.0' - 1.5'	Poorly graded sand (SP); red-brown, low to medium dense, nonplastic, dry; eolian deposited, fine, quartz sand.
1.5' - 2.9'	Caliche; white, high density, soil profile plugged, some gravel to 3-inch diameter.
2.9' - 6.3'	Silty gravel with sand (GM); red-brown, medium dense, nonplastic, dry; moderately to strongly indurated with caliche and gypsum.
6.3' - 10.8'	Clayey sand/sandy lean clay (SC/CL); red-brown, dense/stiff, medium plasticity, dry; moderately indurated by gypsum.

Soil logs prepared in accordance with ASTM standard D 2488-84 Description and Identification of Soils (Visual-Manual Procedure).

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Source: Earthquake Information Bulletin; 6 (5), 1974, p. 28.