Engineering Geology

of the

La Grande Area

Union County, Oregon

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ENGINEERING GEOLOGY OF THE LA GRANDE AREA UNION COUNTY, OREGON

By

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In cooperation with
the governing bodies of La Grande
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ENGINEERING GEOLOGY OF THE LA GRANDE AREA UNION COUNTY, OREGON

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INTRODUCTION

Vast sums of money are lost throughout the country each year because of undetected ground conditions prior to construction of buildings, primarily houses. Today large construction projects are generally preceded by extensive investigations of foundation soils, involving engineering and geologic studies. But, unfortunately, the small structures, such as houses, are usually built without the benefit of such investigations.

La Grande is expanding and this growth is extending into areas having various geologic and soil conditions that pose problems for construction. An understanding of these problems is basic to satisfactory land use.

Minor landslide movement is a constant problem in the area within and adjacent to the west and south part of the city. Slope movement has affected water and sewer lines, has dislocated sidewalks and curbs, and has caused cracks and dislocations in basement walls and floors. The new hospital, which began to suffer damage soon after construction, has required extensive slope treatment.

Although landslides have not been catastrophic in the history of La Grande; geologic evidence indicates that prehistoric landslides were common. The stability of these old landslide masses is questionable. In other parts of the La Grande area there are slopes which have experienced no detectable landslide movement, but which are potentially vulnerable. Use of such areas for building purposes will require preliminary geologic and engineering studies followed by appropriate construction and development practices.

Purpose and scope of report

This investigation was undertaken at the request of Union County and the city of La Grande to provide information on the geologic conditions that are specifically related to residential areas and possible new development sites in and near La Grande.

The report describes the major problem areas, including those with unstable slopes, high groundwater levels, and poor foundation soils. It also suggests certain types of areas suitable for development. The report provides information that should be helpful in locating rock quarries and gravel pits, and it presents information on ground water availability.

Accompanying the report is a geologic map that shows the location of the various geologic units, the geologic structures, the landslide areas, and the depth to the unconfined water table.

Acknowledgments

We wish to acknowledge those who provided services or otherwise gave of their time to assist in the preparation of this report. Financial assistance was provided by Union County. We are grateful to Judge Earle C. Misener for his support and confidence. Mr. Murray D. Snyder, La Grande City Manager, furnished data and gave direction to the report, helping to assure its usefulness. We wish to thank Mr. Grant Millering, President of the City Commission, for his support of the project; Ronald Gross for maps of the city; Greg T. Blackman for his assistance in transportation and guide service into the remote areas; Kenneth Koidahl for giving of his knowledge of the problem areas; Paul H. Calverley and Grant Lindsay, Soil Conservation Service, for use of the aerial photographs of the area; Charles E. Wilson, Manager of General Telephone, for his active interest in the study; and Gary K. Eisler of The Observer for photographs used in this report. We also appreciate the helpful suggestions of Norman Wagner, Oregon Department of Geology and Mineral Industries.

Method of investigation

Four days were spent in field mapping an area of about 70 square miles. The area included the west end of the valley from Ladd Canyon north past Island City to about 4 miles west of La Grande in mountainous terrain. The area was inspected on foot, by automobile, and from a light aircraft. Engineering reports and published geologic literature* were also used in the study. U. S. Geological Survey topographic quadrangle maps published on a scale of 1:24,000 were employed in the field as a base for mapping and publishing, and aerial photographs were helpful in mapping geologic structures.

GENERAL DESCRIPTION OF AREA

La Grande, a city of about 10,000 people, is located at the western edge of the Grande Ronde Valley, in the central part of Union County, in northeastern Oregon. La Grande is 52 miles east of Pendleton on U. S. Highway 30 and 44 miles north of Baker, Oregon.

The area studied encompasses the western part (20 sq. miles) of the Grande Ronde Valley and the adjacent mountains to the west (50 sq. miles).

The major stream, the Grande Ronde River, runs eastward from the Blue Mountains, through La Grande and Island City, then northward to Indian Valley. The Grande Ronde Valley is relatively flat and featureless, and slopes eastward at about 20 feet per mile; in the mapped area the elevation of the valley floor ranges from 2700 to 2850 feet above sea level. West of La Grande the mountains rise abruptly from the valley floor to an average

*Geology and ground-water resources of the upper Grande Ronde River basin, Union County, Oregon, by E. R. Hampton and S. G. Brown, U. S. Geological Survey Water Supply Paper No. 1597, 1964.

elevation of about 4,000 feet, with Mahogany Mountain at 4,650 feet. Numerous fault-trace stream valleys about 500 feet deep trend northwest-southeast through the mountainous areas bordering the Grande Ronde Valley.

The temperature for the last 65 years has ranged from a low of -20° F to a high of 108° F. Because of a marine air flow over the region most of the time, extremes in temperature are of short duration.

Precipitation ranges from 13 inches per year at Union to 20 inches at La Grande, and 35 inches at Meecham. Precipitation occurs mainly from October through June with about one third in the form of snow.

SUMMARY OF THE GEOLOGY

The Grande Ronde Valley is a huge down-faulted block, or graben, of some 250 square miles. It formed as a series of parallel faults which moved the valley downward relative to the surrounding mountains. The total fault displacement is about 3,000 feet, but the movement on any single fault is much less. The total amount of faulting is the summation of movement on a number of parallel faults. The major part of the movement occurred during the Ice Age about 100,000 years ago.

Bedrock units exposed in the surrounding mountains are basaltic lava flows alternating in places with layers of volcanic ash. In the valley area the same bedrock units are deeply buried beneath stream and lake-bed sediments which were deposited on the valley floor after the graben formed. These sediments are composed of clay, sand, silt, and gravel. The gravels are located near the mouths of streams entering the valley from the mountains and are covered with finer sediments which become progressively thicker toward the center of the valley. A more detailed description of the geologic units follows.

GEOLOGIC UNITS

Columbia River Basalt

The oldest rocks within the mapped area are lava flows and interbedded tuffs of middle Miocene age. These rocks are part of the widespread geologic unit called the Columbia River Group and referred to in this paper as the Columbia River Basalt. In the area surrounding the valley, the formation occurs as uplifted fault blocks. In the valley area the basalt has been downfaulted from 550 to 996 feet below the valley floor. Deep-well information indicates that the total displacement in the center of the valley is in the order of 3,000 feet.

The basaltic lava is dark gray to black and generally is somewhat flinty in appearance on a freshly broken surface. Weathered surfaces are reddish brown. Most of the individual lava flows are 10 to 50 feet thick and, according to Hampton and Brown (1964) typically have a chilled fracture zone at the base, a thick dense, massive middle zone and an upper scoriacious zone. In places, the lava sequence contains thick interbeds of volcanic ash or tuff. Tuff beds in the area west of La Grande have been shown to a limited extent on the map, but detailed mapping of all of the tuff beds is beyond the scope of this investigation. The mere fact that they are present is an important consideration, however, because landslides occur in this type of material.

Recent alluvium

Recent alluvium occurs in the stream bed and adjacent to the streams along the modern floodplain. In the channel and river bars the alluvium consists of gravel and sand. Outside of the channel the alluvium is mainly a thin layer of flood-deposited sand, silt, and clay deposited over the fan gravel.

Old landslides

Landslides are partly responsible for the topographic development along the margins of the Grande Ronde Valley. When the valley was formed by down-faulting, the resulting scarp walls, weakened by exposure to weathering and by addition of moisture, were too steep to stand. Thus landslides occurred along the margins of the valley. A number of the old landslides are easily recognizable; others have been so modified that the landslide features have been mostly obliterated. The characteristics of old landslide areas are a hummucky topography, disrupted surface and subsurface drainage, and unstable or nearly unstable slope conditions. Characteristic of the more recent landslides are tilted trees and bent tree trunks.

In the La Grande area, landslides are of two types: 1) those that have occurred in the steep hillsides bordering the valley in the units of the Columbia River Basalt, and 2) those that have occurred in the colluvium. The landslide areas are shown on the geologic map.

A major landslide area is present in the slopes bordering the city on the west and on the south in portions of sections 6, 7, 17, 18, and 19, T. 3 S., R. 38 E. Its terminus can be recognized by a break in the topography at the contact between a flat surface of the terrace gravels and the irregular surface of the landslide mass (Figure 2). This landslide area actually contains two entirely different landslides--one in the Columbia River Basalt and the other in the colluvium.

Another landslide area immediately north of the city in sec. 30, T. 2 S., R. 38 E., is entirely in Columbia River Basalt.

Landslides in Columbia River Basalt: The prime example of this type of landslide in the La Grande area is in the vicinity of the old reservoir south of the city shown in the photograph, figure 3. The slide originated as a mudflow and is composed of basalt and tuff. The tuff is weathered in part to bentonitic clay, which is particularly susceptible to shrink and swell caused by variations in moisture.

The topography of this slide is highly irregular, with ridges and swales; one large swale contains a shallow lake about 1,000 feet wide and 2,000 feet long. Two circular water reservoirs built by the city of La Grande some 40 years ago are located in this landslide area.

A similar but smaller mudflow type landslide is present in the landslide area north of La Grande (sec. 30, T. 2 S., R. 38 E.) This was apparently a faster moving, more liquid flow which terminated in a fanshaped deposit, shown in the photograph, Figure 4.

Landslide in colluvium: This type of landslide borders the city on the west and in the most northerly part of the landslide area adjacent to the city of La Grande. The landslide is within the colluvial deposits composed of angular basalt fragments mixed with soil. The

Figure 1. Road cut in colluvium on U. S. Highway 30 at the north edge of La Grande. Note the angular rock fragments up to 2 feet across scattered in a finer granular and clayey matrix. This composition is typical of the landslide colluvium west of the city.

Figure 2. View looking west from U. S. Highway 30 at the west edge of La Grande city limits. Landslide colluvium at base of fault scarp overrides the flat surface of the gravel terrace.

Recent alluvium

Recent alluvium occurs in the stream bed and adjacent to the streams along the modern floodplain. In the channel and river bars the alluvium consists of gravel and sand. Outside of the channel the alluvium is mainly a thin layer of flood-deposited sand, silt, and clay deposited over the fan gravel.

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The topography of this slide is highly irregular, with ridges and swales; one large swale contains a shallow lake about 1,000 feet wide and 2,000 feet long. Two circular water reservoirs built by the city of La Grande some 40 years ago are located in this landslide area.

A similar but smaller mudflow type landslide is present in the landslide area north of La Grande (sec. 30, T. 2 S., R. 38 E.) This was apparently a faster moving, more liquid flow which terminated in a fanshaped deposit, shown in the photograph, Figure 4.

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Figure 3. View of southwest part of La Grande and the "older" reservoirs. Note the contrast between the hummocky landslide topography in the reservoir area and the flat terrace-gravel surface in the foreground. (Photo by Gary Eisler, The Observer)

topography consists of low humps and swales. Where streets and houses cover the slide, the topography has been greatly modified.

The photograph in Figure 2 shows typical topography of the colluvium landslide. This slide probably developed slowly as the result of excess water concentration at the foot of the slope. Minor movement is still occurring in local areas today.

The location and surface distribution of the geologic units together with the landslide areas are shown on the geologic map. A geologic cross section indicates the thickness and distribution of the units in the subsurface.

AREAS OF GEOLOGIC HAZARDS

There are three general types of areas in and around La Grande that could present serious problems for construction. They are: 1) unstable basalt slopes, 2) areas of unstable colluvium, and 3) valley areas with a high water table. It is possible that certain types of development can proceed satisfactorily in these areas, but the inherent geologic and engineering characteristics that create the problems must first be recognized and considered in the development plans.

Basalt slopes

The steep slopes above the valley sides are composed primarily of basaltic lava flows but some areas have interbeds of tuff or volcanic ash. Just west of La Grande alternating tuff beds and lavas are exposed. The slope stands steeply in places but it has failed in others, resulting in large landslides. In most cases the place of failure in the slope can be traced to failure of an underlying layer of tuff. It must be concluded, therefore, that the tuff beds greatly reduce the slope stability and that areas of steep slope and thick tuff beds should be considered as potential slide areas. If these areas are developed, cuts and fills made during road construction or lot leveling and increased moisture, as the result of disruption of drainage, will make the areas even moré unsafe. Roadside water, water from roof drains, dry wells, and septic tanks turned loose on a hillside, and heavy watering of lawns during the summer months will all combine to maintain a high water table, the major cause of slope movement.

Geologic evidence indicates that some of the prehistoric landslides related to the tuff interbeds in the basalt occurred as rapidly moving mudflows. If this type of landslide were to occur today, it would likely obliterate structures on its surface or in its path. Many lives could be lost, even on the valley floor where a mudflow would finally terminate. Prehistoric landslides of this type have occurred in the area of the old reservoirs south of La Grande and also north of La Grande at the west side of Owsley Canyon, Figures 3 and 4. The surface of many old mudflows will continue to shift for years and, therefore, should be avoided for development if possible.

Colluvium slopes

The colluvium is hazardous from a stability standpoint. It is relatively porous and is easily infiltrated by runoff from the higher slopes. The contained water issues from numerous springs on the slopes of the colluvium adjacent to the valley floor. Because of wetness, the

Figure 4. Mudflow type of landslide north of La Grande and west of Owsley Canyon. The irregular surface of the mass is typical of landslide topography. (Photo by Gary Eisler, The Observer)

colluvial slopes are unstable, and construction and development in these areas frequently sustain damage from slope movement. Movement of the slopes may not be observable until some structures are built. The usual extent of the problem is cracking of basement walls and floors, uneven floors, cracking of sidewalks, uneven settlement, and small displacement of curbs. Isolated cases can be much more severe. The breaking of sewer and water lines can saturate the soil and add instability to the slopes.

Not all of the area of colluvial soils west and south of La Grande adjacent to the steep mountain slopes has been completely developed. As housing density increases, however, the problems of slope stability in these deposits will most likely increase. Persons intending to build in this area should be made aware of the problems. Design and construction should reflect knowledge of the conditions present.

Valley areas with high water table

Unconfined groundwater is a potential hazard in the Grande Ronde Valley. Unconfined groundwater is that water which is under atmospheric pressure and is free to rise and fall in response to recharge and withdrawal from the water body. Confined groundwater, on the other hand, is water under pressure beneath the surface of the ground which cannot migrate upward because of an impermeable stratum above it. Water in a well drilled into this zone of confined water will rise, and if the pressure is great enough, it will rise to the top of the well and flow out on the surface of the ground.

It is important to recognize that a near-surface, unconfined water table is a hazard to construction. In certain areas the water table will stand within several feet of the surface of the ground. Excavations below this level will quickly fill with water. Houses cannot have basements in these areas unless a sump pump is installed. Buried fuel and storage tanks, if less than full, can float upwards and break through to the surface. Basement floors and swimming pools can be broken by water pressure.

In the Grande Ronde Valley near Island City, the water table would normally stand at or above the surface of the ground during winter except for the drainage ditches in the area. Nevertheless, the water table will be near the ground surface during periods when the ditches run full or flood following excessive rainfall or snow melt. Areas where the water table is less than 10 feet from the ground surface are considered hazardous and a higher water table would cause greater problems.

AREAS OF STABLE SOIL AND BEDROCK

The areas that will present the fewest construction problems in future development of La Grande and its environs are those with stable soil and bedrock conditions, i. e., those having good foundation characteristics and not subject to landsliding. These locations are: 1) areas underlain by terrace gravels; 2) basalt surfaces with gentle slopes; and 3) valley areas where the water table remains at least 10 or 12 feet below ground surface at all times. The three areas are discussed in more detail as follows:

1) Terrace gravels occur in a strip half a mile wide and about $1\frac{1}{2}$ miles long with about a third of the area lying in the southeast part of the city and the remaining two thirds along the foothills southeast of the city limits. The unit is also present along the north edge of the valley 1 to 2 miles north of La Grande. Areas underlain by terrace gravel are shown on the geologic map.

Figure 5. View of basalt-capped hill north of Mt. Glenn Road about 1 mile north of La Grande. Basalt surface is suitable for heavy foundation loads, but would require blasting. (Photo by Gary Eisler, The Observer)

2) The valley area considered satisfactory for land development is shown on the geologic map as having perched water at 10 or more feet below the ground surface. This area lies generally west of a line running north-south through Island City and outside of a line surrounding Island City. Light loads in this area would present normal foundation problems, but moderate to heavy foundation loads will require special soils engineering and foundation design.

3) Flat or gently sloping basalt surfaces, such as at Morgan Lake or in section 29 one mile north of La Grande, would be ideal for heavy foundation loads. A photograph of the hill north of La Grande appears in Figure 5. Excavation in these areas for utilities, basements, and roadways would require extensive blasting. On a single-lot or small-tract basis, blasting would cause problems and cost would be excessive. Sewers would be required since septic tank drainage would either contaminate the ground water or the effluent would possibly exit at the surface downslope from the developed area. Topsoil would have to be imported for lawns and gardens.

ENGINEERING STUDY REQUIREMENTS

Engineering studies for safe land development should consider the following points:

1. The natural drainage, amount of normal runoff, and amount of possible heavy runoff.
2. Alterations that will be made in natural drainage pattern and the design necessary to handle runoff.
3. Installation of storm sewers and final disposition of the water.
4. The effect removal and addition of vegetation will have on slope stability.
5. Height of groundwater table during the wettest months.
6. The magnitude of proposed cuts and fills, methods and degree of compaction required for soil types involved, and the maximum allowable safe height and slope angle of cuts and fills.
7. The feasibility of using septic tanks and the area required for drainfields.
8. Density of allowable housing.
9. Sources of water, whether domestic or municipal.

GROUNDWATER AVAILABILITY

Groundwater in the upper Grande Ronde Valley lies at shallow depth beneath the valley floor. In general it lies at or slightly above the level of the major drainage (Hampton and Brown, 1964). The water table fluctuates seasonally and is highest during the winter and early spring and is lowest in late summer and fall.

The valley floor in the mapped area is underlain for the most part by the alluvial fan gravels deposited from the Grande Ronde and Ladd Canyons. Well yields from this gravel average about 22 gpm but as much as 400 gpm is reported. Wells in the unit are shallow and the water is unconfined.

Beneath the fan gravels and in areas outside of the fan gravels the valley fill is a lacustrine (lakebed) deposit composed of medium-to-fine-grained sand mixed with silt and clay. The gravel fans interfinger with the lakebed deposits along the outer extremities of the fans. Water yield from the lakebed sediments is variable depending upon the presence of coarser, more permeable beds and lenses. Well yield ranges from 10 to 45 gpm.

The colluvium is not a consistent producer of groundwater. Because it is poorly stratified and contains blocks of lava mixed with sand, clay, and volcanic ash, its permeability varies considerably. Although some water is present, it emerges from springs along the flanks of the hills. Well yields average about 9 gpm and range from zero to 20 gpm.

The Columbia River Basalt gives the highest yield of any aquifer in the region, and in locations favorable for water impoundment in the rock, the unit produces abundant groundwater. Water impoundment is limited to brecciated inter-flow zones and is controlled to a considerable extent by faulting and folding. In the Grande Ronde Valley, where the basalt was faulted downward as much as 3,000 feet and buried under several hundred feet of lake-bed and valley fill, groundwater is under high artesian pressure, and production ranges as high as 3,500 gpm.

MATERIAL RESOURCES

Gravel deposits

The principal source of gravel aggregate for the region for the future is the fan gravel unit. In most areas the fan gravel has a soil cover ranging from a few feet to about 10 feet, indicating that the gravels could be developed with little overburden removal. If areas away from the Grande Ronde River channel were to be developed as suitable aggregate deposits, the river bed and channel could be utilized more fully for fish spawning and could be landscaped for recreation and aesthetic purposes.

Within the map area, the largest gravel fan is that deposited by the ancient Grande Ronde River. The fan begins at the river's entrance to the valley and spreads out past Island City. Another gravel fan covers about 2 square miles at the mouth of Ladd Canyon. This latter gravel was apparently used for road aggregate from time to time by the county and state, as it contains several presently abandoned pits.

The Grande Ronde River has eroded its channel across the old gravel fan, which now forms the bottom and banks of the river. The fan gravels appear to be the main source of gravels being extracted along with the small amount brought in annually by the river. Channel gravels in the bed of the river and adjacent fan gravels have been mined out from Island City westward for about a mile. Further upstream the gravel deposits occur only as small bars and stream-bed gravels.

Erosion of the Grande Ronde fan in recent geologic times has left gravel terraces northwest of Island City and another paralleling the foothills south of La Grande for a distance of $1\frac{1}{2}$ miles. The terrace and floodplain northwest of Island City are essentially the same as those being removed in and adjacent to the channel of the Grande Ronde River and can be considered a possible future gravel resource.

Although the high terrace gravels south of La Grande are used for selected borrow material for freeway construction, they are not considered a resource for other uses for the following reasons:

1. Part of the deposit in and near the city limits is covered with housing or other uses incompatible with gravel production.
2. Outside of the residential area the deposit is narrow and lies against the steep hillside.

3. The available quantities are not large enough to supply the market.
4. Much of the deposit contains an excess of clayey volcanic ash.

Rock quarries

The upland areas surrounding the valley are composed mainly of basaltic lava with some tuffaceous interbeds. Basalt, although abundant in this area, is extremely variable in value as a quarry rock. These differences are related to distance from the market, the quality of existing haul roads, the topography of the area, the texture, joint pattern, and degree of weathering of the rock, the thickness of the rock layer, and the amount of overburden.

The quarry should be located within 15 miles of its market and have access to a good haul road. The building of roads in rough topography is difficult and expensive. Steep haul roads increase the cost; therefore, the grade of the haul road is an important factor to consider. The rock should be relatively free of vesicles (bubble holes) and the joint pattern should be close so that the rock will break in small pieces that can be easily handled and crushed after blasting. Weathering in seams and joints as well as on the exposed surface produces waste which increases the cost and lowers the quality. The rock face should be high enough for at least one major lift. If it is higher than this, benching will be required. In very steep areas of high relief, the overburden may become too thick to be removed economically .

Figure 6. Quarry in Columbia River Basalt adjacent to U. S. Highway 30 just north of La Grande. The basalt makes excellent aggregate.

Figure 7. View of borrow pit excavation north of La Grande. Basalt and tuff from pit is used for freeway construction. Smoke in upper center of picture identifies landfill disposal site. Basalt quarry at left edge of picture is on Haywire Canyon. Note landslide topography in upper right corner of picture. (Photo by Gary Eisler, The Observer)

It should be understood that quarry sites, even in an area of basalt rock, may not be easy to develop. By applying the criteria previously described it is possible to reduce the size of the areas to prospect and then to eliminate the less desirable portions by inspection. Drilling and test pitting may be required as a final step to evaluate overburden and rock quality and quantity.

Figure 6 is a photograph of the basalt quarry on Haywire Canyon north of La Grande. This quarry is supplying good-quality aggregate for the freeway by-pass.

Borrow material

Tuff beds with minor amounts of basalt are currently being excavated from the hillside north of the city for use as embankment material for the freeway (see Figure 7). The steep initial face of the excavation resulted in cracking of the upper slope, indicating the sensitive relationship of the slope angle to the slope stability.

SUMMARY AND CONCLUSIONS

This report describes the various geologic units in the La Grande area of Union County, Oregon, and the accompanying geologic map shows their distribution. The report explains the performance of each of the units in relation to various types of development, and makes special reference to areas of geologic hazard that might present serious problems for construction. With the knowledge that certain problems are inherent in the ground, appropriate engineering methods can sometimes be employed that will overcome or, at least, reduce these difficulties.

Areas of geologic hazard are outlined on the geologic map and described in some detail in the report. These areas are: 1) valley areas where the water table rises to less than 10 feet from the surface of the ground; 2) colluvium and old landslides along the margin of the valley that either are now moving slowly and intermittently or can fail in the future under the pressure of development; and 3) the steep slopes composed of basalt and interbedded tuff which perform poorly for septic tank drainage and which could develop into landslides.

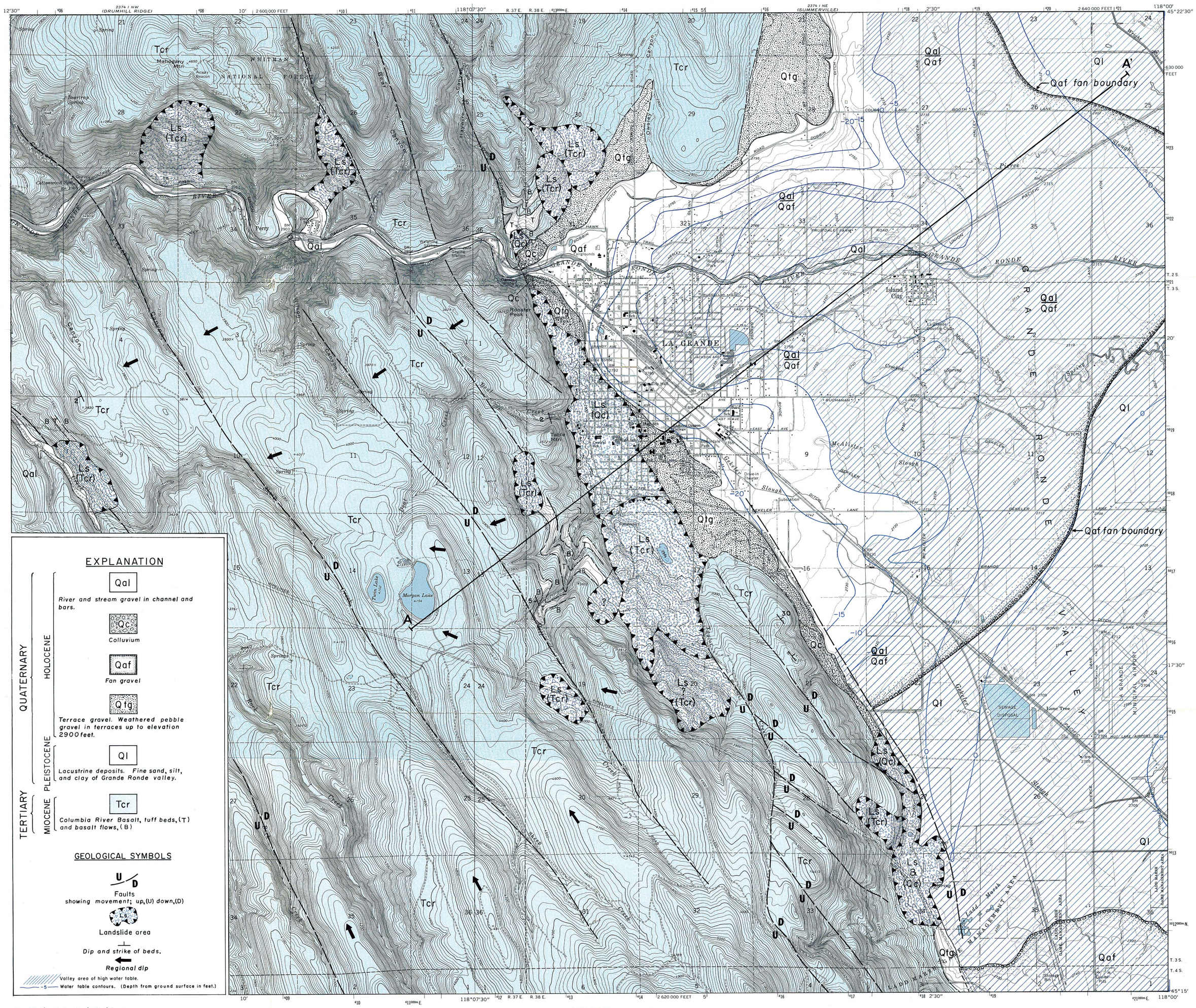
Sand and gravel resources are available in the gravel fan at the mouth of the Grande Ronde canyon and in the gravel terraces. Good crushed rock is produced from quarries in Columbia River Basalt adjacent to the valley.

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

R. E. CORCORAN, STATE GEOLOGIST

ENGINEERING GEOLOGIC MAP OF LA GRANDE AND VICINITY

HILGARD QUADRANGLE
AND
LA GRANDE SE QUADRANGLE
OREGON–UNION CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Base Map by U. S. Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1957. Field checked 1963

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 11, shown in blue

Fine red dashed lines indicate selected fence lines

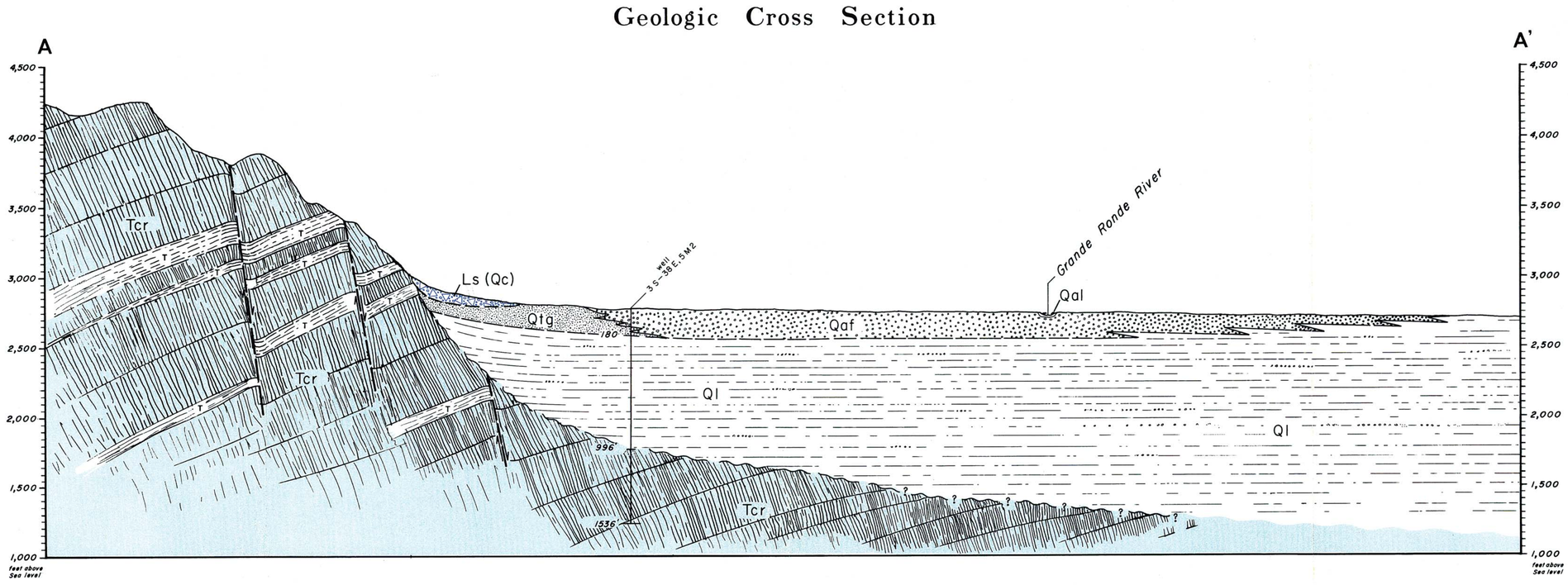
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1970 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

OREGON
QUADRANGLE LOCATION

Water table contours adapted from E. R. Hampton 1957 - 1958

Geology by H. G. Schlicker and R. J. Deacon
Cartography by S. R. Renoud
1970-1971

Geologic Cross Section