EDMONDS

GEOLOGY

BLENHEIM-GILBOA PUMPED-STORAGE POWER PROJECT

SCHOHARIE COUNTY

NEW YORK

by

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INFORMATION AVAILABLE

Geologic investigation of the Blenheim-Gilboa project area was initiated in April, 1968 and consisted of field reconnaissance, a literature search, extensive geophysical prospecting and core borings. In addition, numerous test pits have been dug and a number of auger borings to determine overburden characteristics have been completed.

Publications used included the "Geologic Atlas of New York State" by John Broughton and others; "The Groundwater Resources of Schoharie County, New York" by Jean Berdan; "Glacial Geology of the Catskills" by John Lyon Rich; "Engineering Geology of the Catskill Water Supply" by Charles P. Berkey and James F. Sanborn, (Trans. ASCE, 1923); and "The Shandaken Tunnel" by R.W. Gausmann, (Trans.ASCE, 1928). An important source of information was the Board of Water Supply of New York City, where records and unpublished reports of various employees were made available.

Some data were obtained from local residents relative to water wells and construction materials.

TOPOGRAPHY AND GLACIATION

The project is located in the glaciated northern extremities of the Allegheny Plateau, which extends from the Mohawk Valley of New York southwesterly to central Alabama. The uplands between the Mohawk River Valley on the north and the peaks of the Catskill Mountains on the south, maintain a general elevation of some 2,000 feet above sea level. The surface of the so-called "2,000 foot plateau" is gently undulating and was developed by erosion during a long period of relative stability. Schoharie Creek and other drainage systems have developed deep, narrow valleys in the plateau, resulting in a fairly rugged terrain with flat-topped mountains.

Schoharie Creek is deeply incised in the plateau, and the present channel is approximately 1,200 feet below the crest of Brown Mountain, a promontory at the northeast corner of the proposed upper reservoir.

At some time prior to the last period of glaciation, the entire region was uplifted by tectonic forces, and the formerly placid streams began vigorous down-cutting in the relatively soft rocks of the area. Schoharie Creek eroded its level to approximately 675 feet above sea level in the vicinity of the lower reservoir dam site, and tributary valleys were cut to corresponding depths.

During the Pleistocene or latest "ice age", glaciers covered the entire region, and when the ice eventually melted, both the highlands and the valleys were left mantled with a cover of glacial debris. The valley troughs were partially filled with tills brought in and compacted by the moving ice, and by clays, silts, sands and larger rock fragments deposited by melt waters. While the contemporary streams follow the general courses of the ancestral valleys, they have at some places been diverted from former channels by obstructions in the form of kames, moraines, outwash deltas and other glacial deposits, and in such cases, the present beds do not coincide with the alignments of the previous ones. This does not appear to be the case, however, at the Schoharie Creek site of the project's proposed lower reservoir dam.

With minor exceptions, the moving ice did not change or modify the pre-existing topography to any significant degree. The important terrain features resulting from the Ice Age are almost all depositional in nature and consist of both ice and waterborne materials, and in some cases, combinations of the two.

A notable feature of the Schoharie Valley in the vicinity of the project is the number of tributary streams which plunge over falls or cascades just prior to entering the main stream. The falls of Manor Kill, Mine Kill, Mill Creek, Platter Kill, Keyser Kill and Panther Creek are examples. They have resulted from the inability of the tributaries to keep pace with the erosional progress of Schoharie Creek, both prior to and subsequent to the Pleistocene epoch.

ROCK TYPES

All of the rocks in the area are of sedimentary origin, and have not been metamorphosed nor have they been intruded by igneous bodies. The strata consist of thin to massive bedded sandstone, siltstone, and shale, with a few thin beds of volcanic ash or bentonite at widely scattered intervals. All of the rocks noted in the field and examined in drill cores are fine-grained with the coarsest lithology being a sandstone of sugary texture. The shales are very fine-grained, with individual particles indistinguishable even with a hand lens.

Contacts between various lithologies are obvious in weathered outcrops, especially between sandstones and shales. In drill cores of sound and unweathered rock, the separations are not easily detected at times, since there appears to be a gradational progression from sandstone to siltstone to shale in a cyclical manner.

The sandstones are remarkably uniform in both color and texture within the limits of any one unit, and do not differ greatly from one formation to another. All are "slabby" to some degree, with beds ranging from 1/2 inch to a foot in thickness. Individual bedding planes are usually not obvious to the casual observer, but all samples obtained from apparently massive exposures contained them.

Some of the sandstone is feldspathic, such as the famous "bluestone" which was formerly quarried in small but widespread operations.

The siltstone beds are similar to the sandstones with the exception of grain size. They are usually buff colored where weathered, but of a medium gray to dark gray hue where fresh. They are similar in stratification to the sandstones, but are usually less prone to slab, retaining a more massive appearance in outcrop than the sandstones.

Scattered throughout are beds of thin to thick shale which may be red or green where fresh but which weather to buff or gray on exposure. It is estimated that approximately 40% of the total rock section noted in drill hole B-1 is composed of shale.

Some of the shales break down on prolonged exposure to the atmosphere, as observed in road cuts, while those which approach siltstone lithology appear to possess considerably more strength, and are more durable.

STRATIGRAPHY

Named rock formations involved in project excavations include the various facies of the Genesee and Hamilton groups, both of upper to middle Devonian age.

The youngest unit exposed is the Oneonta Formation, which includes the Kaaterskill sandstone member. It is composed of interbedded sandstone and red shale, and caps the plateau between Reed Hill and Brown Mountain and thus underlies the entire upper reservoir area. Some of this rock unit was removed by pre-glacial erosion and more was removed by the ice. Depending on the present topography, from 200 to 500 feet of thickness of the formation remains.

Underlying the Oneonta is approximately 400 to 500 feet of interbedded shale, siltstone and sandstone of the Moscow formation. The vertical shaft from the upper reservoir to the level of the horizontal power tunnel will penetrate the full thickness of the formation.

The powerhouse and the horizontal portion of the power tunnel, and the lower reservoir dam across Schoharie Creek will be in or on rocks of the Panther Mountain formation, similar to the Moscow but separated from it on the basis of fossil content. In addition, the Panther Mountain formation possesses some beds of more massive and durable character than are found elsewhere in the area.

STRUCTURE

The rocks dip gently and uniformly to the south, with only minor variations. The amount of dip varies from 100 to 150 feet per mile, and the existing tilt of the strata is probably due to a regional uplift emanating from the Adirondack Dome.

Even minor faults are rare in the project area. A small one is exposed in rocks on the west side of Schoharie Creek about a mile downstream from the covered bridge at North Blenheim, and mention has been made of weathered crush zones being encountered at widely spaced intervals in the tunnel from Gilboa Reservoir to Shandaken on Esopus Creek.

The most important structural feature is the joint pattern. Previous investigators have plotted three sets in some detail. The most prominent set trends ENE, while two sets which are only slightly less developed trend NNW and NW.

The joints are usually near vertical, regardless of the type of rock. In the sandstones and in the massive siltstone layers they may be spaced as much as several feet apart, but where the rock is exposed and has been subjected to weathering, the spacing is usually less. Joints are also present in the shales, but are not as obvious in the unweathered cores as they are in the outcrops which have been subjected to the rigorous climate.

Single joints which may continue vertically through several massive beds may terminate in shale beds above or below, or both. In exposed rock bluffs, a few individual joint planes were noted which extended for several tens of feet. Incipient joint planes, where breakage would occur during blasting and other excavation operations, are widespread in their occurrence and follow the trend of the measured patterns. The incipient joint plane spacing is closer than that of the open joints.

Joints are tension cracks resulting from flexing or bending of the strata by tectonic forces. The brittle rocks, such as the massive sandstones and siltstones, are more easily broken than the relatively flexible and pliable shales, which have a greater number of horizontal adjustment planes in a given thickness. On the other hand, the shales have a tendency to crumple when subjected to vertical or lateral pressures when confined between beds of competent rock. Both open and incipient joints and crumpled rock constitute zones of weakness, and are doubly important in that groundwater is channeled into them, allowing faster rates of decomposition than are normal for unexposed rock. Practically all of the groundwater contained in the bedrock in this area is found in the open joints, and all free water movement occurs in the joints and other fractures.

FOUNDATION CONDITIONS

Pumped-Storage Reservoir. The bedrock underlying the reservoir consists wholly of sandstone and shale, which when sound and unweathered, is capable of supporting any contemplated structural and hydraulic loading without significant settlement. The rock is nearly everywhere concealed by a blanket of till or ground moraine which is from a few inches to more than 100 feet thick. The till consists of cobbles and boulders in a matrix of sand, silt, and clay, and is apparently rather impervious, as standing bodies of water or swampy areas are found wherever small basins exist on the surface.

Weathering of the rock consists mostly of shallow decomposition of exposed shale and sandstone near the surface, and deterioration of the walls of joints, resulting in vertical mud seams. The surface expression of the seams may outcrop for many feet, but the depth is relatively shallow, averaging less than 10 feet.

The only other weathering feature noted was the discoloration or staining of horizontal bedding plane surfaces due to the action of moving groundwater. Such staining occurred to depths as great as 400 feet below the surface. In no case was the affected rock deteriorated enough to be termed weathered, nor was it structurally weakened.

Another feature of the surface sandstones is the tendency of the thin-bedded members to "slab" when relieved of their load, leaving extensive horizontal partings between slabs. This phenomenon is probably due to relief of the vertical loading at the time the ice melted. It is not noticeable in the massive beds, nor does it extend to a depth of more than a few feet from the surface.

Possible paths of reservoir leakage will be confined to the joint systems, in conjunction with the horizontal separations. The alternating nature of the sandstone and shale laminations inhibits the vertical percolation of water, and the shales are also practically impermeable either horizontally or vertically. The sandstones and siltstones are composed of such fine fragments and are so well cemented, that they allow very little water to pass, and at a very slow rate. Groundwater investigations in this area have revealed that wells which are drilled into rock are only successful in producing water when a number of joints are penetrated or "cut" by the well bore. Joints which carry water are amenable to conventional sealing methods, and it is believed that a nominal amount of treatment will prevent all but an insignificant loss from the reservoir.

Drill holes and geophysical prospecting indicate that the thickness of the till and other glacial deposits range from a few inches to as much as 120 feet or more. The north dike line has a very thin cover, averaging approximately 2 feet. The south dike line till mantle varies somewhat, ranging from approximately 5 feet in thickness at each end, and deepening to almost 30 feet in the center. The till will average about 20 feet thick along this line. Along the line of the natural dike bordering the east side of the reservoir,rock is also shallow at each end, but near where the line crosses the road, it may be as deep as 120 below the surface. On the west dike line, the greatest depth was found in the knob just south of the large swamp, and amounted to 65 feet.

An east-west seismic line, confirmed by drilling, indicated that the ridge in the central portion of the reservoir was also composed mostly of till, with depths from 40 to 130 feet to rock.

The sampling procedures and the velocities obtained by seismic profiling indicate that the till is compacted and possesses considerable strength with respect to vertical loading. While it contains some pervious lenses of fine granular material, the random scattering of the lenses tend to lessen the chance of interconnections and reduce the possibility of significant leakage.

Vertical Shaft and Tunnel. Rock encountered during boring of the vertical shaft will consist of the siltstone, shale, and sandstone as described in the log of drill hole B-1. Cores of all these materials have shown no deterioration in the core boxes over a period extending in some cases from June through January. Excessive flows of water are not anticipated, although seepage into the shaft bore is expected. Previous experience in the area indicates that the maximum to be expected for a tunnel of the size and length contemplated will be in the order of a few hundred gallons per minute.

Within the vertical portion of the power tunnel, the alternating hard and soft rocks and their differing capabilities to stand exposure and the effects of drilling and shooting may result in a "ringed" bore. To prevent serious deterioration of the shales after excavation and prior to lining, the use of gunite or similar protective measures may be justified.

The tunnel alignment from the bottom of the vertical shaft to the powerhouse parallels the strike of the rock and thus will be constructed in the same stratum for the entire length. Cores from drill holes B-1, B-2, B-3, and B-4 show that the tunnel elevation will be mostly in sandstones and siltstones, with interbedded shale layers. Rock bolting will probably be required above the spring line.

The phenomenon of popping rock may or may not be encountered. While this is usually more characteristic of massive crystalline rocks, and under considerably greater cover than will exist in this shaft and tunnel, it is worthwhile to note that some instances were encountered in the Shandaken tunnel, and interestingly enough in the sections with the least amount of burden.

Pump-Generating Powerhouse. The powerhouse is located on an erosional rock terrace on the east bank of Schoharie Creek, approximately one mile south of the lower reservoir dam site. Drill holes on the preliminary centerline of units (75 feet west of present centerline) encountered rock at elevations between 838 and 855, but immediately to the east of the line, a rock bluff roughly parallel to the lines rises to elevation 960 or higher. The outcrops in the bluff are composed of thinly bedded siltstone and sandstone, separated by fissile shale beds. The rocks are closely jointed and have broken into small blocks due to exposure, resulting in talus heaps at the foot of the bluff. The talus is piled on top of a considerable thickness of alluvium and glacial till.

The breakdown of the rock in the face of the bluff is believed to be a surface feature due to the lithologic characteristics and the rigorous climate, and the mass of rock not exposed is expected to be sound. This idea is at least partially substantiated by the fact that groundwater percolating down the slope behind the powerhouse site flows through the overburden and along the top of rock, emerging as small waterfalls on the rim of the bluff, rather than working down through open joints or other crevices in the rock.

Rock at foundation grade consists of sandstone, siltstone and shale, similar to that exposed in the bluff. Any one of the rock types is capable of supporting the unit loads to be imposed. Cores obtained were sound and unweathered.

Where thick shale beds are present in the powerhouse excavation, protection for the period between excavation and concrete pouring may be necessary to prevent excessive sloughing on prolonged exposure. This is especially true for vertical faces.

Bedrock is concealed along the alignment of the intake-discharge channel from the powerhouse to the creek. The floodplain is a little more than 1,000 feet wide, and the depth of alluvium and underlying till varies from 50 to more than 100 feet. The till consists of silt, sand and clay, with cobbles and boulders scattered throughout. Bedrock is exposed in a rock nose on the west side of Schoharie Creek downstream of the channel. Between the nose and the powerhouse site the preglacial channel of the creek occurs, apparently passing the powerhouse site east of the present channel. Practically all of the intake-discharge channel excavation will be unconsolidated materials.

Lower Reservoir Dam. The lower reservoir dam is located across Schoharie Creek at a point one mile south of the village of North Blenheim. The right abutment is anchored to a rock bluff and the alignment crosses over a massive outcrop of rock on the west bank of the creek. The rock on the east bank is visible for a distance of approximately 3,000 feet along the shore and behind the floodplain, while on the west bank it is exposed from the damsite upstream for a similar distance and under the same conditions. The vertical height of the bluff on the east bank is 100 feet or more, while it is about half that on the west bank.

The bedrock is classified as the Panther Mountain formation, which contains some massive beds which form impressive outcrops along the bed of the creek. Separating the massive beds of very fine grain sandstone are thin to thick beds of shale and some siltstone. Where sound and unweathered, these rocks are capable of supporting any vertical and horizontal loadings imposed by the project structures or impoundments.

Bedrock is concealed between the outcrops on the west abutment and the rock cuts on State Route 30, some 3,000 feet to the west. A seismic profile indicates that the bedrock surface slopes upward uniformly to the level of the road, although it does not follow the topography, as at least two terraces are superimposed on it.

At the dam site the left bank of the creek is in rock. The preglacial buried channel is under and to the east of the present creek, and one drill hole penetrated to a depth of 129 feet before reaching bedrock. According to the samples, permeable alluvium underlies the floodplain. Special provision should be made to insure against piping and heavy seepage through this alluvium.

Sealing of the abutment rock to prevent leakage will be necessary. The depths to which the joints are open is not expected to be great, and an effective curtain should be obtained by using a pattern which would extend 40 feet from the exposed surface rock.

CONSTRUCTION MATERIALS

Concrete Aggregates. Natural aggregates in this area are in short supply and of dubious quality when found. Due to the lithologic characteristics of the bedrock from which they were derived, and the type of glaciation by which they were quarried and then deposited, gradation is limited to the very fine and very coarse, and sorting is almost non-existent.

The original source consisted almost wholly of fine grain rocks, and under the processes of erosion, these have been reduced to fine sand, silt and clay. Although the cobbles and boulders at the other end of the size range are composed of identical fine grain materials, they have retained size because of the lack of incipient joint planes, more inherent durability, and probably less attack by the forces of decomposition.

A typical deposit, whether it is till or ground moraine from the upper reservoir level or the mixed alluvial and glacial deposits in the Schoharie valley at the head of the ancient lake which was backed from Middleburg to the vicinity of North Blenheim by an ice barrier, largely consists of fine sand and silt with a small percentage of clay, and contains a generous quantity of cobbles and boulders. Coarse sand and gravel sizes are almost always conspicuous by their absence, and where they are present, are so mixed with fines that careful washing would be necessary before use as filter material.

All exposed concrete which was examined in the area, and which showed signs of deterioration, contained natural aggregate, at least in part. The deflectors on the crest of Gilboa Dam and the concrete curbs, rails, and pavements of several nearby bridges are examples.

The manufacture of aggregate sizes from the durable sandstones is possible, but those experienced in its use in concrete state that while it possesses sufficient strength and durability for use where it is protected, it must never be exposed to the weather.

The nearest sources of relatively uniform quality and sufficient quantity exist in the limestones of the Helderberg Escarpment, which is the northern rim of the Allegheny Plateau. The quarry at Schoharie was examined, as was one near Cobleskill. Random samples of crushed stone selected at Schoharie indicated the presence of shaly rock, while samples from the Cobleskill quarry indicated the presence of cryptocrystalline chert. The latter quarry exhibited what appeared to be the most durable rock, and adjustment of the alkaline content of the cement could compensate for any excess chert.

Other sources of manufactured aggregate are all located at a distance from the project area, such as at Cementon and Tarrytown, both in the Hudson Valley. The rock from the Cementon area is calcareous, while that from Tarrytown is a diabase or "trap". The latter is well known for its durability. Further study of possible aggregate sources is underway.

Dike Materials. Till deposits are located within the limits of and adjacent to the upper reservoir and when processed by separating the larger cobbles and boulders, will form acceptable zoned fills. The fines are composed largely of sand and silt, with a small percentage of clay, and when wet, are fairly cohesive, but when dried, crumble easily. They can be placed and compacted to form a watertight barrier. Oversize cobbles and boulders which could not be effectively rolled into an impervious zone could be utilized in outer shells and as rip-rap.

The same situation applies at the lower reservoir site, with some minor differences. In the floodplain of Schoharie Creek, some separation has occurred and alluvial bottoms with smaller percentages of boulders exist, while bars of cobbles and boulders, with fines washed out, are found at various places along the present stream channel. In addition, terraces of glacial lake bed deposits bordering the channel contain quantities of clayey and silty soil suitable for impervious core.

Filter gradations from natural sources are practically non-existent. It might be feasible to manufacture filter material from the durable sandstone beds or boulders.

Rip-rap for the lower dam may be obtainable from the numerous boulder bars which line the stream channel from the lower dam site upstream to Gilboa Reservoir. The boulders which form the bars have withstood the test of natural selection insofar as durability is concerned, and a large quantity is available.

Other sources of rip-rap include quarries. The handplaced stone which protects the upstream face of the earth fill at Gilboa Dam was obtained from the quarry near the present Gilboa Central School, and a recent inspection indicated that it has held up well during the 40 or more years it has been in place. The beds from which this stone was quarried outcrop on Reed Hill, and form prominent cliffs.

SPECIAL CONSIDERATIONS

Seismicity. Earthquake tremors of any intensity are rare in the Gilboa area, and none have been reported during historic time of damaging proportions. As a matter of record, the entire Allegheny Plateau is stable, with only occasional minor earthquakes. Vibrations which reach this area usually originate in the Hudson-Mohawk Valley, or in the Adirondacks. While it is possible, according to the state of the art of predicting earthquakes, that a catastrophic tremor can be experienced anywhere, at any time, we can only assume probabilities according to the record. In this case, a design factor of O.lg is considered to be more than adequate.

Mineral Deposits. No minerals of economic value are reported to exist within the project area, nor were any traces of any found in the samples from the extensive drilling program. The only material mined during the period of occupancy of the region by white men is the feldspathic sandstone or "bluestone" and such mining was in isolated and scattered hand operated pits, for local consumption only. All such quarrying has long since ceased.

A recent development has been the leasing of local lands by oil producing firms. It is not clear whether the leasing is for the purpose of drilling for gas or oil, or for underground storage. As far as can be determined by questioning local residents, no development work has taken place at this time. The leasing activity is widespread by several large companies, and is not confined to Schoharie County.