भारतीय मानक

जल वैज्ञानिक संरचनाओं के लिए भूमिजल अन्वेषण — मार्गदर्शी सिद्धान्त

Indian Standard

GROUND WATER INVESTIGATION FOR HYDRAULIC STRUCTURES — GUIDELINES

ICS 93.160

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Geological Investigation and Sub-surface Exploration Sectional Committee, RVD 5

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Geological Investigation and Sub-surface Exploration Sectional Committee had been approved by the River Valley Division Council.

Ground water is of vital importance to the civil engineers not only as a source of water supply but as a controlling factor in all drainage operations, foundation excavations, reservoir storage, etc. Despite this importance, ground water is the most neglected aspect in civil engineering constructions especially hydraulic structures. If the ground water data are not considered properly or if these are not obtained with due care and caution, it may lead to damage or even failure of the hydrological structure.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GROUND WATER INVESTIGATION FOR HYDRAULIC STRUCTURES — GUIDELINES

1 SCOPE

This standard deals with various aspects which have to be considered while carrying out ground water investigation for hydraulic structures.

2 REFERENCE

The Indian standard 6935 : 1973 'Method for determination of water level in a bore hole' is a necessary adjunct to this standard.

3 ENGINEERING CONSIDERATIONS

3.1 Dam Foundations

Prior to excavation of the foundation of any hydraulic structure, it is essential to have a knowledge of the ground water distribution in the area. When the water table is higher than the recommended depths of cut-off/foundation, especially when thick pervious unconsolidated strata like sand and gravel is present, the problem of dewatering during excavation should be anticipated in advance. The possibilities of presence of artesian water should also be studied by observing the water table and the geological data and suitable measures for depressing the water table should be thought of prior to taking up foundation excavation.

3.2 Reservoir

3.2.1 *Competency of Reservoir*

The position of the water table in the proposed reservoir area should be thoroughly established, as well as the fluctuation it undergoes during the year. Such studies will indicate the possibility of seepage from the reservoir and provide a sound basis for calculations to be made for arriving at the inventory of the reservoir and its vicinity.

3.2.2 *Stability of Reservoir Rim*

Occurrence of landslides in reservoir areas is a common phenomenon. In a reservoir area of high relief with adversely oriented joints/bedding planes, landslides may occur. The process may accelerate if the drawdown is sudden. The presence of ground water has three main effects:

a) It will increase the effective weight of the material that it saturates,
b) It will create appreciable pore pressure and thereby reducing the shear strength of the slope forming material, and
c) It will tend to weaken weaker kinds of rock and unconsolidated material.

These effects lead to the conclusion that slides normally occour in wet weather and the drainage system offers an effective remedy for preventing landslides.

4 GEOLOGICAL CONSIDERATIONS

4.1 The geological aspects as given in **4.2** to **4.6** should be considered for carrying out systematic investigation for ground water at the site of any hydraulic structure.

4.2 Influence of the Nature of Rock

4.2.1 Rocks seldom show the same water bearing qualities in different regions. The two most important properties which make a rockmass an aquifer of any importance are porosity and permeability. Ground water occurs in consolidated rock materials (hard rock) and in loose unconsolidated materials (soft rock). Any type of rock that is sedimentary, igneous or metamporphic, whether consolidated or unconsolidated, may form an aquifer if it is sufficiently porous and permeable. Based on these factors of porosity and permeability, the water bearing properties of the more common rock groups are discussed in **4.2.1.1** to **4.2.1.3**.

4.2.1.1 *Sedimentary rocks*

a) *Sands and gravels* — Since these materials are both porous and pervious they may act as most ideal water bearing strata.
b) *Clays and Shales* — As a general rule, these do not contain any ground water. Hard shales may yield water at joints.
c) *Sandstones* — These sedimentary rocks show great variation in their water yielding capacity which is chiefly controlled by the texture and nature of cementing materials. Coarse grained sandstones with imperfect cementing material may prove excellent aquifers while fine grained varieties which are thoroughly cemented may yield a poor quantity of water.

d) *Limestones* — These rocks also show great variation in their water yielding capacity. If the rock is having solution channels, cavities and crevices, etc, it may be a good aquifer. When such openings are absent it may prove to contain very little water.

4.2.1.2 *Igneous rocks*

a) *Acid Volcanic Rocks* — These rocks may or may not prove to be successful water bearing strata because acidic lava is comparatively viscous and generally fragmentary at the time of eruption. Interstices will normally be common in such lava and hence the possibility of their retaining water, however these interstices may subsequently get filled with ash or other materials and hence the uncertainty of these rockmasses being aquifers.

b) *Basic Volcanic Rocks* — These rocks are characterized by high mobility at the time of eruption and hence they flow to a great distance. They may thus form thick sheets rich in cavities (occurring due to escape of gases from cooling lava) and cracks (due to contraction) and hence may be sufficiently permeable to be water bearing strata.

4.2.1.3 *Metamorphic rocks*

The rocks like schist, slate and even gneiss which are often foliated and highly fractured may prove exceptionally good aquifers. But marble and quartzite are normally almost impermeable, except along original beddings. Where folding is pronounced, quartzite is usually jointed in nature, at these locations quartzite may prove to be water bearing.

4.2.2 *Porosity*

Some typical values of porosity for well known rocks are given in Table 1.

Table 1 Porosity of Rocks

Type of Rock	Maximum Porosity, Percent
a) Soil and loam	Up to 60
b) Chalk	Up to 50
c) Sand and gravel	25-30
d) Sandstone	10-15
e) Limestone	10
f) Limestone and marble	5
g) Slate and shale	4
h) Granite	1.5
j) Crystalline rocks	Up to 0.5

4.2.3 *Permeability*

4.2.3.1 Permeability of rock depends on the following:

a) Size and shape of the constituent grains,
b) Sorting of the grains,
c) Continuity and nature of interstices,
d) Hydraulic gradient and hydraulic conductivity,
e) Stratification,
f) The amount of consolidation and cementation undergone, and
g) The presence and nature of discontinuities.

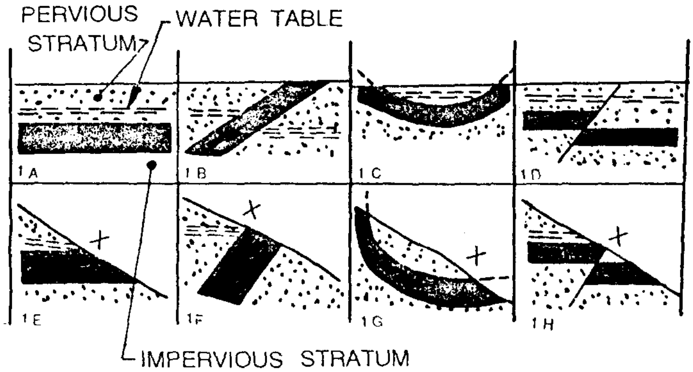
4.2.3.2 The ultimate permeability of a rockmass is the outcome of the combination of the factors given in **4.2.3.1** which most obviously cannot, and do not, fall strictly under any thumb rule generalization.

4.3 Influence of Geological Structures

4.3.1 Underground conditions affecting ground water differ from the ideal case not only because of the wide variety of materials in contact with the water but also because of the way in which the various rock strata are arranged in general and in relation to one another. The disposition of the pervious and impervious strata below the surface and its influence on ground water table is illustrated in Fig. 1.

4.4 Quality of Ground Water

The quality of ground water is a matter of vital importance as the water is used for industrial, domestic and/or construction purposes. Ground water will almost certainly contain dissolved solids and gases. Most ground water contains no suspended matter and practically no bacteria. The main gaseous impurities are methane, hydrogen bisulphide, carbon-dioxide, etc. It should be kept in mind that severe corrosion is observed in steel pipelines due to presence of free carbon dioxide. Pure water will dissolve only 20 ppm (parts per million) of calcium carbonate and 20 ppm of magnesium carbonate, but water containing carbon dioxide will dissolve many hundreds of parts per million of the solid. The dissolved carbonates impart temporary hardness to the water while the dissolved sulphates cause permanent hardness which cannot be removed by simple chemical procedures. Chemical analysis is necessary to determine the degree of hardness of the water, and if this exceeds about 200 ppm of calcium carbonate the water requires softening. The presence of high concentrations of calcium and magnesium sulphates in ground water can cause serious trouble with concrete work in contact with the ground. This can, however, be solved by use of sulphate resisting cement.



1A indicates the position of water table when impervious bed is lying horizontally below the pervious bed.
1B indicates that the inclined impervious stratum will constitute a barrier between two pervious beds, so that the elevation of the respective water table need not, and probably will not, be the same.
1C shows how water will collect in distorted stratum creating a perched water table.
1D demonstrates the effect of a fault on the distribution of ground water in alternating strata. The variations possible in this case are dependent on the relative thickness of strata, the nature of fault and the throw of the fault.
1E, 1F, 1G and 1H show altered ground water conditions when the surface of the ground is inclined. At the point marked 'X', bodies of ground water will come into contact with the atmosphere.

FIG. 1 DISPOSITION OF THE PERVIOUS AND IMPERVIOUS STRATA

4.5 Ground Water Survey

4.5.1 Ground water survey for hydraulic structures should always be associated with geological information of the dam vicinity and reservoir area. This information should include regional and local geological maps and cross sections, lithological characteristics of the rocks, structural features, well inventory, etc. The ground water survey should be carried out by sub-surface exploration by means of drilling, geophysical survey, well inventory, etc.

4.5.2 In well inventory, the information on existing wells is gathered. The information on location, depth and diameter of well, depth to water table, amount of water pumped, type and nature of rocks the wells have penetrated through, quality of water, etc, are collected.

4.5.3 Information obtainable from the drill holes may be two fold, that is for the overburden as well as for the rock underneath. Overburden may consist of soil, clay, sand, gravel, boulders, glaciated materials, etc, whereas rock may be igneous, metamorphic, sedimentary or a combination thereof. Depth to weathering, jointed and /or sheared/ faulted zones could also be present. In drill holes water level measurements should be made in accordance with IS 6935 : 1973.

4.5.4 In case of reservoir basin area, water table may be measured during well inventory. The water level in the wells located within the reservoir as well as outside the periphery of the reservoir, should be measured before and after monsoon. The pre-impounding ground water levels should be properly monitored. By using measurements of ground water levels obtained from wells and by observing the levels at which springs occur, it is possible to make contour maps of the water table which would give an idea about the depth below which ground water is stored and the direction in which it is moving.

4.5.5 Reduced water level map prepared on the basis of well inventory, in the reservoir and vicinity area, will be helpful in establishment of the influent or effluent nature of the stream across which the structure is proposed. If the ground water level contours are decreasing beyond the periphery of the reservoir, there are chances of losing water from the reservoir after impounding.

4.5.6 As shown in Fig. 2, if water is impounded above the critical water level (*WL* in the figure) and the broken line extending through pervious material is the required underground hydraulic gradient for flow through that material, it is clear that leakage will occur from valley *A* to valley *B*.

In addition to causing loss of water from the reservoir, this under ground flow of water may cause trouble in valley *B* if there is any instability due to unconsolidated deposits (such as aeolian sand volcanic tuff, red bole, fault zone, etc which might be intensified by the presence of excessive underground water.

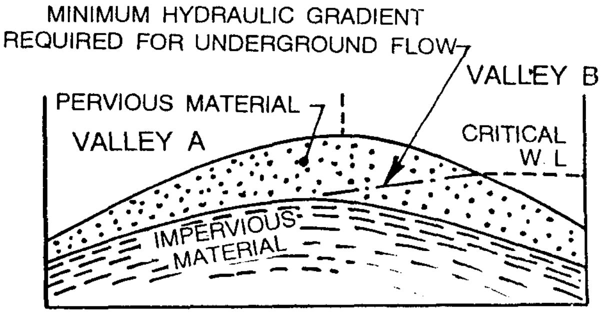


FIG. 2 SIMPLIFIED GEOLOGICAL SECTION

4.5.7 After impounding of the reservoir the groundwater table in the area around the reservoir rises due to artifical recharge. A similar condition also occurs in the command area of the dam due to water flow in the canals. This phenomenon creates the problem of water logging whereby all vegetation including crops are badly affected due to decay of the roots.

4.6 Ground water Table and Reservoir

4.6.1 Construction of a dam and subsequent impounding of water behind it causes interference with natural conditions. A difference is set up in the level of the water table corresponding to the height of the dam between the two sides of the dam. As a consequence, there will be a tendency for the impounded water to find some means of escape through any weakness that may exist in the structure of the ground. In order to assess this behaviour, a study of the ground water, its position and movement in the area adjoining the reservoir site is of primary importance. This will determine how the filling of the reservoir will affect these factors.

4.6.2 *Reservoir Areas of High Water Table*

4.6.2.1 After impounding of the reservoir, the water soaks into the ground until it meets the water table, and consequently changes the grade of the water table. If the surface of the reservoir is below the ground water divide, there will be no loss by seepage and the ground water will flow into the reservoir (*see* Fig. 3). In addition, there will be under ground water storage between the old and the new position of the water table. The volume of this newly saturated ground water will depend on the level of the reservoir and the slope of the original water table. If the ground water divide is lower than the reservoir flow line, the ground water forms an under ground spillway with possible leakage on the opposite side of the ridge.

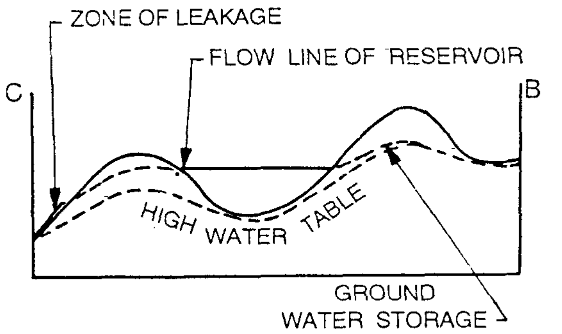


Fig. 3 DIAGRAM SHOWING RELATION OF RESERVOIR LEVEL TO HIGH WATER TABLE

4.6.2.2 Springs in the reservoir site are favourable indication of a water table sloping towards the valley. If they are large, attention should be given to their discharge pressure: for, if it is insufficient to raise the water to the reservoir level, the flow may be reversed when the reservoir is filled. But since this head is not directly measurable, it should be determined indirectly from the level of the water table in the surrounding area.

4.6.3 *Reservoirs Areas with Deep Water Table*

A deep water table is likely to occur in areas where the rocks are exceedingly porous or contain large

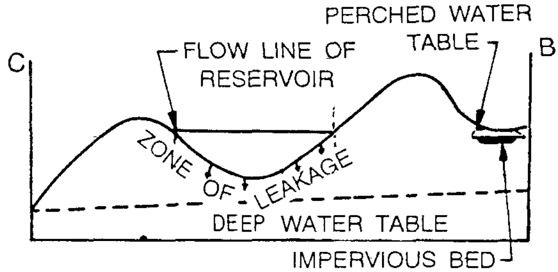


FIG. 4 SECTION SHOWING RELATION OF RESERVOIR LEVEL TO DEEP WATER TABLE

openings (*see* Fig. 4). Conditions favourable for a deep water table are soluble rocks, basalt flows containing open cracks, bracciated, vesicular and scoriaceous zones, fractured rocks due to faulting or other movements, and coarse boulder beds.

Under this condition the water table is comparatively flat, and the ground water flows freely with a low gradient. When the walls and bottom of the stream channel are permeable, there will be loss from the stream into the rock. Such a stream is known as an influent stream. In the area of cavernous limestone, the discharge of river water should be measured at regular intervals and the loss of water should be worked out. Similarly, if the cavernous limestone formation is folded into a synclinal structure as shown in Fig. 5, there are chances of loosing water, leaving an empty reservoir behind the dam.

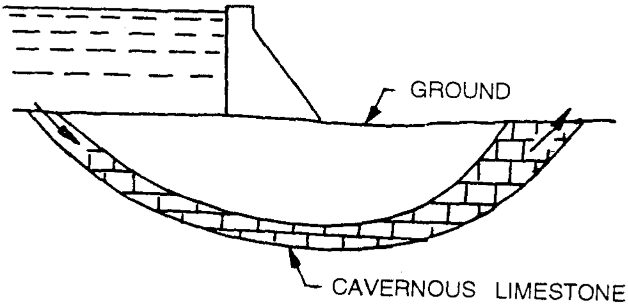


FIG. 5 LEAKAGE OF RESERVOIR WATER TRHOUGH SYNCLINAL FOLD IN CAVERNOUS LIMESTONE BED

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