BUREAU OF INDIAN STANDARD

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भारतीय मानक मसौदा

जलाशयों की योजना और निष्पादन में अवसादन के प्रभावों का निर्धारण — दिशानिर्देश

Draft Indian Standard

DETERMINATION OF EFFECTS OF SEDIMENTATION IN PLANNING AND PERFORMANCE OF RESERVOIRS — GUIDELINES

(*First Revision of* IS 12182)

Reservoirs and Lakes Sectional Committee, WRD 10	**Last date for Comments: 02/07/2024**

FOREWORD

(*Formal Clause of the foreword will be added later*)

The storage reservoirs built across rivers or streams lose their capacity on account of deposition of sediment. This deposition of sediment which takes place progressively over time reduces the active capacity of the reservoir which in turn affects the regulating capability of the reservoir to provide the outputs of water through passage of time. Accumulation of sediment at or near the dam may interfere with the future functioning of water intakes and hence affect decisions regarding location and height of various outlets. It can also result in a greater inflow of sediment into the canals/water conveyance systems provided at the reservoir. Problems of rise in flood levels in the head reaches and unsightly deposition of sediment from a recreation point of view may also crop up in the course of time.

Water resources systems operate over a long period of time and are subject to ever increasing demand for water for various purposes. Besides, long-term changes in terms of technology and production functions are also encountered. Man-made changes taking place in the river basin and consequent changes in hydrologic regime controlling the water inputs over long-term periods are also encountered and have to be provided for (All these factors are to be considered and taken into account while assessing the performance of any reservoir project). In this context, the sedimentation of reservoirs is to be viewed as an additional factor that has to be considered, and its effects have to be studied and evaluated on the reservoir performance.

This standard was first published in 1987 by taking assistance from Chapter II and III of CBIP Technical Report number 19 and practices prevalent in the field across the country. This revision has been brought out to bring the standard in the latest style and format of the Indian Standards. In addition, the following major changes have been incorporated:

a) The definition of full-service time is modified in accordance with IS 4410 Part 6: 2022.
b) Modification in Cl **5.1** (b) for studying the effects of sedimentation.
c) Modification in cl **5.2.2.4** in accordance with IS 6518: 2017**.**

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 : 2022 'Rules for rounding off numerical values (second *revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

GUIDELINES FOR DETERMINATION OF EFFECTS OF SEDIMENTATION IN PLANNING AND PERFORMANCE OF RESERVOIRS

(*First Revision of* IS 12182)

Reservoirs and Lakes Sectional Committee, WRD 10

Last date for Comments: 02/07/2024

1 SCOPE

This standard lays down guidelines for determining the various effects of sedimentation on the performance of reservoir projects in order to make suitable allowances in the design of such projects at the time of initial planning.

2 REFERENCES

The Indian Standards listed below contain provisions which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on these standards are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 4410 Part 6 : 2022	Glossary of terms relating to river valley projects Part 6 Reservoirs (*second revision*)
IS 4890 : 1968	Methods for measurement of suspended sediment in open channels
IS 6518 : 2017	Guidelines for control of sediment in reservoirs (*second revision*)
IS 5477 (Part 2) : 2020	Methods for fixing the capacities of reservoirs Part 2 Dead storage (*second revision*)
IS 5477 (Part 3) : 2002	Fixing the capacities of reservoirs - methods: Part 3 Live storage (*first revision*)

3 TERMINOLOGY

3.1 For the purpose of this standard, the definitions given in IS 4410 (Part 6) and the following shall apply.

3.2 Dead Storage — Storage of reservoir not susceptible to release by means of the in-built sluices/outlets.

3.3 Economic Life — If at any point in time, the benefits likely to accrue in further operation of the reservoir compare unfavorably under the relevant economic criteria with the future costs involved in operating and maintaining the system, but excluding any element to cover the past costs incurred, the reservoir shall be said to have reached the end of the economic life.

3.3 Feasible Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide a part of planned benefit in respect of storage in the reservoir being impaired by sedimentation. Customarily, it is estimated as the time after which the new zero elevation of the reservoir would equal the sill of the outlet relevant for the purpose.

3.4 Full Service Time — For a specified purpose, the period or notional period for which the reservoir provided or is/was expected to provide, the full planned benefit unaffected by the reason of sedimentation (*refer* IS 4410 Part 6).

3.5 New Zero Elevation — The level up to which all the available capacity of the reservoir was or is expected to be lost due to progressive sedimentation in the reservoir up to the specified time.

NOTE — New zero elevation is a time-related concept and as sedimentation progresses, the new zero elevation may rise. Thus, the specified time should be any length of time such as full service time, feasible service time, etc.

4 PROBLEMS ASSOCIATED WITH SEDIMENTATION OF RESERVOIR

4.1 Following are the main effects of sedimentation on the reservoir:

a) The reduction in active storage capacity may reduce the reservoir's capability to deliver the benefits that could have been achieved if sedimentation hadn't occurred. The progressive reduction of the active storage capacity may reflect on the outputs from the reservoir in the following ways:

1) It may reduce the dump or secondary output. However, where demands have not grown as expected, this effect may not be felt. During years of exceptional good run or secondary off, there may be no reduction in dump outputs.

2) It may reduce availability of firm water in marginal years by increase in both the number and quantum of failures. However, in very bad years where no spills would have occurred even otherwise, the number and quantum of failures may remain unaffected by reduction in active storage capacity. Some reduction of benefits from the existing reservoir projects as a result of sedimentation of active storage capacities is inevitable. However, efforts should be made to make the best use of remaining storage capacity as described in **5**.

b) Sedimentation at or near the dam face may tend to block the outlet causing difficulties in operation of the gates. Sedimentation up to intake of the outlet may induce more sediment to be carried through the conservation outlets, thus causing problems of sedimentation of canals, machinery parts, etc. Elevation to which sediment will accumulate at the dam in a given period of time affects the design elevation of outlets for water withdrawals, namely, the sill level of canal's taking off from reservoir and power penstock sills. The location of these outlets is, however, also dependent on other considerations like command areas to be covered and minimum head required for functioning of turbines. In cases, where outlet elevations are controlled by above considerations, the effect of sediment accumulation may not pose any problem. Sedimentation may cause operational difficulties by tending to jam the intake gates of the outlet when new zero elevation reaches above the gate sill. The problem becomes more severe for gates which are not frequently operated, especially in situations where early floods occur, depositing sediment near the intake when the reservoir is low. However, in frequently operated gates, a local deep approach channel may develop and allow withdrawal of water. However, in such cases, difficulties caused by passage of sediment in irrigation canals, power houses, etc., may become serious.

c) Sediment accumulation at the dam face may increase the loading on the masonry concrete dam structure beyond what has been provided for.

d) Sedimentation in upper portion of the reservoir may change the back water profile. The increase in flood levels upstream of the reservoir may cause additional submergence, formation of marshy lands, etc.

e) The river regime at the entry to the reservoir may get affected due to sediment deposits. This could lead to delta formation and a braided river pattern, which may be unsightly. Tree growth in the delta increases evapotranspiration.

f) The operation constraints for a reservoir may necessitate certain minimum reservoir level and filling generally starts at around same level or range of levels. Over a period of years, large deposits of sediment may be built up in the reservoir. The depth of sediment upstream and downstream of this location is small, resulting in a sort of hump in the reservoir bed. This hump acts as a natural barrier to the flow of sediment closer to the dam. The deleterious effect of this hump formation is the early reduction of live storage capacity.

g) The process of sedimentation in reservoirs may also increase the turbidity of water resulting in the environment problems like deterioration of water quality and reduction of visibility in the reservoir water for fish survival.

5 STUDY OF EFFECTS OF RESERVOIR SEDIMENTATION

5.1 The study normally comprises of the following:

a) Performance assessment with varying rate of sedimentation, and

b) Likely effects of sedimentation at dam face or near dam spillway and intake.

NOTE — In special cases where the effects of sedimentation on backwater levels are likely to be significant, backwater studies would be useful. Similarly, special studies may be required to bring out delta formation regime changes.

5.2 Performance Assessment (Simulation) Studies with Varying Rate of Sedimentation

5.2.1 The following steps are involved in simulation studies:

a) Selection of annual sediment yields into the reservoir or the average annual sediment yield, and of trap efficiency expected;

b) Distribution of sediment within the reservoir to obtain a sediment elevation and capacity curve at any appropriate time;

c) Simulation studies with varying rate of sedimentation; and

d) Assessment of effect of sedimentation.

5.2.2 *Sediment Yield Assessment*

5.2.2.1 Estimation of sediment yield from the catchment area above the reservoir is usually made using river sediment observation data or more commonly from the experience of sedimentation of existing reservoirs with similar characteristics. On adopting the first procedure, it is usually necessary (though often not complied within practice) to evolve proper sediment water discharge rating curve and combine it with flow duration (or stage duration curve) based on uniformly spaced daily or shorter time units in case of smaller river basins. Where observed stage/flow data is available for only shorter periods, these have to be suitably extended with the help of longer data on rainfall to eliminate, as far as possible, the sampling errors due to shortness of records. The sediment discharge rating curves may also be prepared from hydraulic considerations using sediment load formulae, that is, modified Einstein's procedure. It is also necessary to account for the bed load which may not have been measured. While bed load measurement is preferable; when it is not possible, it is generally estimated to range from 5 to 20 percent of the suspended load. However, practical means of measuring bed load of sediment needs to be undertaken particularly in cases where high bed loads are anticipated. To assess the volume of sediment that would deposit in the reservoir, it is further necessary to make estimates of average trap efficiency for the reservoir in consideration and the likely unit weight of sediment deposits, time-averaged over the period selected. The trap efficiency would depend mainly on the capacity inflow ratio but would also vary with the location of controlling outlets and reservoir operating procedures. Computation of reservoir trap efficiency may be made using the trap efficiency curves such as those developed by Brune and by Churchill. An illustration of these computations and curves is given in Annex **A**.

5.2.2.2 The density of deposited sediment would vary with the composition of the deposits, the location of the deposit within the reservoir, the flocculation characteristics of clay and water, and the age of the deposit. For coarse material (0.062 5 mm and above), variation of density with location and age may not be important. However, for silt and clay, it may be significant. Normally, a time and space average density of these fractions, applicable for the period under study is required for finding the overall volume of deposits. For this purpose, the trapped sediment for the period under study should be classified in fractions by corrections in inflow estimates of the fractions by trap efficiency. Most of the sediment removed from the reservoir should be from the silt and clay fraction. In some special cases, local estimates of densities at a point in the reservoir may be required instead of average density over the reservoir.

5.2.2.3 The reservoir surveys give valuable additional information regarding the rate of sediment accumulation. This information may be of guidance in deciding the annual sediment inflow and deposition for the problem of catchment. However, as given in **5.2.2.4**, information obtained through capacity re-survey of reservoirs would have little use unless it is accurate enough. While transferring the rates observed in the adjacent reservoir(s), considerations for differences in the sediment production or trapping characteristics of the cases involved have to be kept in view.

5.2.2.4 Estimates of annual sediment yield/sedimentation rate assessed from past data are further required to be suitably interpreted and where necessary, the unit rates which would apply to the future period are computed by analysing data for trends or by making subjective adjustments for the likely future changes. Where the contributing drainage area is likely to be reduced by upstream future storages, only projects which are currently under construction or those prioritized for completion alongside the project in consideration are taken into account when assessing the total sediment yield. Sediment observation data (*see* IS 4890) is necessary if the yield is being assessed from hydrometric data. If observational methods are inadequate, the possibility of large errors should be considered. For drawing conclusions from reservoir re-surveys, it's crucial to observe a reduction of at least 10 percent or more in the capacities between the two successive surveys. Failure to meet this criterion can lead to inaccuracies in the successive surveys, thus distorting the estimation of capacity reduction between them. If the loss in capacity is small, useful conclusions may not be forthcoming, and in such cases, river sediment measurements with their large observational errors may still provide a better estimate. It is essential to make a proper assessment of sediment yield for the reservoir under study taking relevant factors into account. While calculating sediment yield from reservoir resurvey, any kind of reservoir operation or sediment management strategies such as sluicing/flushing should be taken care of. Any ad-hoc adoption of a sediment yield rate, from experience not fully analyzed, may lead to large errors. The probable rate of sedimentation in any proposed reservoir may be estimated on the basis of sedimentation in the existing reservoirs with similar catchment characteristics, the sedimentation deposits of which have been surveyed over a sufficiently long period {**3.2**(c) of IS 6518}.

5.2.3 *Distribution of Sediment Volume* — Once an assessment of the expected volume of total sediment deposition for the required time period has been made, the revised elevation area capacity curves of the reservoir are prepared by using empirical area reduction methods, for large reservoirs.

5.2.4 *Simulation Studies with Varying Rate of Sediment* — The following are the two ways in which the effect of sedimentation may be considered in the simulation.

a) The first method considers the progressive reduction of capacity every year or for blocks of a few years, and as the simulation progresses, uses the newly updated curve. This method would be more appropriate in bringing out the progressive effects on the reservoir; however, it requires that the simulation be carried out for a long period up to which the benefits of the project are required to be monitored through the simulation.

b) The second method lumps the progressive effect of sedimentation up to an appropriate time horizon up to which no reduction in firm target benefits is contemplated (full service time) and considers situation as at the end of that period throughout the simulation. Thus, though the performance as given by this method is the one that considers the effect of sedimentation up to that period (full service time), the progressive reduction of the dump or secondary benefits within that period should not be brought out in this method. The main advantages of this method are:

1) It is relatively simple, and
2) It does not require that the period of simulation should correspond to the full service time.

5.2.5 *Assessment of Sedimentation Effect on Outputs* — The comparison of the sedimentation studies would bring out the effect of sedimentation, as a vector of the differential performance, as time progresses if method given in **5.2.4**(a) is followed. If the method given in **5.2.4**(b) is followed, it would bring out the change in the range and distribution of the performances over the time period considered. If the studies are for planning purposes, changes in the project features, and necessary progressive adjustment in targeted outputs beyond the full service time would become apparent and the studies may be repeated after modifying the planning decisions.

6 PERFORMANCE ASSESSMENT FOR STORAGE RESERVOIR

6.1 General — The performance of reservoir project under varying hydrologic inputs to meet varying demands is required to be assessed. Although analytical probability based methods are available to some extent, simulation of the reservoir system is the standard method. The method is also known as the working tables, sequential routing, and performance assessment studies, etc. In this method, the water balance of the reservoirs and of other specific locations of water use and constraints in the systems are considered. All inflows to and outflows from the reservoirs are worked out to decide the changed storage during the period. In simulation studies, the inflows to be used may be either historical inflow series, adjusted for future upstream water use changes or a synthetically generated series so adjusted. Whichever approach is used; it shall be used uniformly for assessment of alternate scenarios in regard to sedimentation {*see* IS 5477 (Part 3)}.

NOTE — A synthetic generation of hydrologic series is a technique which involves mathematical modelling of the statistical properties of historical series and the activation of the model to generate alternate equally likely sequences.

6.1.1 A set of practicable and pre-determined operation policies is essential, to such studies; so is the idea of a firm demand which the reservoir shall meet, as long as possible, within the policy and physical limitations. For this purpose, firm irrigation and power and other demands which the reservoir should meet are to be pre-determined. Demands over and above firm demands are considered as secondary or dump demands, meeting of which, although beneficial is not obligatory.

6.1.2 The acceptability of performance as seen in the simulation is decided by checking if the firm demands have been met with the desired reliability: that is, whether these meet the acceptability criteria. In case, these are not met or the performance is better than required, it is customary to change the assumptions and conduct simulation study again in the planning phase of the project. In general, for irrigation and hydro-power projects, it is customary to adopt the following acceptability criteria:

a) Any year or water year in which the firm demands are not met fully in each time period separately is labeled as a failure year.

b) The ratio of failure years to the total years of simulation is determined. For irrigation and hydra-power, the ratio shall not exceed 0.25 and 0.1 respectively. The evaluation of performance may also be made through economic analysis considering the series of benefits from year to year during the period of simulation.

6.2 Time Units and Period of Simulation

6.2.1 In general, for within-the-year projects, a monthly simulation is sufficient for assessing conservational benefits. Shorter period simulation is required for assessing benefits of flood control and secondary power. Units longer than one month may be used for carry over projects. The period of simulation has to be long enough to contain different hydrologic situations which are experienced (*see also* **6.1**).

6.3 Inflows and Demands — The water inflows in the desired time units may be derived from historical data as observed, historical data estimated from hydrologic observations of related phenomenon, or synthetic hydrologic data. The last method has the advantage that it does not make any assumption about the actual flows repeating themselves. In all cases, observed trends in hydrologic data can be projected in the future operational period. Similarly, the effect of the manmade future upstream development may be incorporated, either in the form of time-dependent changes, or in the form of scenario studies, with a pseudo-stationary approach with different levels of development. The pattern of firm demand is decided on the basis of assessment of future energy requirement. Seasonal requirements may or may not be built in the demands. The growth of demands after construction may also be considered.

7 STANDARD PROCEDURES FOR PLANNING

7.1 Procedures for New Storages — A rough assessment in seriousness of the problem is necessary to classify the reservoir sedimentation problem as insignificant, significant or serious. Assessment of reservoir sedimentation problem, in a particular case, may be made by comparing the expected average annual volume of sediment deposition with the gross capacity of the reservoir. If the ratio is more than 0.5 percent per year, the problem is usually said to be serious and special care is required in estimating the sediment yields from the catchment. If it is less than 0.1 percent per year, the problem of siltation may be insignificant and changes in reservoir capacity can be neglected during the studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

7.1.1 The following studies are required if the problem is insignificant:

a) Simulation studies with sediment conditions are not necessary.
b) The feasible service time for the project needs to be decided. Sediment distribution studies to ensure that the new zero-elevation does not exceed the dead storage level may be made.

7.1.2 The following studies are required if the problem is significant but not serious:

a) Both full service time and feasible service time for the reservoir may be decided.
b) Simulation studies for conditions expected at the end of full service time may be made by the procedure explained in **5.2.4**(a) to ensure that firm outputs with required dependability are obtained. The studies used also assess non-dependable secondary outputs, if relevant, available at the end of this period. Studies without sedimentation, with the same firm outputs should bring out the additional potential secondary outputs which might be available in the beginning, and this information may be used, if required in the economic analysis using a linear decrease of these additional benefits over the full service time.
c) Simulation studies beyond full-service time are not essential.
d) Studies as described in **6.1.1** for feasible service time are essential.

7.1.3 The following studies are required if sedimentation problem is serious:

a) All studies as described in **7.1.2** would be required.
b) The secondary benefits available in the initial years should be more in such cases. If these are being utilized, for a proper assessment of the charge of these, a simulation at half of full service time should be required.

c) In these cases, the drop of benefits after the full service time may be sharper. To bring out these effects, a simulation of the project at the end of the feasible service time is required to be done.
d) Considering (a), (b), and (c) together, it may be worthwhile to resort to the more realistic method, given in **5.2.4**(a) in simulation for cases where the problem is serious. For this purpose, it is sufficient to consider sediment trapped in every 10-year block, and to use the expected sedimental elevation area capacity curve at the end of each 10-years block, for simulation of that block.

8 PROCEDURE FOR EXISTING PROJECTS

a) Assess the present elevation area curve either by reservoir re-surveys or by projecting from the earlier survey data, using the estimates of sediment yield and its distribution.
b) Decide the target firm level of the outputs. To start with, this may be based on the earlier planning or on existing situation.
c) Simulate the reservoir by the method described in **4.2.4**(a). It should suffice if 10-yearly block is considered and expected sedimented elevation area capacity curve at the end of each 10 years' block is considered for simulation of that block.
d) Screen the performance to see if the frequency of failures, after proper smoothening tends to cross from an acceptable frequency to an unacceptable frequency (*see* **4.1**). If this is happening, estimate the time of switchover from an acceptable frequency of failures to an unacceptable frequency. It represents the end of the full service time, thus giving an estimate of the residual full service time. If the total full service time (lapsed period plus remaining period) is approximately equal to the prescribed full service time in the criteria, this would show that the actual sedimentation has no effect on the project.
e) For period beyond the full service time, it should be necessary to determine the policy changes in operation which may include measures discussed in **7.1** and **7.2**.

8.1 In hydro-electric projects, the gradual reduction in the total energy generation as a result of partial loss of active capacity can be managed within the system by adjusting the load factor, thus retaining the peaking benefits. It is also important to note that even if the reservoirs for such projects were to become completely silted up, the head available in the reservoir would still provide a permanent benefit.

8.2 In the case of irrigation projects, the reduction in availability of water may be adjusted to some extent by changing the crop pattern and/ or the dependability criteria.

8.3 The simulation shall have to be repeated with these changes. If it is necessary to bring out the overall effect of sedimentation, or the effect of sedimentation due to change in the estimate of sediment load from the earlier planning, it should be necessary to recompute steps given in **7**(a) to (e) for either the no sedimentation case or for the earlier assumption of sediment rate. The time series of the differences in performance should bring out the differential effect.

8.4 If at any time, the new zero elevation crosses the sill levels of an outlet serving a primary purpose, this should indicate the conclusion of the feasible service period. However, the extension of this period can be possible through the implementation of new engineering measures (*see* **8.2**) or due to the natural development of an approach channel.

9 LIFE OF RESERVOIR AND DESIGN CRITERIA

9.1 General — The reservoir exists for a long time and the period of its operation should normally check large technological and socioeconomic changes. The planning assumptions about the exact socioeconomic output are, therefore, likely to be changed during operation, and similarly, the exact implication of socio-economic differences in the output due to sedimentation are difficult to assess. The ever increasing demands due to both increase of population and increases in per capita needs are of a larger magnitude than the reductions in outputs, if any, of existing reservoirs. Thus effects of sedimentation, obsolescence, structural deterioration, etc, of reservoirs may require adjustments in future developmental plans and not simply replacement projects to bring back the lost potential. On a regional or national scale, it is the sufficiency of the total economic outputs, and not outputs of a particular project which is relevant. However, from local considerations, the reduction of outputs of reservoir like irrigation and flood control may cause a much greater degree of distress to the population which has got used to better socio-economic conditions because of the reservoir.

9.2 Life of Reservoir — Life strictly is a term which may be used for system having two functional states ‘ON’ and ‘OFF’. Systems showing gradual degradation of performance and not showing any sudden nonfunctional stage have no specific life period. Reservoirs fall in the latter category.

9.2.1 The term ‘life of reservoir’ as loosely used denotes the period during which or a specified fraction of its total or active capacity is lost. In calculating this life, the progressive changes in trap efficiency towards the end of the period were commonly not considered. In some of the projects, it was assumed that all sedimentation would occur only in the dead storage pocket and the number of years in which the pocket should be filled under this assumption was also sometimes termed as the life of reservoir. This concept was in fact used to decide the minimum size of the pocket. Under this concept, no effect of sedimentation should be felt in the live storage of the reservoir. It has subsequently been established that the sediment occupies the space in the live storage of reservoir as well as the dead storage.

9.2.2 It shall not be possible to express the life of the reservoir as a specific period. The concerned life related terms such as economic life, feasible service time and full service time are defined in **2.2** to **2.4**.

9.2.3 If the operation of the reservoir becomes impossible due to any structural defects, foundation defects, accidental damages, etc, this situation should also signify the end of the feasible service time. Before the expiry of this feasible service time, it may be possible to make large changes in the reservoir (for example, few higher level outlets, structural strengthening, etc) or other measures, if it is economically feasible to do so. If these studies are done, the feasible service time may be extended.

9.2.3.1 *Economic life* — By definition, the economic life cannot be more than the feasible service time. In general, for reservoir projects with gravity irrigation, operation and maintenance costs are so small compared to benefits even from much reduced capacity that economic life should be determined by the feasible sedimentation problem; no check should be required.

10 DESIGN CRITERIA FOR NEW PROJECTS

10.1 General Design Criteria — The design criteria given in **9.1.1** to **9.1.3** are recommended.

10.1.1 *Irrigation Projects* — Full service time shall not be less than 50 years after the start of operation. Feasible service time shall not be less than 100 years after the start of operation. For reservoirs with serious sedimentation problem where extension of feasible service time to overcome social distress is perhaps feasible, the period may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

10.1.2 Far hydro-power projects expected to supply power to a community, in isolation the feasible and full service time shall be the same as for the irrigation projects.

10.1.3 For hydro-power projects supplying power to a grid, full service time shall not be less than 25 years. Feasible service time shall not be less than 70 years. For reservoirs with serious sedimentation problem where extension of feasible service time to overcome social distress is perhaps feasible, the periods may be suitably reduced, provided detailed studies as detailed therein are done, and also provided that rigorous economic analysis up to the feasible service time and with changing stream of benefits is made.

11 CONSIDERATION OF EFFECTS OF SOIL CONSERVATION PROGRAMME

11.1 Soil conservation may lead to reduction of sediment. This programme, apart from benefiting downstream reservoir, could have large beneficial effects on production of the protected area. However, because of the different areas benefitted, socio-economic implication, etc, these programmers normally are not included in the economic analysis of the reservoir project. Therefore, any change in trend of sediment yield, attributable to such programmers, may not be considered in assessment of performance of the reservoir. If economic feasibility of the soil conservation programme is to be established, any properly established reduction of yield, and its effect on the reservoir benefits may be considered in that analysis.

11.2 Normally at the project planning stage, the sediment load calculations used in the sedimentation studies are as per the land use existing then. If adverse human actions come into operation in the catchment, it may result into a higher sediment load than the one assumed in the project planning. This should be reflected in the project.

ANNEX A
(*Clause* **5.2.2.1**)

TYPICAL EXAMPLE TO CALCULATE TRAP EFFICIENCY

A-1 GENERAL

A-1.1 Trap efficiency of a reservoir, over a period is the ratio of the total deposited sediment to the total sediment inflow. Gunnar Brune analyzed data from 44 reservoirs with catchment areas varying from small to very large and presented a median curve together with lower and upper envelope curves which is shown in Fig. 1. Using data from Tennisse Valley Authority, M.A. Churchil developed a relationship between the percentage of incoming sediment and the sedimentation index of the reservoir and presented a curve which is shown in Fig. 2.

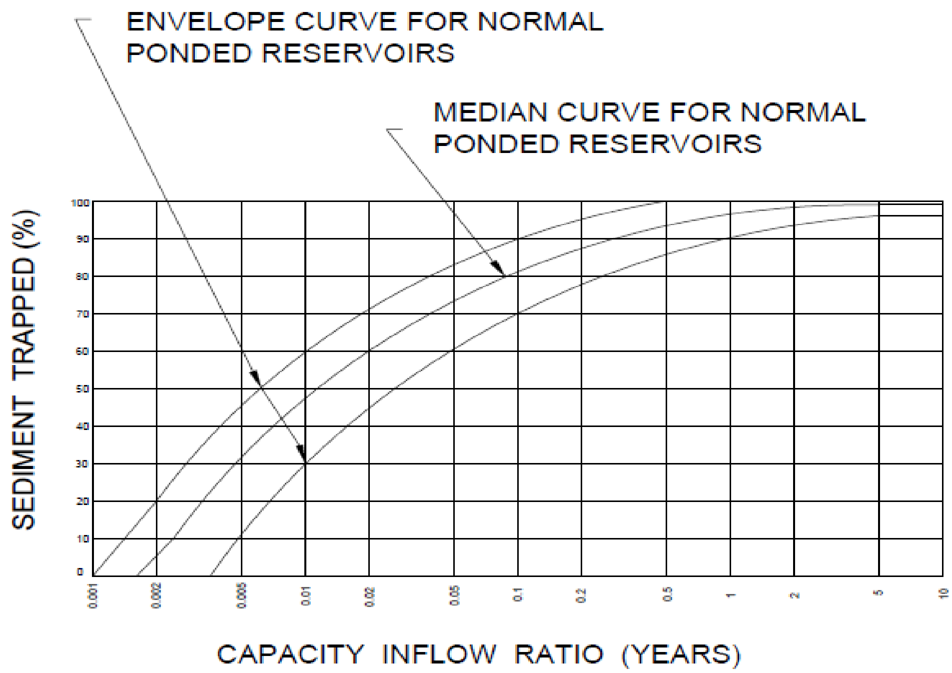

FIG. 1 BRUNE'S CURVE

A-1.2 Description of Terms in Brune's Curve

a) *Capacity* (C_1) — Reservoir capacity at FRL
b) *Inflow* — Average annual inflow in volumetric units.

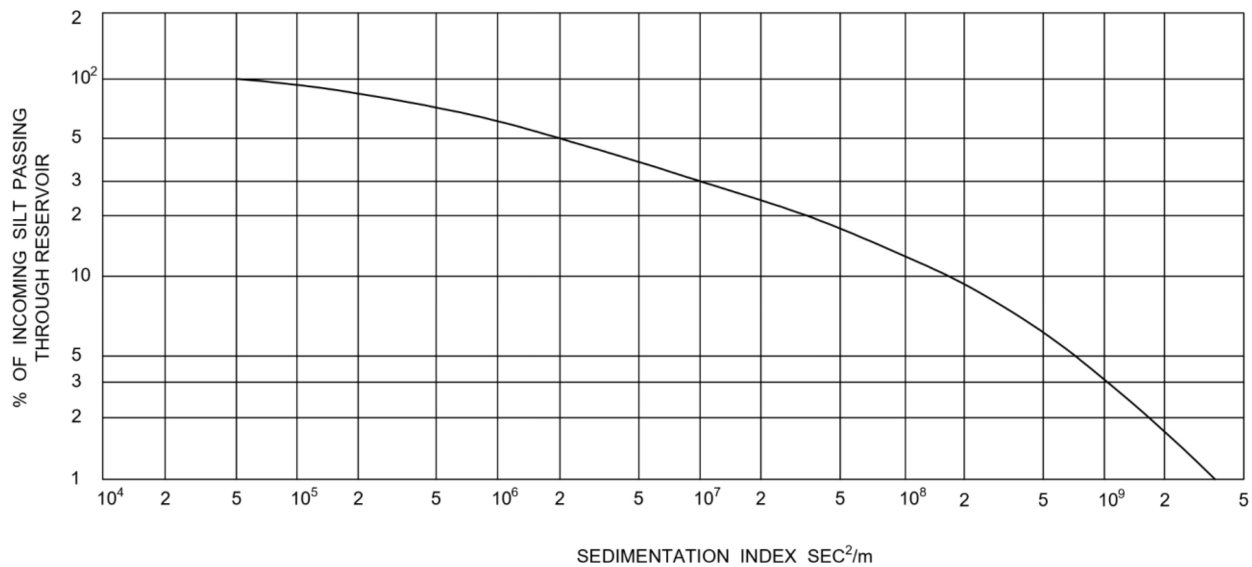

FIG. 2 CHURCHIL'S CURVE

A-1.3 Description of Terms in Churchil's Curve

a) *Capacity* (C_2) — Reservoir capacity at the mean operating pool elevation for the period considered.
b) *Inflow* (I) — Average inflow rate during the study period.
c) *Period of Retention* — Capacity divided by inflow rate. Retention
d) *Length* (L) — Reservoir length at mean operation pool level.
e) *Velocity* — Mean velocity obtained by dividing the inflow by the average cross-sectional area. The average cross-sectional area is computed by dividing capacity by length.
f) *Sedimentation Index* — Period of retention divided by the velocity.

A-2 EXAMPLE

A-2.1 Reservoir Data

a) Full reservoir level

(FRL) = 400

b) Mean operating pool elevation = $399\ m$
c) Capacity at FRL, C_1= 55.1 x 10^6 m^3
d) Capacity at mean operating pool elevation, C_2= 51.5 X 10^6 m^3
e) Average inflow, I, over the study period of 10 years, in volumetric Units = 1 380.06 x 10^6 $m^3/year$

f) Length of reservoir, L, at the mean operating level = 19 312.13 m

A-2.2 Brune's Method

Capacity inflow ratio

$$C_1/I = \frac{55.1}{1\ 380.06}\ 0.0399\ \text{year}$$

Trap efficiency corresponding to above ratio C/I as read from median curve of Fig. 1 for normally ponded reservoir = 75 percent

A-2.3 Churchil's Method

a) Average inflow ratio (I) = 1 380.06 x 10^6 $m^3/year$
= 43.76 m^3/sec

Retention period $\frac{C_2}{I} = \frac{51.5 \times 10^6\ \text{m}^3}{43.76\ \text{m}^3/\ \text{sec}} = 1.176\ 9\ \times\ 10^6\ \text{sec}$

Average cross-sectional area (A) = $\frac{C_2}{L}$

$$= \frac{51.5 \times 10^6\ \text{m}^3}{1\ 9312.13\ \text{m}} = 2\ 666.7\ \text{m}^2$$

Velocity= $\frac{I}{A} = \frac{43.76\ m^3/\text{sec}}{2\ 666.7\ \text{m}^2} = 0.016\ 41\ \text{m/sec}$

Sedimentation index = $\frac{\text{period of retention}}{\text{velocity}}$

$$= \frac{1.1769 \times 10^6\ \text{sec}}{0.016\ 41\ \text{m/sec}} = 7.1718\ \times\ 10^7 \text{sec}^2/\text{m}$$

Percentage of incoming sediment passing through as read from Fig. 2 corresponding to above sedimentation index = 15 %.

Trap efficiency = $100 - 15$ = 85 %.