



Rectangular Desilting Basin as Upstream Physical Barrier for Interception of Turbidity Causing Fine-grained Particles of Mineral Origine Carried Along with Surface Runoff Feeding the Lake: A Case Study of Jait Sagar Lake, Bundi, Rajasthan, India

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Abstract

Lakes in hot semi-arid climatic condition are susceptible to turbidity and degraded water quality parameters, due to routine influx of fine-grained mineral particles along with surface runoff contributing to the contained waters in the lakes. Turbidity causing mineral particles originate as a result of fluvial erosion of exposed and often weathered rocky outcrops and unconsolidated sediments within the catchment of the lake; that gets transported to the lake in suspended state along with surface runoff generated after events of torrential rains. These, turbidity causing suspended particles primarily consist of very fine-grained mineral particles comprising of clay, silt, salts, non-metallic and metallic minerals along with some debris of organic origine; together they provided nourishment supporting the growth of autotrophic microorganism (phytoplankton and filamentous algae) in the contained waters of the lake. Fine-grained mineral particles, autotrophic microorganisms and gaseous microbubble collectively cause the actual turbidity in the contained waters of the lake in a state of colloidal equilibrium. This research paper attempts to address the issue of turbidity due to continuous influx of fine-grained mineral particles along with surface runoff entering in the contained waters of the lake, by installation of an upstream physical barrier in the streamlet supplying surface runoff to the lake; as a case study for Jait Sagar Lake, Bundi, Rajasthan, India. The paper presents an easy to construct, customizable design of rectangular desilting basin with baffling structure as an upstream physical barrier, for the envisaged interception of suspended mineral particles flowing along with runoff, prior to their entry into the lake; that is achieved by reducing the flow velocity of runoff. The paper also examines the functional efficiency of rectangular desilting basin by sampling and measurement of post intervention turbidity (in NTU) for two seasons (pre-monsoon and post-monsoon) and its comparison with pre-intervention (baseline) turbidity of two seasons at same sampling locations. The outcome of this comparison has provided scientific evidence in favour of functional efficiency of this engineering intervention, that has reduced overall turbidity in contained waters of the lake in excess of 50% for both the seasons (pre-monsoon and post-monsoon season). This design of rectangular desilting basin with baffling structures can be replicated in many other lakes/reservoirs situated in arid and semi-arid regions across the globe for successful interception of suspended mineral particles from the runoff, well-before their entry in the contained waters of the lakes and reservoirs.

Keywords: Desilting Basin; Turbidity Reduction; Jait Sagar Lake; Semi-Arid Lakes; Runoff and Sedimentation; Lake Water Quality

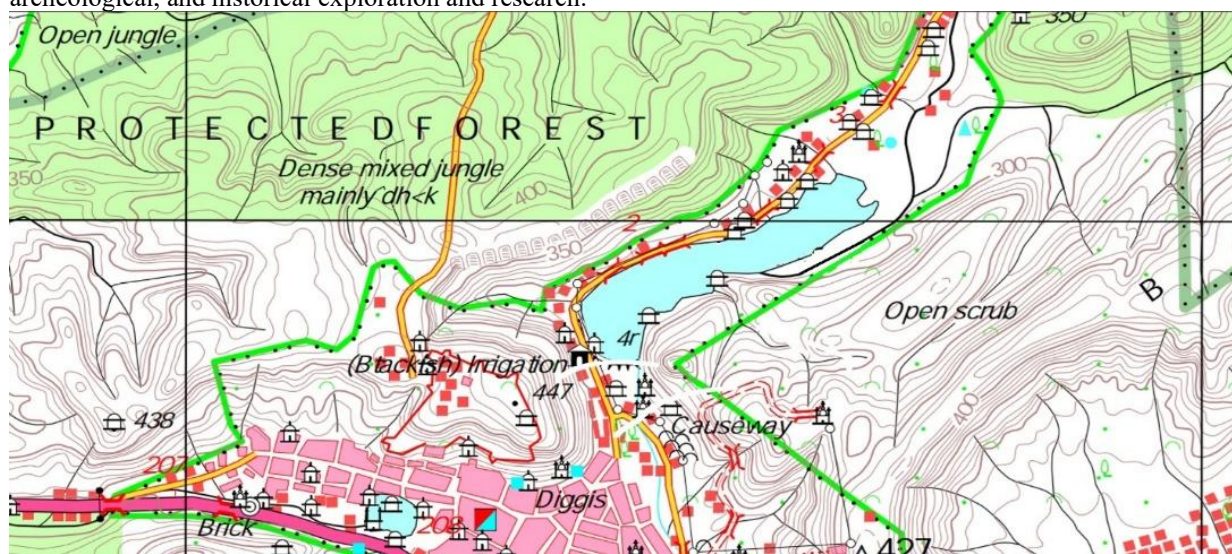
1. Introduction

In arid and semi-arid regions, lakes are very important for biodiversity and human society, as a source of drinking water and other life supporting uses of humans, livestock, wildlife; and it also regulates the local microclimate. Lakes, rivers and waterbodies have been revered in India since the beginning of human civilization; culture in India has ingrained practices pertaining to the protection, restoration, rejuvenation, and conservation of lakes and its catchment. Significance of lakes further increases in water starved semi-arid conditions in Rajasthan; where people and their rulers have done meticulous efforts to maintain lakes and waterbodies in pristine conditions. In the instant case study, Jait Sagar Lake in Bundi District of Rajasthan, India has been studied for addressing the issue of turbidity caused by routine influx of fine-grained mineral particles along with the surface runoff contributing to the lake. In this research paper interception of turbidity causing mineral particles have been achieved by installation of an upstream physical barrier in the streamlet feeding surface runoff into the lake.

1.1. An Introduction to Jait Sagar Lake for the Case Study

Jait Sagar [25°27'26.49"N 75°38'55.32"E] is a picturesque lake once renowned for its pleasant floral fragrance in the ambience, emanating from blooming flowers of lotus in the lake, particularly from March to October in every calendar year. This natural lake is surrounded by hills, dominated by exposed rocky outcrops, within a dry deciduous forest, belonging to Ramgarh Vish Dhari Tiger Reserve. The lake is on the southern edge of this tiger reserve, located at a distance of three kilometers from the city of Bundi. Taragarh Fort is to the Southwest of the lake; towering walls of Taragarh Fort Complex surrounds the lake; there are four gateways in this wall, that serve as entry points to the lake. Sukh mahal palace and an old temple are situated on the bank of the lake along with some antiquities and artifacts, that have been preserved in the courtyards of Sukh Mahal. This lake and its immediate environs have immense significance for its unique hydrology, limnology, geology, geomorphology, geo-hydrology, ecology, wildlife, archeological heritage, history, culture, antiquities, and artifacts associated with the lake. Alongside these, there are

reports of paleontological remains of some megafauna in the region; egg shell remains of extinct ostrich species have been discovered in this area. That makes the immediate environs of the lake significant for paleontological, archeological, and historical exploration and research.



Topographic Map of Jait Sagar Lake on a scale of 1:50,000 [Sources: Survey of India Topographic Sheet No.G43 P11]

1.2. Historic and Cultural Perspective of the Lake

There exists a strong connection of local people of south-eastern Rajasthan [popularly known as Hadoti Region] with Jait Sagar Lake. The lake is an important tourist attraction in the region for multiple perspective, that attracts tourists of diverse interest.

The region around Jait Sagar Lake has a rich historic, archeological, and cultural background, starting from pre-historic times of early hunter gatherer societies, who have made some cave painting in the region. Continuous human presence around this lake is recorded since ancient historic times, that continues till date. Water holding capacity of Jait Sagar had been augmented by construction of a regulatory structures along the outlet channel by a stone masonry structure around 8th century CE. The lake had immense significance during the era of Hada Rajput Kingdom of Bundi State, who conserved, protected and meticulously maintained this lake. An episode of major restoration work for this lake was undertaken in 14th and 15th century CE by Maharani Gehlotni Jayvanti Bai, the mother of Rao Raja Surjan Singh; her notable restoration work included removal of silt deposited at the bed of the lake (desilting), bank restoration, maintenance and/or reconstruction of regulatory structures at the outlet, removal of unwanted weeds and riparian vegetation; and protection of desirable aquatic flora like lotus. Maharani Jayvanti Bai developed the lake into an aquatic garden with turquoise water and sweet floral fragrance emanating from blooming lotus in the lake; that created mesmerizing effect in the ambient air around the lake. Numerous nobilities, European dignitaries and officers visited this lake, stayed in Sukh Mahal Palace on the bank of this lake to get engrossed in the fragrance and picturesque views; the long list of dignitaries includes history chronicler Col. James Todd to novelist Rudyard Kipling. With the end of British Rule and merger of princely states in Union of India, Jait Sagar Lake was subjected to new priorities and changed utility. In changed circumstances, the lake became a source for municipal water supply to the city of Bundi. This fundamental shift in utility of the lake, adversely impacted ecological health and aesthetics of the lake and its catchment. The catchment of this lake witnessed widespread degradation in forest cover and change in land-use pattern; that caused enhanced weathering of exposed rocky outcrops and unconsolidated sediments, followed by fluvial erosion, enhanced transport of fine-grained mineral particles along with surface runoff into the contained waters of the lake. Added inflow of mineral particles has increased turbidity in the contained water of Jait Sagar Lake and notable decline in water quality parameters, that created public demand in favour of rejuvenation and conservation of lake, including long-term solution to the issue of turbidity, so that the lake remains a tourist attraction.

1.3. Efforts to Rejuvenate and Conserve Jait Sagar Lake in Last Decade

Persistent public demand was addressed by a structured approach dedicated to restoration, rejuvenation and conservation of Jait Sagar Lake under National Lake Conservation Plan (NLCP), Phase - II under the Team Leadership of the author of this research paper. The Detailed Project Report was prepared under NLCP, that included comprehensive planning for restoration of aquatic environment of the lake, including the issue of turbidity in the contained waters of the lake. Key recommendation for rejuvenation of the lake in this plan included: (i) sediment removal/de-silting from the bottom of the lake; (ii) interception of mineral particles entering in the lake along with surface runoff by construction of an upstream physical barrier; (iii) bioremediation to control and manage existing autotrophic microorganisms; (iv) installation of oxygen micro-bubble supply system for the contained waters of the lake through perforated piped network installed at the bottom of the lake. Sediment removal and de-weeding have already been executed in the lake as per the recommendations of the DPR under NLCP; followed by construction of desilting basin for interception of fine-grained mineral particles carried in suspended state along with surface runoff contributing to the contained waters of the lake, as elaborated in this research paper.

1.4. Source of Turbidity Causing Mineral Particles

Geologically Jait Sagar Lake is situated in a region where Vindhyan Sedimentary Rocks meet the older, more resistant Pre-Vindhyan Metamorphic/Meta-sedimentary Rocks along a major reverse fault known as – ‘The Great Boundary Fault (GBF)’. This tectonic activity has caused significant upliftment of land on one side of the fault compared to the other side, creating a well pronounced escarpment along the fault line. Tectonic activity has displaced geological formations, creating a series of topographic depressions along the lineament of escarpment; that got filled by fresh water forming a number of tectonic lakes, including Jait Sagar.

Catchment of this lake is dominated by exposed rocky outcrops crisscrossed by structural deformations, joints, and faults, and relatively thin layer of unconsolidated sediments deposited on top of the weathered and weakened rock formations. Climatic condition leading to significant variation in diurnal temperature impacts exposed rocky outcrops, that gets subjected to thermal weathering, a characteristic of semi-arid region. Chemical weathering is another phenomenon, responsible for degeneration of exposed rocky outcrops, that goes simultaneously with thermal weathering. As a result of combined action of both these phenomenon of weathering, rocky outcrops in the catchment of this lake, gradually lose their mechanical strength to withstand as a competent rock formation; ultimately degenerating into fine to ultra-fine grained mineral particles, comprising of a complex mixture of quartz (SiO_2); feldspar; mica as dioctahedral and trioctahedral phyllosilicates; hydrous aluminum silicates in form of phyllosilicates in tetrahedral and octahedral sheetlike structure with variable amounts of magnesium, iron, potassium, sodium, and calcium; other silicates in mineral form; calcium carbonate; oxides and hydroxides of iron in various chemical complexes; chlorides; salts of sodium, potassium and magnesium; non-metallic and metallic minerals; other rock fragments depending upon their source rock formation; and some organic matter. These particles are broadly classified into fine grained sand, silt, and clay minerals along with soluble and semi-soluble salts; that is available for fluvial erosion, transportation, dispersal and deposition along with surface runoff after events of torrential rain, that is common during monsoon season. Fluvial erosion in the catchment of the lake provides routine supply of dissolved, suspended and transported solids of mineral origine along with surface runoff, that eventually accumulates in the contained waters of the lake either in suspended form causing turbidity or gets deposited at the bottom of the lake leading to relatively rapid sedimentation at lake’s bed, reducing net water storage capacity of the lake. Runoff feeding the lake also transports some fine fragments/debris (almost of particle size) of organic origin, originating from dead terrestrial and riparian plant materials, and decomposed carcasses of terrestrial animals, that is often disposed along the streamlets as a cultural practice in the region.

Role of agricultural runoff into the lake is insignificant/nonexistent, since large part of the catchment is designated as forest land under a tiger sanctuary with strict law enforcement. There is no municipal sewer outfall in the lake and other degrading factors of anthropogenic origine that could cause turbidity is also nonexistent.

1.5. Turbidity in Jait Sagar Lake

In Jait Sagar Lake, routine supply of fluvially transported fine to ultrafine grained mineral particles, organic debris, and gaseous micro-bubbles support the growth of autotrophic microorganisms (phytoplankton and filamentous algae). Phytoplankton in the lake forms the essential foundation of almost entire aquatic food chain in the lake, making it possible for the zooplankton, herbivorous invertebrates and ichthyofauna to survive, grow, and multiply their numbers; that provide food and energy to the next trophic level. Nevertheless, continuous supply of turbidity causing mineral particles results into accumulation and enrichment to the extent, that becomes counterproductive for the aquatic ecosystem; some of its adverse impact includes: reduction in available sunlight for photosynthesis of submerged and benthic flora, reduction in availability of dissolved oxygen in the contained waters of the lake, increase in chemical oxygen demand (COD), and increase in temperature of aquatic system of the lake etc.

Turbidity in freshwater aquatic system of Jait Sagar Lake is due to a dynamic equilibrium of colloidal mixture comprising of fine to ultrafine grained mineral particles, dead organic debris, phytoplankton (live autotrophs) along with trapped gaseous micro-bubble; that is somewhat stable, until the state of equilibrium is disturbed. Due to this phenomenon, trapped mineral particles in the colloidal mixture remain in suspended state for a longer duration within the contained waters of lake i.e. they do not settle-down easily by action of gravity. Settlement pattern of mineral particles trapped in a colloidal mixture within the contained waters of the lake is noticeably different from the settlement pattern of mineral particles in open channels conveying freshwater (as in the case of streamlets feeding Jait Sagar Lake), where reduction in flow velocity/stagnation leads to relatively rapid settlement of suspended mineral particles. Therefore, to address the issue of turbidity in the contained waters of the lake, dynamic equilibrium among various ingredients of the colloidal mixture causing turbidity, needs to be destabilized; that is achieved by removing or intercepting the supply of one or more key ingredients of this colloidal mixture.

Most of the lake management regime views turbidity in contained waters of the lake from a particular standpoint; often as an exclusive and endemic problem of aquatic ecology attributed to excessive growth of autotrophic microorganisms. In majority of the rejuvenation and conservation schemes for lakes, control/prevention of turbidity have been attempted by administering either chemical additives or bioremediation, targeting autotrophs thriving within the contained waters of the lake. Chemical additives are effective in controlling turbidity for a fixed time frame; i.e., their effect lasts till the added chemical reagents are present in the water for their intended chemical actions; nevertheless, this approach to the problem of turbidity leaves behind secondary impacts on aquatic environment due to the fact that chemical residue gets deposited at the bottom of the lake. Another approach to management and containment of turbidity in lakes is bioremediation; that is also an effective way of managing turbidity by targeting phytoplankton and blooming filamentous algae. In both these approaches pertaining to the management of turbidity, problem is addressed without intercepting the routine influx of turbidity causing mineral particles and nutrients in the lake along with surface runoff entering into the contained waters of the lake. Therefore,

the issue of turbidity, predominantly due to continuous supply of turbidity causing mineral particles, cannot be resolved by chemical additives and/or bioremediation within the contained waters of the lake; in such a situation, upstream interception of turbidity causing mineral particles is required so that these particles could not enter in the contained waters of the lake; that is exactly the case of Jait Sagar Lake.

2. Scope of Research

This research paper attempts to provide a long-term solution to the problem of turbidity due to fine-grained mineral particles carried along with the surface runoff, by interception of these particles using an upstream physical barrier, prior to their entry and integration into the contained waters of the lake. This upstream physical barrier is created by installation of a rectangular desilting basin at a suitable location on firm grounds, in the open channel (of the streamlet) feeding surface runoff generated by stormwater, into the lake. The paper presents an easy to construct design of rectangular desilting basin with baffling structures, along with details pertaining to the minimum design dimensions, their adequacy, and functional efficiency in interception of suspended mineral particles.

This research paper has been structured to deal with: (i) an account of the design of rectangular desilting basin with baffling structures, installed in the open channel of the streamlet feeding the lake, for interception of mineral particles and debris prior to their entry in the lake; and (ii) quantitative comparison of post intervention turbidity data for two seasons (pre-monsoon and post-monsoon) with respect to pre-intervention turbidity (baseline) data for two seasons (pre-monsoon and post-monsoon) at two depth levels, monitored at four pre-identified points of observation in the lake.

3. Rectangular Desilting Basin with Baffling Structure

Rectangular desilting basin with baffling structure has been conceptualized and constructed as in-situ cast concrete structure in the open channel of streamlet feeding Jait Sagar Lake, with following design principles.

3.1. Design Principles

Design principle in instant research paper for the rectangular desilting basin with baffling structure is based on the phenomenon of precipitation of suspended mineral particles on reduction (or stagnation) in flow velocity of runoff carrying these particles in the open channel. Therefore, by creating an upstream physical barrier, the flow velocity is reduced to an extent, that suspended mineral particles precipitates at the bed of desilting basin and could not get resuspended. Precipitation of mineral particles is achieved by the action of gravity on each of the particle; since the forces responsible for their suspended state and forward movement along with the runoff, significantly weakens or cease to exist after reduction (or stagnation) in velocity of flow. This endeavor is achieved by an adequately designed rectangular desilting basin with baffling structure, installed in the open channel of the streamlet through which the surface runoff flows into the lake; this intervention reduces the flow of surface runoff to the extent that allows suspended mineral particles to settle down (precipitate) at the bottom of desilting basin and prevents resuspension of these settled particles. The conceptual basis of this design principle is based on 'Manual on Simple Methods for Aquaculture – Version 2'; published by Food and Agriculture Organization.

The design of desilting basin is specific to a target particle size intended to be precipitated by action of gravity. Rate of settlement of these particles is governed by the concept of 'settling velocity' and 'horizontal critical velocity'.

Settling Velocity [V_s (in m/s)] is the ability of suspended particles flowing through the open channel (of the streamlet) to settle down at the bottom of the waterbody [desilting basin] with decrease in velocity of flow under the action of gravity, that acts on each of the suspended particles. Settling velocity is directly proportional to the size of suspended particle; i.e., with decrease in size of suspended particles flowing along with the runoff, settling velocity will also decrease.

Horizontal Critical Velocity [V_c (in m/s)] is velocity of flowing water needed to pick up and carry away a particle from the bed/base of the waterbody after it has been settled down; therefore, it is an important factor in dealing with effective settlement of suspended particles. Horizontal critical velocity is also directly proportional to the size of particles; i.e., this velocity also decreases as particle size decreases.

Typical values for settling velocity (V_s) and horizontal critical velocity (V_c) for mineral particles have been experimentally established, that has been universally recommended by FAO as presented in Table -1.

Table – 1: Relation between Settling Velocity [V_s (m/s)], Horizontal Critical Velocity [V_c (m/s)] and Diameter of Mineral Particle Flowing in State of Suspension

	Diameter of Mineral Particle (mm)										
	0.05	0.10	0.20	0.30	0.40	0.50	1.00	2.00	3.00	5.00	10.00
V_s (m/s)	0.002	0.007	0.023	0.040	0.056	0.072	0.15	0.27	0.35	0.47	0.74
V_c (m/s)	0.15	0.20	0.27	0.32	0.38	0.42	0.60	0.83	1.00	1.30	1.90

Source: Section 11.6 Settling basins; Chapter 11 Flood and Silt Control Structures; Manual on Simple Methods for Aquaculture – Version 2; FAO Training Series; ISBN: 9789250056128

3.2. Design of Rectangular Desilting Basin with Baffling Structures for Jait Sagar Lake

In case of rectangular desilting basin for Jait Sagar Lake, target diameter of mineral particles for settling down from the state of suspension has been considered as 0.05mm (50 micron) and all other particles above this size; therefore, settling velocity (V_s) and horizontal critical velocity (V_c) for the target mineral particles of this size are 0.002 m/s and 0.15 m/s respectively (Table – 1). Therefore, the design parameters for rectangular desilting basin with baffling structures has been considered accordingly to deal with this target particle size. This desilting basin has been constructed in the open channel of the streamlet contributing to the lake as an in-situ casted concrete structure.

Baffling structure has been added to enhance settling efficiency by increasing effective path of retarded/reduced flow velocity that also provides additional time for settlement of suspended mineral particles under the action of gravity. Standard simplified design for rectangular desilting basin with baffling structure adopted for Jait Sagar Lake has been presented in Figure – 1.1 (Section Drawing/Profile) and 1.2 (Plan). Design criteria adopted for rectangular desilting basin with baffling structures includes following subcomponents:

3.2.1. Design Area for Horizontal Base Floor [β] (in m^2)

Horizontal Base Floor [β] for the rectangular desilting basin has been designed on the basis of empirical equation – 1:

$$\beta = (Q/V_s)\xi \quad (1)$$

In this equation:

Q (in m^3/s) is the maximum water to be discharged per second;

V_s (in m/s) is the settling velocity for the smallest particle size to be removed; and

ξ is the end allowance factor for extra space at each end needed to allow the water to run smoothly and evenly. For the in-situ cast concrete structure, typically, $\xi = 1.3$ or 1.4 .

Therefore, design area for horizontal base floor for rectangular desilting basin for Jait Sagar Lake [β] = $[2.5/0.002]*1.3 = 1,625 \text{ m}^2$

In which,

Targeted Diameter of Particle = 0.05 mm

$Q = 2500 \text{ l/s} = 2.5 \text{ m}^3/\text{s}$

$V_s = 0.002 \text{ m/s}$

Therefore, design area of the horizontal base floor of the rectangular desilting basin for settlement (precipitation) is 1625 m^2 to settle down 100% of the targeted particle diameter of 0.05 mm (or larger in size) of mineral origine. Partially particles smaller than 0.05 mm will also get settled down at the horizontal base floor of rectangular desilting basin, due to slightly longer and zig-zag path created by the baffling structure, that further retards the flow velocity and increases the retention time of flow. However, this is also a fact that in case if proportion of particles smaller than 0.05 mm is more in the surface runoff, then in such a scenario percentage of precipitation/suspension of particles will be less.

3.2.2. Design Cross-Section (in m^2) of Desilting Basin [A]

Design cross-sectional area of the rectangular desilting basin [A] has been designed on the basis of empirical equation – 2:

$$A = Q/V \quad (2)$$

In this equation:

Q (in m^3/s) is the maximum water to be discharged per second out of desilting basin in to the lake;

V (in m/s) is the selected water velocity for discharge of the desilting basin (into the lake); that has to be less than the horizontal critical velocity (V_c) to avoid resuspension of mineral particles (if the mineral particles are resuspended then they have the potential to enter in the lake along with discharge released from the desilting basin). Size of smallest particles intended to be settled down at the bottom [for removal out] of the rectangular desilting basin is considered as a factor in design of the cross-section area of the desilting basin.

Therefore, in instant case, cross-sectional area of the rectangular desilting basin for targeted diameter of mineral particles of size 0.05 mm or more has been considered in the design; for which the horizontal critical velocity (V_c) is 0.15 m/s .

Since for effective desilting $V_c > V$

Therefore, in case of rectangular desilting basin for Jait Sagar Lake, Selected Water Velocity (V) has been taken as 0.10 m/s , to avoid resuspension and removal of particles of diameter equal to or greater than 0.05 mm (for which, $V_c = 0.15 \text{ m/s}$).

For Jait Sagar Lake, design discharge Q has been taken as $2.5 \text{ m}^3/\text{s}$; i.e., that is the maximum discharged out of desilting basin, that will go into the lake;

With these factors, cross-section of the desilting basin

$A = 2.5/0.10 = 25 \text{ m}^2$.

3.2.3. Design Width (in m) of Rectangular Desilting Basin [ω]

Design width (in m) of the rectangular desilting basin [ω] has been taken up on the basis of empirical equation – 3:

$$\omega = A/h \quad (3)$$

In this equation,

A (in m^2) is the cross-section area; and

h (in m) is the maximum water depth in the rectangular desilting basin

Therefore, for the rectangular desilting basin of Jait Sagar Lake,

$A = 25 \text{ m}^2$ and

$h = 1.25 \text{ m}$

then the width (ω) of the desilting basin = $25/1.25 = 20 \text{ m}$.

3.2.4. Design Length (in m) of Desilting Basin [L]

Design length (in m) of the rectangular desilting basin [L] has been taken up on the basis of empirical equation – 4:

$$L = \beta/\omega \quad (4)$$

In this equation,

β (in m^2) is the horizontal area; and

ω (in m) is the width.

Therefore, for in instant case

Standard length (L) = $1625/20 = 81.25$ m.

3.2.5. Design Slope of the Horizontal Base of Desilting Basin

To facilitate a smooth flow, standard design slope of 2% has been considered in the design of the desilting basin between the entrance point to the outlet point.

3.2.6. Ratio of Design Length and Width

The ratio of design length and width [$L : \omega$] has been planned in conformity to the internationally accepted design recommendation of FAO; that is typically considered between 2:1 and 5:1. In case of the rectangular desilting basin for Jait Sagar Lake,

$$L : \omega = 81.25 : 20 = 4 : 1$$

3.2.7. Level of the Horizontal Base of the Rectangular Desilting Basin

The horizontal base of the rectangular desilting basin is designed for construction at a lower level compared to the bed level of the streamlet feeding surface water runoff in the lake; and it has been ensured that the bed of the outlet channel is also slightly higher than the base level of the basin. This is designed and constructed to concentrate the precipitated/suspended mineral particles targeted to be removed out of the surface water runoff prior to its entry into the lake.

3.2.8. Readjustment/Improvement in Dimensions of Designed Rectangular Desilting Basin

Design dimensions of rectangular desilting basins are flexible for readjustment within the available land for construction, as long as the critical velocities are not exceeded; i.e., design dimension of desilting basin is open for readjustment and re-shaping to fit within locally available space, to avoid land purchase, tree felling, and limit construction cost of the structure. In space constrained situation, design dimension of rectangular desilting basin can be wider, with a larger cross-section, that will allow the standard design length to be shorter. Nevertheless, in instant case of rectangular desilting basin for Jait Sagar Lake, such changes are not required.

The foundation of the in-situ cast concrete structure is pitched and leveled, so that no possibility remains for sinking or development of cracks and failure of the structure. Thickness of bed and wall is casted with adequate steel reinforcement.

Design dimensions of rectangular desilting basin to deal with the target particle size of the order of 0.05mm and above are presented in Table – 2.

Table – 2: Design Dimensions of Rectangular Desilting Basin for Jait Sagar Lake

		Design Dimension
Inside width = ω (in m)		25.00m
Inside length = L (in m)		81.25m
Depth (in m)	water depth (h in m)	1.25m
	freeboard (0.20 m)	0.20m
	settling depth (0.10 to 0.30 m)	0.30m
Total Depth = D (in m) = water depth (h in m) + freeboard (0.20 m) + settling depth (0.10 to 0.30 m)		1.75m
Net Slope of Bottom Surface in the Desilting Basin		2%
Net Volume of the Desilting Basin = $\omega * L * D$ (m^3)		= $25 * 81.25 * 1.75$ = $3554.69m^3$
Ratio of Length : Width [$L : \omega$] [Recommended Range of 2:1 to 5:1]		= 4 : 1

3.2.9. Additional Design Features Added in to the Rectangular Desilting Basin

Some additional design features added to the standard design of rectangular desilting basin, that includes:

3.2.9.1. Water Spreading Features

A. At the entrance of rectangular desilting basin, water spreading structure has been incorporated in the design to ensure that the water will pass over a wide edge near the entrance into the desilting basin from the feeder streamlet. This has been included in the design to minimize disturbances in the flow of water, similar to that of a weir.

B. At the exit point of the rectangular desilting basin, a structure has been made to spread the flow over a wide edge near the outlet of the desilting basin.

3.2.9.2. Protection from Cross-wind Exposure

The plan and directional sighting of the entire structure have been done to avoid cross-wind exposure since that can potentially agitate the water, causing re-suspension of precipitated particles at the horizontal base of the rectangular desilting basin.

3.2.9.3. Structural Element to Baffle the Flow to A Zig-Zag Path

Baffling structural features have been added in the designed rectangular desilting basin to compel the flow of runoff to pass through a zig zag path to baffle the flow; that further retards the flow velocity of runoff. Addition of the baffling feature at a regular interval in the desilting basin has effectively increased the length/distance to be covered by the runoff; that also increases the effective retention time of runoff in the desilting basin, that facilitates precipitation of additional ultrafine particles. The baffling structure ensures that the water flows evenly and quietly through the desilting basin avoiding turbulence or rapid flow. Schematic design of this baffling structure in the rectangular desilting basin is presented in Figure – 1.2.

3.2.10. Silt Removal Regime for the Designed Desilting Basin

A management plan for clearing of suspended mineral particles has been recommended, that should be done on

regular basis at least once in three months in the dry season ensuring that the basin is cleaned before onset of monsoon season and after the retreat of monsoon. Ideally, clearing should also be done after every event of increased runoff due to major torrential rain. Clearing should be done after closing the water supply for a short interval. This accumulated sediment/silt can also be removed using a simple siphon or succussion device. The mineral articles/sediment accumulated at the base of the desilting basin is very fertile, that can be used in nurseries of forest department or in the gardens maintained by municipal bodies to grow the plants.

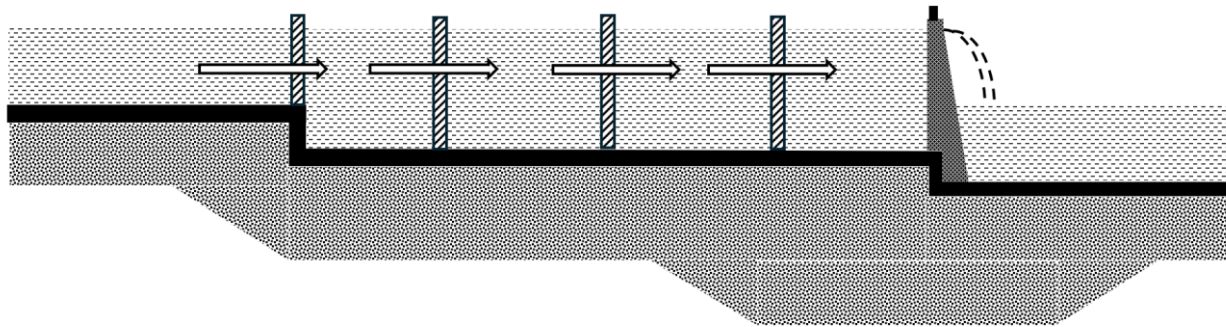


Figure – 1.1: Simplified Section Drawing of Rectangular Desilting Basin for Jait Sagar Lake

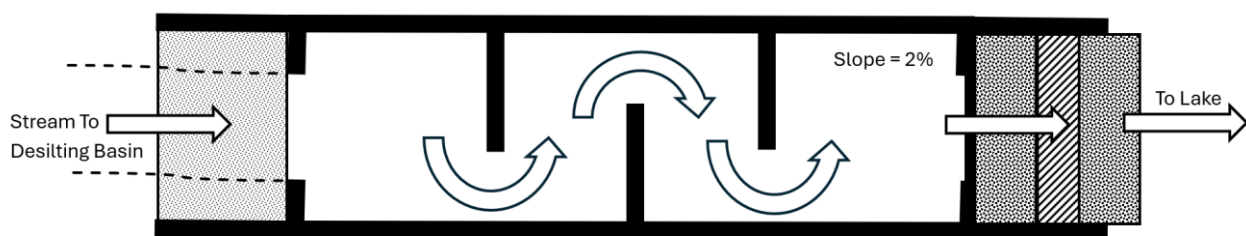


Figure – 1.2: Simplified Plan of Rectangular Desilting Basin for Jait Sagar Lake with Baffling Structures

4. Turbidity in Jait Sagar Lake

Four locations within Jait Sagar Lake were taken up in this research as Observation Points for sampling of turbidity at two depth levels: 1.0m below the top water level; and 3.5m below the top water level of the lake. Location of these observation points are given in Table – 3 with WGS 84 coordinates.

Table – 3: Locations/Observation Points for Turbidity in Jait Sagar Lake

Location – 1	25°27'15.47"N	75°38'29.99"E
Location – 2	25°27'18.67"N	75°38'40.20"E
Location – 3	25°27'26.53"N	75°38'49.11"E
Location – 4	25°27'24.92"N	75°38'58.65"E

Turbidity at these four observation points (for two depth levels each) in Jait Sagar Lake, were sampled and measured for two seasons (pre-monsoon and post monsoon) in Nephelometric Turbidity Units (NTU), covering both the pre-intervention and post intervention stages; i.e., sampling and measurement of turbidity was done before construction of the rectangular desilting basin (pre-interception) and after construction and operation of this structure (post-interception).

4.1. Pre-intervention (Baseline) Turbidity in Jait Sagar Lake

Pre-intervention turbidity of contained waters in Jait Sagar Lake was sampled and measured for two seasons for a calendar year (pre-monsoon and post monsoon); that is presented in Table – 4 along with its comparison with post-intervention turbidity data at same observation points for two seasons (pre-monsoon and post monsoon season). Pre-intervention turbidity in Jait Sagar Lake was in range of 32 to 36 NTU.

4.2. Post-intervention Turbidity in Jait Sagar Lake

Post-intervention turbidity was measured after installation of rectangular desilting basin; i.e., after it has started functioning. Sampling and measurement conditions at all the four pre-decided observation points in the lake were exactly the same; i.e., at two depth levels 1.0 m below the top water level in the lake and at 3.5 m below the top water level of the lake, for two seasons in a calendar year (pre-monsoon and post monsoon). The details of observed value of post -intervention turbidity are presented in Table – 4 along with corresponding pre-intervention turbidity data at the same observation points for two seasons (pre-monsoon and post monsoon).

Table – 4: Turbidity in Jait Sagar Lake (in NTU) Between Pre-intervention (Baseline) and Post-intervention for Two Seasons (Pre-monsoon and Post-monsoon)

	Pre-intervention (Baseline) Turbidity				Post Intervention Turbidity				Difference in Turbidity in Pre-monsoon Months	Difference in Turbidity in Post-monsoon Months	Difference in Turbidity in Pre-monsoon Months [in %]	Difference in Turbidity in Post-monsoon Months [in %]
Season and Date of Sampling & Measurement of Turbidity	Pre-monsoon (Date: 20/03/2023)		Post-monsoon (Date: 19/10/2023)		Pre-monsoon (Date: 20/03/2024)		Post-monsoon (Date: 19/10/2024)					
Depth of Sampling (in meters)	1.0	3.5	1.0	3.5	1.0	3.5	1.0	3.5				
Turbidity at Location 1 (in NTU)	34	35	35	36	17	17	18	19	17	17	50.00	51.43
Turbidity at Location 2 (in NTU)	33	34	35	36	16	17	18	19	17	17	48.48	51.43
Turbidity at Location 3 (in NTU)	33	34	35	36	16	17	18	19	17	17	48.48	51.43
Turbidity at Location 4 (in NTU)	32	34	35	35	16	17	18	18	16	17	50.00	51.43

4.3. Comparison of Pre-intervention and Post-intervention Turbidity

Post-intervention turbidity in Jait Sagar Lake has been observed in range of 17 to 19 NTU; compared to 32 to 36 NTU during pre-intervention turbidity; i.e., post-intervention turbidity in contained waters of Jait Sagar Lake has reduced in range of 50% compared to their respective pre-intervention (baseline) turbidity. This outcome establishes the success of this intervention and its utility in rejuvenation and conservation of aquatic ecosystems & wildlife and also for recreational uses and aesthetic values of the lake.

5. Discussion

Global standard for turbidity is recommended under 5 NTU as optimal value for supporting light penetration, plant photosynthesis, and fish health; however, turbidity between 10 – 50 NTU is considered normal in semi-arid climatic conditions with high to very high solar radiation. Turbidity in natural lakes situated in semi-arid region is considered good for supporting healthy aquatic ecosystem of the lake; fish-life, birdlife, and terrestrial wildlife, livestock; and for recreational uses of humans, if it is maintained in range of 10 – 20 NTU. Post intervention turbidity in Jait Sagar Lake is within acceptable range; however, that can be further improved by application of bioremediation within the contained waters of the lake, since remaining turbidity causing suspended particles in contained waters are primarily due to phytoplankton, free floating particles of organic origine, zooplankton, other micro-organisms, trapped gaseous micro-bubbles and resuspension of residual unconsolidated precipitates at the bottom of the lake.

Algal bloom has not been reported in Jait Sagar Lake in past decade(s), unlike other waterbodies in similar climatic conditions across the world, where it has been reported to peak during summer season.

6. Achievements and Way Forward

Installation of rectangular desilting basin with baffling structures in the open channel of the streamlet contributing surface runoff in Jait Sagar Lake is proven to be an effective engineering intervention to prevent entry of turbidity causing mineral particles in the contained waters of the lake. That has resulted in overall improvement in water quality parameters of the lake, including reduction in overall turbidity in excess of 50%. This intervention has also reduced total suspended solids in the contained waters of the lake, and improved the availability of net dissolved oxygen in the contained water of the lake due to reduction in chemical oxygen demand (COD). These improvements have potential to reduce temperature of the contained waters within the lake; however, that is subject to confirmation based on a long-term observation. Alongside these direct benefits, there are also secondary benefits including (but not limited to):

1. Capture of phosphates and nitrates of mineral origine is achieved along with suspension (precipitation) of other mineral particles; that has helped in prevention of harmful algal blooms.
2. Capture/Reduction in the load of heavy metals, and toxic compounds of mineral origine; that has been captured with other mineral particles prior to their entry in contained waters of the lake. This is a function similar to a pollutant filtration mechanism.
3. Lower turbidity (cloudiness) has increased clarity of contained water in the lake, allowing sunlight to penetrate and support photosynthesis for healthy growth of submerged/benthic aquatic flora.
4. Prevented deposition of thick layers of lacustrine sediments at the bottom of the lake, that has potential to cover fish spawning grounds and suffocating bottom-dwelling macroinvertebrates and ichthyofauna; i.e., this intervention has prevented smothering in the aquatic ecosystem of the lake.
5. Protects overall storage capacity of the lake and prevents premature filling or shallowing of the aquatic basin; i.e., preserves the depth and net water holding capacity of the lake.
6. Accumulates mineral rich sediment in the rectangular desilting basin that can be periodically excavated and reused as soil conditioner in nurseries; i.e., the suspended sediment in the rectangular desilting basin also functions as a resource recovery mechanism.
7. Potentially facilitate scientific research in tracking of downward settling fluxes, carbon budgets, and short-term particle movement in the water column.
8. Prevents entry of excess iron oxide carried along with other particles of mineral origine.
9. Supported growth of fishes and other aquatic life in the lake.
10. Lower turbidity has supported the birdlife in and around the lake, particularly birds dependent on lake for their food and survival.

7. Conclusion

Turbidity causing mineral particles carried along with surface runoff into Jait Sagar Lake has been efficiently intercepted by installation of rectangular desilting basin with baffling structures as physical barrier within the open channel of streamlet contributing surface runoff to the lake. Entire process, has been elaborated in simple and easy to understand language in the instant research paper with details of design and its functional efficiency in quantitative terms. Turbidity data for two seasons (pre-monsoon and post monsoon) for two depth level at four locations in the lake has been sampled and measured in NTU and a comparison has been done between post-intervention turbidity with respect to pre-intervention (baseline) turbidity; the outcome confirms that post-intervention, surface runoff contributing to the lake became largely free from turbidity causing fine-grained mineral particles like sand, silt, clay, insoluble salts, non-metallic and metallic minerals. As a result, overall turbidity in the contained waters of the lake has reduced by over 50%, for both seasons (pre-monsoon and post-monsoon) i.e., by interception and removal of mineral particles prior to their entry in the contained waters of the lake has also restricted the growth of turbidity causing autotrophic microorganisms and trapped gaseous micro-bubbles in the lake. This outcome is encouraging and establishes the functional efficiency of rectangular desilting basin with baffling structures as physical barrier to intercept turbidity causing mineral particles, as a role model for turbidity management of similar lakes, reservoirs and large tanks located in semi-arid and arid regions where ever the primary cause of turbidity is due to suspended particles of mineral origine transported along with the surface runoff feeding the waterbody.

References

1. Design of sediment detention basins: Scaled model experiments and application; Anita Moldenhauer-Roth, Guillaume Piton, Sebastian Schwindt, Mona Jafarnejad, Anton J. Schleiss; International Journal of Sediment Research; Volume 36; Issue 1; February 2021
2. A Simplified Design Procedure of Settling Basins with Inclined Plates in Irrigation Canal Network Using Trapping Efficiency Criterion; Abdelkarim D. Elfadil, Hassan Ibrahim Mohammed, Abbas ElSheikh, Wasfi Hamad Abu Sador; World Scientific News; Volume 179; April 2023
3. Analysis and Design of Sedimentation Tank; V.E.S. Mahendra Kumar, G. Venkatesh, K. Dinesh, N. Vihar, B. Sumalatha; International Journal for Modern Trends in Science and Technology; Volume 11, Issue 03, March 2025
4. A new combination approach for optimal design of sedimentation tanks based on hydrodynamic simulation model and machine learning algorithms; Ahmad Ferdowsi, Mahdi Valikhan-Anaraki, Saeed Farzin, Sayed-Farhad Mousavi; Physics and Chemistry of the Earth; Elsevier Ltd.; Volume 127; October 2022
5. Research and improvement of the design of a sedimentation tank for hydropower and irrigation; Rashad Saffan Oqlu Abilov; Machinery & Energetics; National University of Life and Environmental Sciences of Ukraine; Volume 15; No. 3. 2024

6. A CFD methodology for the design of rectangular sedimentation tanks in potable water treatment plants; Ghawi A. Hadi, Jozef Kriš; Journal of Water Supply: Research and Technology-Aqua; IWA Publishing; Volume 58, Issue 3; May 2009
7. Design and Construction of a Model Sedimentation Tank Using Existing Slow Sand Filter for NDA Treatment Plant; A Saminu, U Tsoho, G Harunaand, L Sagir, Saminu; International Journal of Engineering Sciences & Research Technology; Volume 2, Issue 7; July, 2013
8. Design of Class-I Sedimentation Tanks; Prabhata K. Swamee, Aditya Tyagi; Journal of Environmental Engineering; ASCE; Volume 122, Issue 1; January 1996
9. Physical Processes in Stormwater Wet Ponds and Wetlands and Implications for Water Quality Control; Sherif S. Ahmed, Mark R. Loewen, David Z. Zhu, Wenming Zhang, Khizar Mahmood, Bert van Duin, Tadros R. Ghobrial; Journal of Environmental Engineering; ASCE; Volume 152, Issue 12; September, 2026
10. Improving design guidelines for class-I circular sedimentation tanks; Prabhata Swamee; Urban Water Journal; Tylor & Francis; Volume 1; Issue 4; August 2010
11. Sedimentation Tanks for Treating Rainwater: CFD Simulations and PIV Experiments; Krystian Czernek, Marek Ochowiak, Daniel Janecki, Tomasz Zawilski, Leszek Dudek, Stanisław Witczak, Andzelika Krupinska, Magdalena Matuszak, Sylwia Włodarczak, Michał Hyrycz, Ivan Pavlenko; Energies; MDPI Journals; Volume 14; 2021
12. Settling basins [Section 11.6]; Chapter 11 Flood and Silt Control Structures; Manual on Simple Methods for Aquaculture – Version 2; FAO Training Series; Food and Agriculture Organization; Year 2006 [ISBN: 9789250056128]