# Development of Autonomous Dredger for Inland waterways and enclosed water bodies

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## ABSTRACT

The conceptual layout of the proposed autonomous dredger is presented. The potential for dredging in inland water bodies - reservoirs and inland waterways – in India is five times larger than the conventional dredging (ports and channels). Unlike marine dredgers, these small dredgers cannot be directly scaled up due to restrictions imposed by transportation, environmental conditions, draft and deployment. To overcome some of the difficulties, Indian Maritime University at Visakhapatnam campus IMU[V] is working on the development of an Autonomous Dredger (AD). The design philosophy revolves around modularity, ease of transport and autonomous operation. Modularity will ensure that the dredger can be dismantled for road transport and assembled at dredge site with minimal handling machinery. AD is being designed for calm water operations with four point mooring support and meant for clay and sand removal by water jet based dredging. The autonomous operation will ensure unattended dredging operation on 24x7 basis. The AD will have an in-built bathymetric survey system that will provide pre and post dredging quantification. While deployment the overall reservoir site will be divided into small 'cell' of convenient size (say 100 x 100m). After deployment, the AD will survey, dredge and verify the work done autonomously within the cell. Manual intervention for operational purpose will be kept to a minimum for shifting the AD from one cell to next.

***Key words: reservoir, dredger, modular, autonomous.***

## INTRODUCTION

### *Siltation in reservoirs*

Reservoir siltation is caused by the flow of water and sediments like silt, sand, gravel and boulders etc., from upstream side of the river. The water storage capacity is severely affected by the accumulation of the sediments. In India, as on March 2013 the total live storage capacity of completed large and medium dams was about 253 billion cubic meters (BCM) i.e. 37% of the estimated utilizable surface water resources (696 billion cubic meters). Thakkar and Bhattacharyya (2006), estimates that India is losing at least 1.95 BCM (or about 1%) storage capacity through siltation every year, valued at about Rs.2017 crores at replacement costs. The Report of a Task force on Irrigation (2006) constituted by Planning commission estimates this annual loss at a conservative level of 0.5%. Considering the total installed capacity of 253 BCM in the country, the loss amounts to about 1 BCM/ year. The Implication of such magnitude on the irrigation, food security and society at large cannot be over stated. The following table illustrates an alarming reduction in the storage capacity over a period of 40 years.

The table-1 is based on the data from compendium of siltation in Indian reservoirs (CWC, 2015). This report is published by Watershed and Reservoir Sedimentation Directorate of Central Water Commission (Ministry of Water Resources) in the year 2015, after analyzing the data from 253 reservoirs in the country. Among those reservoirs covered, the top 10 reservoirs that have been most affected by siltation are listed in the following Table-1

Table 1. Loss of storage capacity in select reservoirs in India due to siltation
($Mm^3$ = 1 Million meter Cube)

| Name | State | Initial Storage $Mm^3$ | Initial year of Impound | Last year of survey | % loss up to last survey | Annual loss % | Loss up to 2016 (*) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | In % | In $Mm^3$ |
| [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] |
| Hirakud | Odisha | 8105 | 1957 | 2000 | 27 | 0.6 | 37 | 3027 |
| Srisailam | Andhra | 8724 | 1976 | 2011 | 29 | 0.8 | 34 | 2989 |
| SriramSagar | Telengana | 3171 | 1970 | 2013 | 28 | 0.6 | 30 | 966 |
| Mettur | Tamil | 2708 | 1934 | 2004 | 26 | 0.3 | 31 | 838 |
| Nizamsagar | Telengana | 841 | 1930 | 1992 | 60 | 0.9 | 84 | 707 |
| Matatila | Uttar | 1132 | 1956 | 1999 | 38 | 0.8 | 53 | 600 |
| Bhasavasagara | Karnataka | 1071 | 1982 | 2007 | 26 | 1.1 | 36 | 391 |
| Chamera-I | Himachal | 391 | 1994 | 2010 | 39 | 2.4 | 54 | 212 |
| Tilaiya | Jharkhand | 335 | 1953 | 1997 | 36 | 0.8 | 52 | 173 |
| Bhadar(S) | Gujarat | 237 | 1964 | 2004 | 38 | 0.9 | 50 | 119 |
| Total siltation of top ten reservoirs in ($Mm^3$) | | | | | | | | 10,022 |

* *Loss as of year 2016 are projections assuming annual rate indicated in (7) remains constant*

A conservative estimate will indicate that even if the above ten reservoirs alone are considered, there is a gigantic task that is crying for nation's attention. Following are some of interesting projections based on table-1 that should convince dredging community / Government the need for immediate action.

Total volume of sedimentation to be dredged : 10,000 $Mm^3$

Estimated annual siltation rate : ~ 200 $Mm^3$/year

Assuming that the back log to be cleared in next twenty years, the annual dredging efforts required would be in the order of 700 $Mm^3$, worth about Rs.14000 Crores/ year to serve ten reservoirs listed. It may be noted that, if country's annual loss of storage from all major reservoirs is considered, the annual requirement jumps nearly fivefold to more than 1000 $Mm^3$.

In contrast, the projections in the Report of working group for port sector for the 12th five year plan (Ministry of Shipping, Government of India, As reported in DCI-2015) indicates a total dredging forecast of 1170 $Mm^3$ over five year period (or about 200 $Mm^3$/ year). It is obvious that potential in reservoir dredging is 500% more than that of conventional marine dredging.

It is observed that the rate of siltation is maximum in the reservoirs lying in west flowing rivers beyond Tapi and South Indian Rivers. The median value of siltation observed in this in various geographical regions are listed in Table-2

Table 2. Inland rivers sedimentation rate in India.

| Region | Sedimentation - height (mm/year) |
|---|---|
| Himalayan rivers | 1.581 |
| Indus and Gangetic plains | 0.752 |
| West flowing Peninsular rivers (South of Tapi) | 2.132 |
| East flowing Peninsular rivers (up to Godavari) | 0.678 |

Going by the commitments made by the Government towards developing Inland waterways in the near future (RITES report-2013), about 4500 km of waterways will be developed and maintained for navigable channels. Assuming a 100m channel to be developed for this magnitude with an average 1m deepening, the total capital dredging quantity will be about (4500000 x 100x 1) = 450 $Mm^3$. The maintenance of these water ways will be additional requirement that would be recurring. It is inexplicable that the Dredging industry seems hardly contributing to Inland/ Reservoir de-siltation in our country. One possible cause for such lopsided attention could be the reliance on large Multi-national companies in the Indian Dredging scenario, who can rapidly relocate the dredgers to meet fluctuating demands of global market. Table -3 indicates the composition of various entities that contribute to the overall dredging spread in our country.

Table 3. List of major Dredging companies operating in India[2].

| Company | No. of Dredgers (as on 2014) | | | | |
|---|---|---|---|---|---|
| | TSHDs | CSDs | Backhoes | Others | Total |
| Adani Ports and SEZ Ltd. | 1 | 12 | - | 3 | 16 |
| Boskalis Dredging India Pvt. Ltd. | 23 | 18 | 15 | 9 | 65 |
| Chellaram Shipping Pvt. Ltd., Mumbai | 2 | - | - | - | 2 |
| Dharti Dredging and Infrastructure Ltd., Hyderabad | - | 10 | 2 | 4 | 16 |
| International Seaports Dredging Pvt. Ltd., Chennai | 25 | 20 | 7 | 8+ | 60+ |
| Jan De Nul Dredging India Pvt. Ltd., | 28 | 15 | 6 | 35+ | 85+ |
| Mercator Limited, Mumbai | 5 | 1 | - | - | 6 |
| Van Oord India Pvt. Ltd., | 21 | 23 | 5 | 42 | 91 |

It may be noted that only 40 out of 340 dredgers deployed in India are of domestic players (DCI corporate presentation – 2015). Remaining 320 dredgers belong to MNCs - mostly from Europe.

The consequences arising out of the dependence on large dredgers are:

1) The scale of economy may drive the profitability – larger the dredger, better.
2) Relocation can be rapid. At times of lean market spells, most of them can vanish from Indian shores
3) Systems and operations become more complex with increasing size – The local competence in building and operating cannot afford to keep abreast with changes.
4) Few large jobs will be more attractive than many smaller jobs spread over large geographical extent.

All the above implications do not bode well for indigenous capacity building in the dredging sector – especially for inland applications, which itself is in nascent stage. However, looming threat of water scarcity and expected remedial (de-silting) measures of Government could be a catalyst in developing the capacity for inland dredging. The next boost for demand in small dredgers should emanate from the Government's stated policy of rapid development of Inland Waterways. The demand for dredging of Inland water ways and the reservoirs will far outstrip the conventional dredging in ports and harbors in the coming decades.

The present scenario provides a potential opportunity to the domestic dredging industry to develop cost effective dredgers and dredging activities suitable for calm, shallow water conditions preferably with amphibious and autonomous capabilities.

Ideally, the following characteristics are desirable for a small dredger intended for inland waterways or reservoir:

- Modular design
- Size suitable for road transport

- Minimal human intervention
- Assemble/dismantle configuration at dredge site
- Features for autonomous mode - like unattended bathymetric surveys, programmable track control, real-time monitoring and communication of dredger parameters and operation.

IMU[V] being an university with research mandate along with academic activities, is best equipped to contribute to this national need. As a medium term project, IMU[V] plans to develop, demonstrate and promote the concept of small autonomous dredgers with above features.

## DESIGN REQUIREMENTS

The Autonomous Dredger (AD) design is mainly to develop a dredging tool to operate 24x7 basis with minimum human intervention. The system shall be modular – in the sense that dredger shall be scalable and also amenable for being handled component wise. The system shall be capable of being relocated / deployed by few truck loads and using mobile crane on a make shift ramp on waterfront. The scalability is required to modify the capacities (pump, motor, buoyancy, and endurance) to suit individual site requirements at least in a limited range.

The requirement of road transport and handling imposes limits on the individual sizes of components. The buoyancy chambers shall be compartments that could be loaded on trailers and shall be connected at site with frames. The platform shall be held in position by combination of four point anchor mooring while dredging. Slow maneuvering/cruising shall be carried out by water-jet propulsion. The dredging is carried out by water-jet & agitator combination. One central motor shall be optimized to drive the operations of pumps required for water jet propulsion, and windlass/capstan for anchor control system. Arrangement of buoyancy chambers shall enable hydrodynamically smooth operation while permitting the dredging sweeps from aft.

For economical operation and maintenance, as far as possible, the components shall be off-the-shelf items and sourced from domestic suppliers. This requirement is of paramount importance as the small dredgers are expected to be installed in remote parts of country and maintained by operators with limited technical background/training and shall be free from proprietary or single source specifications.

The advantage of modularity is that depending on the deployment site, the sizing and fabrications can be tuned. Some of the items can be prefabricated and shifted to the site independently. The most expensive component – the motors and pumps – could be sourced from many suppliers spread across the country. The sizing and configuration of all other components can be defined and built around these main components. The base platform will be installed on buoyancy chambers of required capacity. Sub-systems like pumps for water-jet propulsion, mooring winches for anchor control, handling systems for positioning, navigation control package will be built on the platform. The system will also have extensive sensor suite to provide real-time data on various parameters of interest.

Provision shall be built in to scale up the dredging productivity by increasing the parallel operation with multiple dredging elements sharing some of the common resources.

The major components of the AD are (Figure -1):

- Floating platform
- Dredge pump
- Propulsion

- Mooring system
- Sensors and other control systems
- Navigation and communication
- Support system
- Other services (Software and Manpower)

Figure 2 and 3 presents the preliminary arrangement of the AD with salient features. The figure 4. Indicates the to and fro transverse movement of the dredge head with the help of the A-frame within the dredge track. The forward movement of the platform shall be with the help of the mooring arrangement.

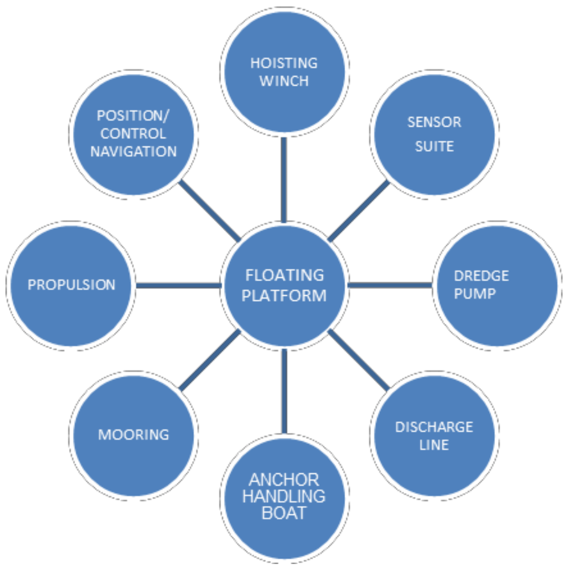


Figure 1. Major components of the AD.

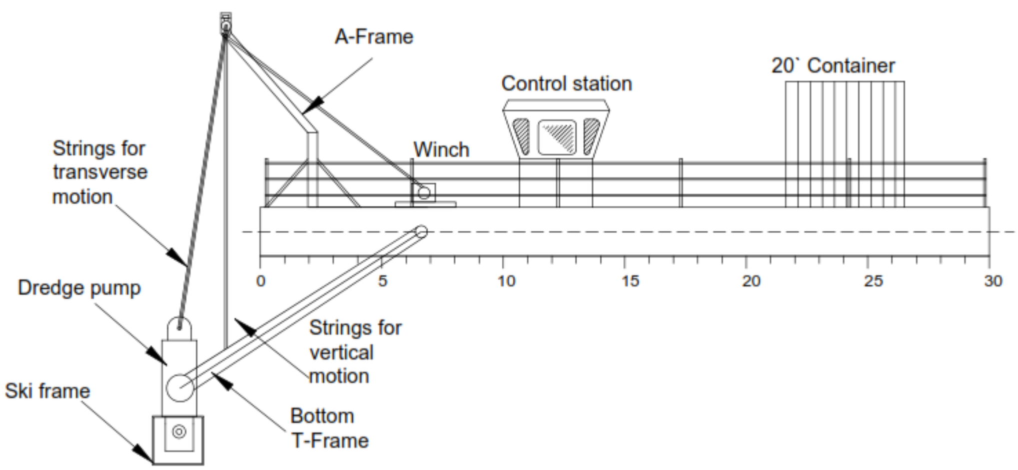


Figure 2. Preliminary AD profile sketch.

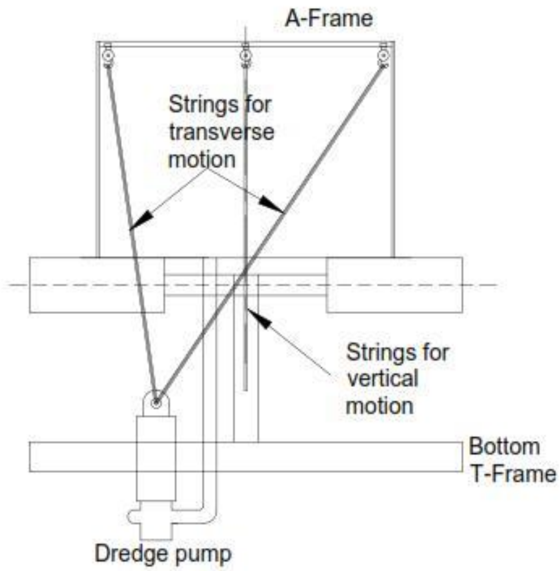


Figure 3. AD dredge pump transverse and vertical movements arrangement.

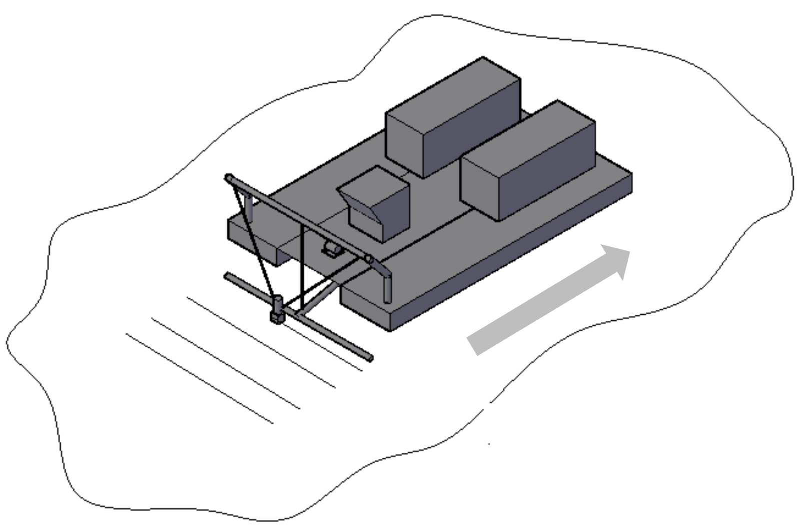

Figure 4. Schematic layout of AD with dredge tracks

## Details of sub-systems

a. Floatation chambers

The buoyancy chamber shall be designed of sufficient capacity. The hull form shall be a catamaran. The structure shall be able to withstand major load elements like the machinery, handling and other components. Sizing shall be made in multiple chambers suitable for transportation in such a way that assembly can be done at the site. The chamber shall be made of neutrally-buoyant materials like HDPE pipes. The outline dimensions of the demi-hull shall be 15x2.5x1 m with spacing of 3m between each demi-hull. A frame to handle the dredging components positioned in line with the center opening for lowering, lifting and to and fro transverse movement of the submerged components. The capacity of the frame depends on pump weight and size. In the present case 5 ton A-frame is suitable. Additional motor with strings shall be placed on the frame to support the transverse movement of the pump within the dredge track. A container with air conditioner shall be provided for office space, stores etc. Hoisting winches suitable of capacity for lowering the dredge head and mooring lines. A generator or shore connection for power supply shall be provide as per site feasibility. A control station will monitor the operation including the navigation and communications systems.

b. Dredge Head

The major component shall be the agitator and dredge pump deployed for the excavation of bed material. The capacity (125-390$m^3$/hr) and number of the pump shall be decided based on the sediment quantity, de-siltation time, size, weight and environmental conditions of the reservoir. The pump shall be lowered to the bottom using a handling system. The bottom end of the agitator shall be mounted on a ski frame suitable for taking the shock loads and maintain optimum clearance at the bottom. The sensors shall be mounted for monitoring the discharge rate, density, productivity etc. The dredge pump shall be able to make transverse movements guided by the bottom T-frame with the help of small winches mounted on the A-frame as shown in figure 4. The vertical movement shall be controlled with another winch along with the bottom T-frame. Based on the sensor mounted on the ski frame for maintaining effective clearance at the bottom, the vertical movement can be automatically adjusted.

c. Propulsion system

The buoyancy chamber shall maneuver at a slow speed for station keeping and carry out the pre/post survey activities. A water-jet propulsion system shall be provided for the movement of AD. A separate pump shall be used for the propulsion system (but the main motor shall drive this also along with other pumps). The piping configurations shall cover four sides of the buoyancy chamber with valves and nozzle outlets, in multiple numbers allowing the platform to maneuver in four directions. The intake of the water-jet shall be from the lowest portion of the platform, with outlets on all the four sides.

d. Anchor and Mooring control

A four point mooring system with anchors at each end shall be used. The mooring lines shall be controlled for the movement of the platform as and when required for the dredging operation in the specified cell. The mooring lines of 100m long each shall be controlled by windlass/capstan of 100 kN for tightening and loosen as required, which in-turn is controlled by a central motor. The interface between the position control and anchor control shall be done by the predefined set path. The central motor shall automatically generate tension in the mooring lines to move the AD as per the specified path. The manual intervention shall be only used for shifting the anchors of 50kg each to next cell.

e. Discharge configuration

One of the critical operation is the discharge of the slurry at suitable location downstream close to the site. The discharge line shall be floating using buoys at regular intervals along the discharge line depending on the discharge location. If the length of the discharge line is quit long then additional booster pump shall be used to have a continuous uninterrupted discharge.

f. Instrumentation

The instrumentation incorporated shall play a vital role in accessing the performance of the AD. The AD position shall be monitored using a DGPS mounted on the platform deck. The pre/post survey of the site shall be carried out by an Echosounder, which shall be mounted on the platform bottom. The pressure sensors shall be located in the suction and discharge lines to monitor the flow in the pipelines. The density sensor located in pipelines, for knowing the slurry density during dredging. The agitator depth clearance shall be measured by placing a depth sensor on the T-frame at the bottom. The environmental parameters like the wind (speed, heading), temperature shall be obtained from the Automatic weather station (AWS) on the deck. The water quality testing can be done at regular intervals in an oceanography lab. The sensors shall be multiple in number for redundancy and interfaced such that there shall be a data logging and real time display units onboard as well as at base stations through internet. The entire integration shall help in quick decision making on the performance of the AD and also to understand the project execution from a remote base station.

## INTEGRATION AND TESTING

Sensors integration

The major sensors mounted on the AD shall be integrated to a single system for easy data logging and transmission in a standard signal format. It also helps in monitoring multiple parameters in single display for performance evaluation. The figure 5 presents the general flow of information and control among the sub-systems of AD.

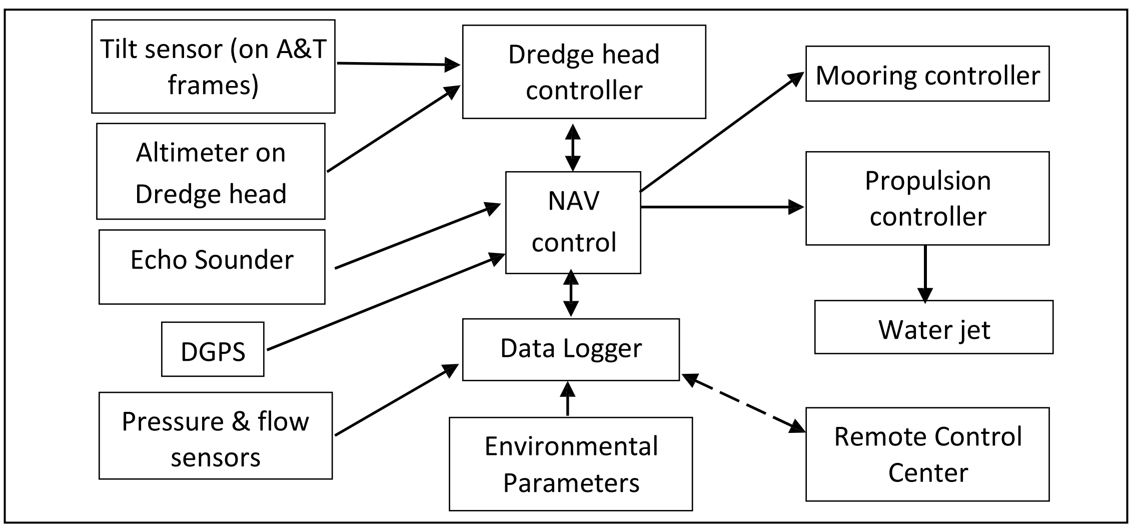


Figure 4. Control Scheme of AD.

## DEMONSTRATION PLAN

Meghadri Gedda is a fresh water reservoir for the Visakhapatnam district, Andhra Pradesh. The original capacity of the reservoir being around 23 $Mm^3$, got silted up substantially over the past years. Since this reservoir is the source of water supply to the Visakhapatnam city, de-silting and restoring its capacity has become an urgent need. The DPR conducted in the year 2016 indicate that the required dredge volume is around 3.26 $Mm^3$. The available capacities for off-the-shelf dredge pumps (submersible, agitator dredge pumps) are in the range of 150-1200 m$^3$/hr. With the present dredge volume, considering lowest removal rate of 150m$^3$/hr, with 24hrs/day operation, about 900 working days will be required. It is to be noted that the initial demonstration of the AD shall be technology demonstration to implement on a larger scale. The disposal issues with manual dredging could be more involved with additional lift/pump requirements unlike AD. It may be noted that the disposal strategy will depend on more factors like lead distance, reusability of dredge spoil, etc.

The operational sequence proposed is illustrated schematically in the following figure 6.

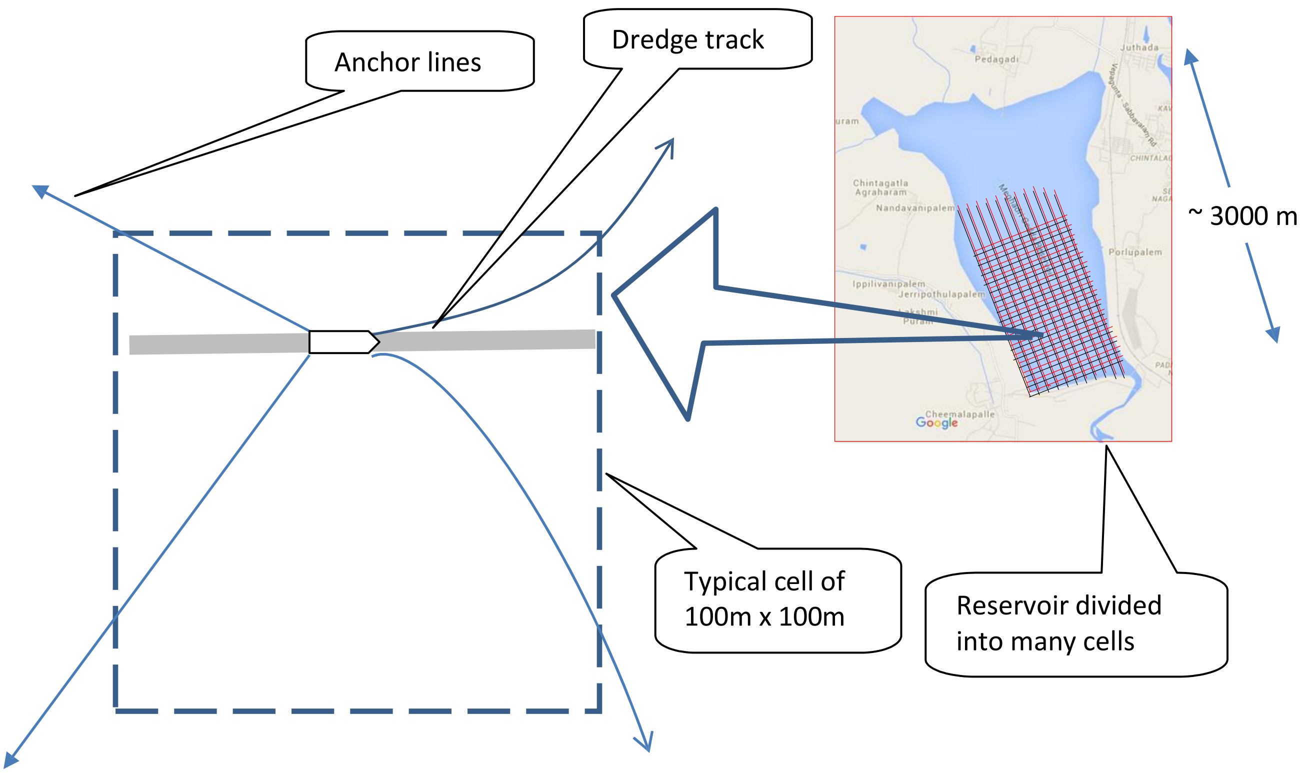


Figure 5. Operational sequence layout of the sample reservoir.

The preliminary cost estimate indicates that the AD operation with power supply from shore in the test site would be about Rs. 130/m$^3$, which compares very favorably if considered against conventional marine dredging (ranging from Rs. 200 – 300 /m$^3$). The reasons for such cost advantage mat be lying in the manpower requirement, maintenance and shore supply of power.

## CONCLUSION

The potential for inland dredging is enormous when compared to conventional marine dredging. To take advantage of calm water conditions and shallow water operations, an attempt is being made to develop an Autonomous Dredger. This will boost the domestic capability required for Inland waterway development and reservoir de-siltation. The dredger is being designed to comprise state-of-the-art subsystems in dredging, maneuvering, propulsion and monitoring. The AD will be very useful dredging tool for clam water operation with minimal manual intervention. The operational constraints will apply in terms of distance from shore and water depth. However both can be overcome with site specific modifications with additional cost. The experience from the demonstration will lead to possible standardization and improvements in overall process. The major advantage shall be the modular arrangement and autonomous operation of the AD, which are eminent requirement for a remote site with logistical bottlenecks and constraints on trained manpower.

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