Sediment Classification of Tropical Littoral Water Using SONAR System

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by

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1 Introduction

Tropical regions like India witness concentration of monsoons within three months of the year resulting in high rate of flow during the period. The high rate of flow manifests as high siltation in the reservoirs created for storing water for the long dry spell post monsoon. The incessant siltation during the monsoon period over the years depletes the storage capacity of the reservoirs created at very high cost. Water reservoir capacities have been created at huge cost, infrastructure investment and the government continues to spend huge sums each year for creating additional storage capacities. Most of the developed projects have not been yielding expected output, primarily due to underestimation of sedimentation problems [1].

History reveals that great amount of sediment is carried out by Indian rivers down to reservoirs, lakes, estuaries, bays at a rate of $2000 - 3000 tonnes/km^2/year$ in north east to $500 - 1000 tonnes/km^2/year$ in central and southern regions, out of which 29% is transported to sea and 10% deposited in reservoirs [2-3]. Such deposition causes loss of storage capacity and could adversely affect planning for long term utilization of reservoir storage capacity for irrigation, power generation, industry, urban power supply and flood moderation.

The present situation in India is really critical and urgent measures for de-siltation is called to ensure reasonable availability of water resources for varied applications. Desiltation efforts require precise sediment classification for effective water resource management. The satellite remote sensing is very useful, economical and reliable tool for conducting monitoring sedimentation in lakes or reservoirs [4]. However, this method does not incorporate the precise sediment type such as sand, mud, rock etc. Acoustic methods can substantially enhance the measurement and analysis accuracies. Use of acoustic signals obtained from Active Sound Navigation And Ranging (SONAR) system, combines the bottom mapping capability with the identification of the type of bottom material based on the features of echo signal received. Therefore, significant research effort has been dedicated to methods allowing for classification of the sea/river sediments using acoustic techniques [5]. Analysis of the details and structure from the sonar backscatter signal provides the means to classify sediments to determine the composition (sand, rock, mud etc.), the vegetation cover and to extract other information including geotechnical properties. But acoustic techniques suffer from being sensitive to the medium fluctuations so knowledge of environmental conditions at the experimental site is important.

The site-specific seasonal and the diurnal variability in the acoustic behavior in tropical shallow freshwater is a challenge for any acoustic survey effort. The work presents a rare on-site experimental validation of the medium parameters and its manifestation as the sound speed profile. One of the key contributions of the proposed work is to present a complete framework of environmental changes at the experimental site and its effect on the sound speed profile, along with formulation of a computationally efficient mathematical of sound speed at the tropical shallow freshwater systems and model validation. Further objective of this research work is simulation and characterization of tropical littoral freshwater channel impulse response. Statistical characterization of the channel impulse response for variable environmental conditions is presented in this study. The research further aims to sediment characterization at the experimental site along with ground truth validation.

The tropical littoral freshwater environment at Khadakwasala Lake, situated in Pune (Maharashtra state) is taken under consideration as the experimental site for this research work.

1.1 Motivation

Water and energy are tightly interlinked and highly interdependent. Freshwater and energy are crucial for human well-being and sustainable socio-economic development. Their essential roles in achieving progress under every category of developmental goal are now widely recognized. Hydropower development is one of the most prominent resources for future economic development of any country [1].

India and many third world countries depend on rainfall for their domestic and other freshwater requirements. The non-monsoon months that constitute around 65% of the period annually, is supported by the water stored in the reservoirs. However, due to the process of water flow and accumulation, the silt in the water from the rivers settle in the reservoirs referred as siltation. Deposition of sediments in reservoirs increases the magnitude, frequency and severity of flood. So it becomes vital to analyze pre-impoundment and post-impoundment sediment texture and density.

Acoustic methods have significant potential in analyzing underwater sediments and finds relevance for enhancing the performance of de-siltation efforts. Knowledge of the sediment type is crucial before dredging initiatives. Use of acoustic techniques for classification of the sediment type could be an effective tool in guiding the dredging agencies in utilizing appropriate dredging equipment.

Acoustic methods can substantially enhance the measurement and analysis accuracies; however these techniques are highly sensitive to the medium properties of the underwater medium [6]. Use of SONARs in any underwater application demands the acoustic propagation study at the experimental site. Before deploying SONARs for any underwater application it is essential to understand acoustic propagation at the study site and statistical characteristics of channel impulse response. As the sound speed in water is dependent on physical parameters of water including temperature, pressure and salinity, it becomes essential to understand effect of variation of these parameters on sound speed. Validation of existing sound speed models and development of a mathematical model based the local environmental characteristics is essential. Development of the computationally efficient mathematical model suitable for tropical shallow environment is the need.

1.2 Literature Survey

The literature survey is organized in two sections **1** Literature survey on sound speed models and characteristics of underwater acoustic channel impulse response **2** Literature survey on sediment classification methods

1. Understanding the physical properties of the channel and the acoustic propagation at the experimental site plays a vital role in the deployment of SONAR systems for an acoustic application [7]. Such scientific information about the lake is important for an improved understanding of the physical dynamics of the lake for guiding the stakeholders for the design of the policies. We found various empirical models in the literature for the sound speed calculation at the freshwater system [8-12]. The commercially available CTD meters calculate sound speed by using any one of the said formulae. The computational complexity of these models is an issue that needs to be addressed. This led us to formulate our first objective as study of sound speed at shallow tropical freshwater system and development of computationally efficient sound speed model. The acoustic propagation in the tropical region witnesses twofold challenge while ensuring optimal sonar performance for an underwater application. The first is the perpetual shallow water behavior due to time-varying multipath interaction with the two boundaries. The second challenge pertains to the random surface fluctuations due to diurnal and seasonal temperature and other variation that impact the thermal stratification, thereby modifying the Sound Speed Profile (SSP). Sound propagation in underwater is highly dependent on the channel parameters including temperature, pressure and salinity. Unlike radio channels where a number of models for the probability distribution are well accepted and even standardized, there is limited consensus on statistical characterization of underwater acoustic channels [13].

   Significant literature does exist on underwater communication work, though it may not be directly related to the proposed work in terms of application, however, similarities can be drawn on the propagation analysis and reasonable inferences concluded. Some authors find Ricean fading or Rayleigh fading good approximation for their data [14-15]. Hovannes K.et al. [16] presented a statistical characterization of shallow and very shallow water communication. The KL divergence Goodness-of-fit test results presented by Hovannes, K. et al. confirm that very shallow water impulse response does not necessarily follow Rayleigh distribution rather exhibits close to Weibull or Rice distribution and shallow water environment matches close to beta distribution. Yang [17] confirms to the K distribution fading for the underwater channel. Jian et al. [18] presented a statistical characterization of the underwater acoustic channel at Narragansett Bay. The KS test employed by Jian Zhang concluded that the magnitude of channel impulse response PDF matches the compound K distribution. Parastoo Qarabaqi et al. [19] proposed a statistical model developed for underwater acoustic communication by considering channel variations. The channel variations are classified as small scale and large scale model. Large scale model considers location uncertainty and environmental variations. Comparative analysis of Rice and Rayleigh fits for direct path, bottom reflected and surface reflected paths of magnitude baseband impulse response are is carried out based on Jensen-Shannon divergence goodness of fit test. The results showed that Rice distribution is the best fit for direct path, surface and bottom reflected paths. Authors suggested use of hypothesis testing for characterization of surface and bottom reflected path impulse response. The literature presents the variety of proposed models; this would be due to the site-specific and experiment-specific properties. Taking these fact into account, we formulated our objectives as study of acoustic propagation at tropical shallow freshwater system and analyze the statistical characteristics of characteristics of a typical tropical shallow freshwater lake.

2. Christian Molder et al. presented an overview on two image processing techniques, sediment layer contour extraction and inter-layer texture analysis to characterize the recorded data. From the resulting image, two attributes- shape of sea/river bottom and textural information under horizon are obtained. Features extracted from GLCM are homogeneity, contrast, entropy, correlation, directivity, uniformity and maximum probability. The co-occurrence matrices are computed for $0°$, $45°$, $90°$ and $135°$. Wavelet 2D, Wavelet Packet 2D and the Over-Sampled Wavelet 2D transforms used for image analysis in spectral domain. Features extracted from approximate wavelet coefficients were energy, entropy and mean. Accuracy of rock and sand was 87%, mud was 76%, Plateau was 66%, and Grit was 50%. Feature selection techniques can be explored for reduction in size of feature vector [20].

   Imen Karoui et al.described characterization of seafloor/riverbed using a set of empirical distributions estimated on texture responses to a set of different filters. Similarity measures are twofold: first is, each filter is weighted according to its discrimination power and additional weight is evaluated as an angular distance between the incidence angles of compared texture samples. Second method used is based on similarity between global region texture and predefined prototypes. A Bayesian Framework is used where conditional likelihood is expressed using similarity measure between local pixel statistics and seafloor prototype statistics. The results show that the performance of the Bayesian approach depends on the size of analysis window so selection of window size can be explored [21].

Chanchal De et al. described acoustic characterization of seafloor sediment in the western continental shelf of India using the echo features extracted from single-beam Echo-Sounder at normal incidence angle. SONAR is operated at dual frequency of 33 KHz and 210 KHz. Combined two frequency inversion approach have been explored for improved characterization of Sea floor. Temporal backscatter model developed by Sternlicht and de Moustier was employed for model-based characterization of seafloor sediments. The linear regression analysis (between the estimated mean values of $M\varnothing$ and the laboratory-measured values of $M\varnothing$) showed that the correlation coefficients are 0.98, 0.96, and 0.97, respectively for 33 kHz, 210 kHz, and 2F inversions. The comparison of the results with ground truth at two operating frequencies revealed that this hybrid method could be efficiently used for sediment classification [22].

Dimitrios Eleftherakis et al. discussed riverbed classification using MBES. The authors deployed Kongsberg EM3002 SONARs with single-head multi-beam echosounder, operated at frequency of 300 kHz. Three cases of sediment classification are investigated: classification based on backscatter features, classification based on depth residual feature and hybrid approach using both the features. The method fits a number of Gaussian Probability Density Functions (PDFs) to the histogram of the backscatter data at a given incident angle. The optimum number of PDFs were found by consecutively increasing the number of PDFs until a chi-square distributed test statistic became less than a critical value. Authors extracted mean, standard deviation, minimum value, maximum value, median and higher order statistical moments (skewness, kurtosis) features from backscatter signals. Principal Component Analysis tool was demonstrated for optimum features selection. First and second principal components account for 96.4% and 2.4% of the variability of the data, respectively which are fed to K-means clustering algorithm [23].

Huu-Giao Nguyen et al. described seabed characterization and recognition of sonar images using key point based approaches to address the invariance to contrast change and geometric distortions. Authors demonstrated use of Difference of Gaussian (DoG), Fast Hessian Detector (FH) and Harris Detector for key-points detection. Further to match the points across different images of same texture descriptors like Scale Invariant Feature Transform (SIFT) and Speeded up Robust Feature (SURF) were implemented. Characterization of detected key-points was carried out based on spatial statistics which uses spatial key-point statistics and Log Gaussian Cox model. Combination of detectors and descriptors are applied to K-NN, SVM and Random Forest (RF) classifiers. The usage of SVM and RF classifiers presented improved of classification of seabed. Use of Log Gaussian Cox model shows accuracy of 93.14%, 92.15%, 93.65%, 87.35%, 90.5%, and 91.34% for Mud, Sandy Mud, Gravey Sand, Clearly Sand, Rock and Mixed Sediment respectively. This work suggested use of statistical model such as Neyman Scott, Shot noise Cox or Gibb's Process for further investigation. Comparison of Log Gaussian Cox model with powerful statistical tools, including goodness-of-fit or hypothesis test can be explored [24].

Mirjam Snellen et al. presented sediment classification methods based on multibeam echo-sounder backscatter. Authors proposed two methods, first is Bayesian estimation method that uses average backscatter data per beam for classification and second method uses a model based technique based on Kirchoff and Composite roughness model. Authors used average backscatter data per beam which made the classification independent of quality of the MBES calibration. The Applied Physics Laboratory, University of Washington (APL UW Model) was used for calculation of backscatter strength. Bayesian method is used for the backscatter values per angle, for sediment classification [25].

Fakirisa E. et al. presented object based classification of sub-bottom profiling data. In this work, 100-kHz Side Scan Sonar and 3.5 kHz Sub-bottom Profiler data was collected simultaneously during a geophysical survey at a $5.53.3km$, in shallow water with $10 - 50m$ depth. The first order statistical features including mean, standard deviation, skewness and kurtosis along with second order grey level statistical features such as contrast, correlation, energy, entropy and homogeneity are extracted from Side Scan Sonar images. The SBP images were processed using edge enhancement/detection techniques. The features extracted from SBP images includes, mean, standard deviation and coefficient of variation, regarding the acoustic appearance, transparency and density of the automatically detected seismic reflectors. Further authors' applied Random forest supervised classifier. Use of hybrid platforms like SSS and SBP derivatives could be beneficial and explored further [26].

1.3 Objectives

The work focuses on four problems:

1. Study of acoustic propagation at tropical shallow water.
2. To develop a computationally effecient model for determining sound speed at tropical shallow freshwater system.
3. To analyze statistical characterstics of channel impulse response in tropical shallow freshwater system.
4. Classification of sediment at Khadakwasala Lake using acoustic techniques.

2 Summary of Major Contributions

The research work presents complete frame work of acoustic propagation at tropical shallow freshwater system. The work focuses on study and modeling of acoustic propagation at tropical freshwater systems. The contributions of this research are summarized as follows:

1. **Echo Signal Analysis for Underwater Sediment Classification in Tropical Regions** [1]

   Analysis of underwater sediment type using single-beam and multi-beam echo sounders has been recognized as an effective tool in sea/river floor classification. Empirical method of sea/river floor classification relies on features extracted from the backscatter signal such as maximum amplitude, echo duration, energy and higher order moments. These features are highly dependent on the medium properties, bottom properties and specifications of the sonar like frequency, beam width, incident angle, and etc. Received signal characteristics are sensitive to physical properties of medium such as sound speed and sediment reflectivity. This paper discusses the significance of grazing angle, transmission loss and seasonal variation in the Sound Velocity Profile (SVP) for the application of sediment classification. Literature presents many empirical relations for calculation of sound speed based on temperature, pressure (depth), salinity values [8-12]. In this work we computed sound speed by using Medwin's empirical model [9]. Real data of temperature, pressure and salinity at Khadakwasala Lake was used for computation of sound speed. We analyzed seasonal variation in SVP. Analysis of

[1] Jyoti Sadalage, Arnab Das, Yashwant Joshi, "Echo signal analysis for underwater sediment classification in tropical regions," OCEANS 2016 MTS/IEEE Monterey, pp.1-5, 2016

the backscatter signal for different sediment types at variable water sound speed is presented using Kirchhoff roughness scattering model [27]. We used bellhop ray tracing model used for computation of transmission loss and the channel impulse response. Linear Frequency Modulated (LFM) signal with the spectral band 50 kHz to 100 kHz was used as a probing signal for sediment types: sand, fine sand, mud and mixed sediment.

2. **Statistical Characterization of an Underwater Channel in a Tropical Shallow Freshwater Lake System**[2]

   In this work, we attempt to present the seasonal variations in the surface temperature for a tropical freshwater system at Khadakwasla Lake [28], in India. The thermal gradient is computed, based on the surface temperature to derive the Sound Speed Profile (SSP) that facilitates the underwater channel characterization. The channel characterization includes computation of the surface and bottom path impulse response. The seasonal variations are statistically analyzed and a close match to known Probability Density Functions (pdfs) [29-30] derived. The efforts will facilitate the understanding of the medium fluctuation on the acoustic propagation and possible design of algorithms to mitigate the impact on the received echo at the sonar receiver. The temperature gradient along the water column for the Khadakwasla Lake is obtained using the one-dimensional Freshwater Lake Model (FLake) [31-33]. The detailed seasonal variations have been recorded using the FLake model in the site for the entire year using average temperature values. The temperature gradient information is fed to the Medwin formula to compute the SSP which is further fed to the acoustic channel simulator. The underwater channel simulator model is used to derive the surface and bottom impulse response. This paper presents the use of a large-scale model of the underwater acoustic simulator that allows uncertainty in the channel geometry. The medium and the physical parameters of the Khadakwasla Lake are fed to the channel model to obtain the channel parameters. The physical parameters include the channel geometry such as water depth, transmitter and receiver depth, bottom type, etc., whereas the environmental parameter includes the water SSP. The Goodness-of-fit test like the Kolmogorov–Smirnov (KS) test has been then used to find the close match to known pdfs. The simulation study on real surface temperature data presents encouraging results that match the known distributions for the surface, bottom reflected paths. In the absence of

[2] Jyoti Sadalage, Arnab Das, Yashwant Joshi, "Statistical Characterization of an Underwater Channel in a Tropical Shallow Freshwater Lake System," Computing, Communication and Signal Processing, Springer, Singapore, 2018.

a known benchmark and the wide variation in the statistical properties of the underwater channel, here we use a battery of pdfs for comparison. The surface and bottom reflected path impulse response matches with the three-parameter Weibull distribution with a confidence level of 98%.

3. **A Computationally Efficient Model for Sound Speed in Tropical Shallow Freshwater System with Field Validation** [3]

   This work aims to explore tropical shallow freshwater system for its acoustic behavior which would help the researchers in near future for sonar design and deployment. Limited resources are available in the open-source about the thermal gradient, salinity change and the sound speed profile at Khadakwasala Lake. This proved to be the driving force behind our experiment plan. In this work, we presented the temperature, salinity and the sound speed profile at different locations in the Khadakwasala Lake. Further, we proposed a linear and a polynomial regression model for sound speed, based on in-situ CTD measurements during two days of the experiment. We built a linear and polynomial regression model and tested their performance with the Chen and Millero's model [10] based on Root Mean Square Error (RMSE). In-situ measurements of Conductivity, Temperature, and Density (CTD) were carried out using the Valeport 602 CTD meter. We acquired around 125 CTD samples during a two-day experimental study, conducted at the Khadakwasla Lake from 11 Oct 2017 to 12 Oct 2017. The data collection was undertaken throughout the day at multiple locations in the lake over a spatial distance of 16 km. The data did represent diurnal variations in the water temperature and spatial variations in salinity. The Valeport 602 CTD meter uses the Chen and Millero formula which is the most conventional sound speed equation which is computationally much complex. The objective of the proposed work was development of computationally efficient mathematical model for determining sound speed at tropical shallow freshwater systems. The computational complexity of the proposed models was measured in terms of the number of addition and multiplication operations required. We carried out the validation of both the models by allowing the model input parameters to vary within defined limits. The validation of the proposed models was carried out for the water temperature in the range of 10 $^\circ$ C to 40 $^\circ$ C , salinity in the range of 0.01 ppt to 0.5 ppt and pressure in the range of 0.1 bar to 1.5 bar. The model inputs were derived from an in-situ experimental data collection process in a typical

[3]Jyoti Sadalage, Arnab Das, Yashwant Joshi,"A Computationally Efficient Model for Sound Speed in Tropical Shallow Freshwater System with Field Validation,", Journal of Lakes and Reservoirs, Wiley, 2019

tropical shallow freshwater system. The key contribution of the proposed work is to present a complete framework of environmental changes at the experimental site and its effect on the acoustic field, along with the computationally efficient mathematical formulation of sound speed for the tropical shallow freshwater systems. The proposed multiple linear regression model requires three addition and three multiplication operations. The second order polynomial regression model provided a computationally efficient solution for sound speed with only four addition and six multiplication operations over the specified bounds of the model input parameters. The linear regression model showed the RMSE of 4.15 m/s, while the polynomial regression model showed a good agreement with RMSE of 0.5 m/s over aforesaid range of temperature and pressure.

4. **Validation of Model-Based Techniques for Characterization of Surface Sediment at Khadakwasala Lake with Field Data** [4]

   The proposed work presented the analysis of the reflection coefficients of the surface sediment at Khadakwasla Lake. The chirp sub-bottom profiler used in this study transmits Gaussian-shaped frequency modulated pulse to obtain high resolution and enhanced sediment penetration. The chirp signal penetrates the sub-bottom layers, the received echoes reflected from the layered sediments give information about sediment layer structure and type. Since the geophysical and geo-acoustic properties of sediment are correlated, the reflection coefficients are computed where there is high impedance contrast, and are then matched with the mean grain size of the sediment. The energy model is used here to calculate the reflection coefficients using the spherical spreading loss by considering variations in absorption coefficient [34]. The calculated reflection coefficients are compared with Hamilton and Bachman's (1972) model for predicting the sediment type. In this paper, we also used the central frequency shift method to estimate surface sediment type. The EdgeTech sub-bottom profiler SB216S was deployed along with MK III single-beam echo-sounder. The Gaussian chirp pulse was selected with an aim to preserve signal resolution with sediment penetration. The chirp signal frequency was set at 2 kHz to 10 kHz with a pulse duration of 20 ms and the sampling frequency of 25 kHz. The transmitted power was 210 dB. The water depth over the survey track was found to be in the range from 9 m to 15 m, whereas maximum penetration recorded was 3 m to 4 m below the top layer of sediment. The acoustic survey was carried out at an approximate speed of

[4]Jyoti Sadalage, Arnab Das, Yashwant Joshi, "Validation of Model-Based Techniques for Characterization of Surface Sediment at Khadakwasala Lake with Field Data", communicated to Indian Journal of Geophysical Union in Jan 2019.

3-4 knot with ping frequency 1 Hz. The surface sediment samples were collected from locations G1 to G5 using the Van Veen grabber. As per on boat visual inspection of grabber sample by the geologist, it was observed that the surface sediment type was laminated clay, coarse clay, and clay with laterite. The results presented by using the energy model sensitive to the window width over which the received energy is calculated. In order to overcome this limitation in this work, we presented the central frequency shift model for analysis of surface sediment. The central frequency shift model results showed good agreement with the visual perception as well as ground truth processed in laboratory.

3 Organization of thesis

The thesis will be organized in seven chapters

Chapter 1: Introduction- it introduces current scenario of reservoir siltation and will be a wakeup call on near future consequences that the society could face. Need of desiltation initiatives and prior efforts for desiltation activities will be elaborated. The chapter further elaborates use of acoustic techniques in sediment classification which will be followed by the problem definitions that this research work will address.

Chapter 2: Literature Survey and Experimentation Details- it presents national and international status of sediment classification using acoustic techniques and related challenges. It introduces characteristics of tropical environment and the experimental site along with planning and execution of real data collection at Khadakwasala Lake.

Chapter 3: Sediment classification using acoustic techniques-it will provide working principle of active SONARs and its used sediment classification. It introduces underwater acoustic propagation along with the challenges of site specific sonar performance and sediment classification techniques.

Chapter 4: Sound propagation in Tropical freshwater system with sound speed modeling- it discusses the sound propagation in underwater. Introduces various empirical relations for computation of sound speed. It presents proposed models for sound speed computation at tropical shallow freshwater systems with field data validation.

Chapter 5: Statistical characteristics of Tropical shallow freshwater acoustic channel- it describes underwater Channel Impulse Response (CIR). Simulation results indicating effect of physical parameters of channel on CIR will be elaborated. Hypothesis testing results for Goodness of fit to surface and bottom path impulse response are part of the chapter.

Chapter 6: Validation of model-based techniques for characterization of sediment at Khadakwasala Lake with field data: it elaborates model based techniques of sediment classification. This chapter presents the field data collected using sub-bottom profiler along with simulation and ground truth results which are used for validation.

Chapter 7: Conclusion and future scope: concludes the thesis and discusses future scope.

List of publications

Peer reviewed Journals and Book Chapter

1. Sadalage J.A., Das A., Joshi Y. (2019) A computationally efficient model for determining sound speed in shallow tropical freshwater systems, with field validation, *Wiley Journal of Lakes and Reservoirs*,vol.0, pp.1-7, 2019.

2. Sadalage J.A., Das A., Joshi Y. (2019) Statistical Characterization of an Underwater Channel in a Tropical Shallow Freshwater Lake System, Computing, *Communication and Signal Processing*, vol. 810, pp.717-727, Springer, Singapore, 2018.

3. Sadalage J.A., Das A., Joshi Y., Validation of Model-Based Techniques for Characterization of Surface Sediment at Khadakwasala Lake with Field Data, *Journal of Indian Geophysical Union* (in process: received minor revision).

Conferences

1. Jyoti Sadalage, Arnab Das, Yashwant Joshi, Echo signal analysis for underwater sediment classification in tropical regions, OCEANS 2016 MTS/IEEE Monterey, pp.1-5, 2016.

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Glosssary

Term	Definition
SONAR	Sound Navigation And Ranging
Active SONAR	In active sonar, the system emits a pulse of sound and then the operator listens for echoes.
Tropical Region	The tropics are the region of the Earth near to the equator and between the Tropic of Cancer in the northern hemisphere and the Tropic of Capricorn in the southern hemisphere.
Desiltation	The process of removal of earthy materials, fine sand carried by running water and deposited as a sediment.
Modeling and simulation	Modeling and simulation (M&S) refers to using models physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process as a basis for simulations methods for implementing a model (either statically or) over time to develop data as a basis for managerial or technical decision making.
Geotechnical properties	Properties of soil such as gravity, density index, consistency limits, particle size, compaction, consolidation, permeability and shear strength.

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