Sasthamkotta Lake

An Integrated Management Plan

Wetlands INTERNATIONAL

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Wetlands International South Asia ♦ Centre for Water Resources Development and Management

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Cover: A view of Sasthamkotta from Ambalakadavu;
Back Cover: Communities on a boat ride within Sasthamkotta;
Inside Cover: A view of Sasthamkotta from Velanthra embankment

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ABBREVIATIONS

ADAK	Agency for Development of Aquaculture, Kerala
AKSZ	Achen-Kovil Shear Zone
amsl	Above Mean Sea Level
APHA	American Public Health Association
AWB	Asian Wetland Bureau
AWC	Asian Waterbird Census
BMC	Biodiversity Management Committee
BOD	Biochemical Oxygen Demand
CBD	Convention on Biological Diversity
CDA	Chilika Development Authority
CESS	Centre for Earth Science Studies
CGWB	Central Ground Water Board
CWRA	Central Wetland Regulatory Authority
CWRDM	Centre for Water Resources Development and Management
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DoF	Department of Fisheries
DoLR	Department of Land Resources
DoT	Department of Tourism
DTPC	District Tourism Promotion Council
EIA	Environment Impact Assessment
ERRC	Environmental Resource Research Centre
FFDA	Fish Farmer's Development Agency
FIRMA	State Fisheries Resource Management Society
GIS	Geographic Information System
HH	Household
ICAR	Indian Council of Agricultural Research
IMD	India Meteorological Department
IRBM	Integrated River Basin Management
IUCN	International Union for Conservation of Nature
IWMP	Integrated Watershed Management Programme
JICA	Japan International Cooperation Agency
KFWFB	Kerala Fishermen's Welfare Fund Board
KIHMS	Kerala Institute of Hospital Management Studies
KILA	Kerala Institute of Local Administration
KITTS	Kerala Institute of Travel and Tourism Studies
KREWS	Kerala Rural Employment and Welfare Society
KSBB	Kerala State Biodiversity Board
KSPCB	Kerala State Pollution Control Board
KSSP	Kerala Sastra Sahitya Parishad
KTDC	Kerala Tourism Development Corporation
KWA	Kerala Water Authority
LANDSAT	Land Satellite
LDA	Loktak Development Authority
LDPs	Local Development Plans
LPG	Liquefied Petroleum Gas
LSGs	Local Self Governments
LULC	Land Use Land Cover
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MKSP	Mahila Kisan Sashaktikaran Pariyojana
MLD	Million Litres per Day
MMDRA	Mines and Minerals (Development and Regulation) Act
MoEFCC	Ministry of Environment, Forest and Climate Change
MPN	Most Probable Number
MT	Metric Ton
MW	Mega Watt
NASA	National Aeronautics and Space Administration
NGOs	Non-Governmental Organizations
NH	National Highway
NPCA	National Programme for Conservation of Aquatic Ecosystems
NRLM	National Rural Livelihoods Mission
NTU	Nephelometric Turbidity Units
NWCP	National Wetland Conservation Programme
OLI	Operational Land Imager
PFCS	Primary Fisher Cooperative Society
QWSS	Quilon Water Supply Scheme
RIS	Ramsar Information Sheet
RSIS	Ramsar Sites Information Service
SAC	Space Application Centre
SEIAA	State level Environment Impact Assessment Authority
SKSB	South Kerala Sedimentary Basin
SWA	Sasthamkotta Wetland Authority
SWAK	State Wetland Authority Kerala
WIAMS	Wetland Inventory, Assessment and Monitoring System
WRIS	Water Resources Information System
WWF	World Wide Fund for Nature

1. Introduction

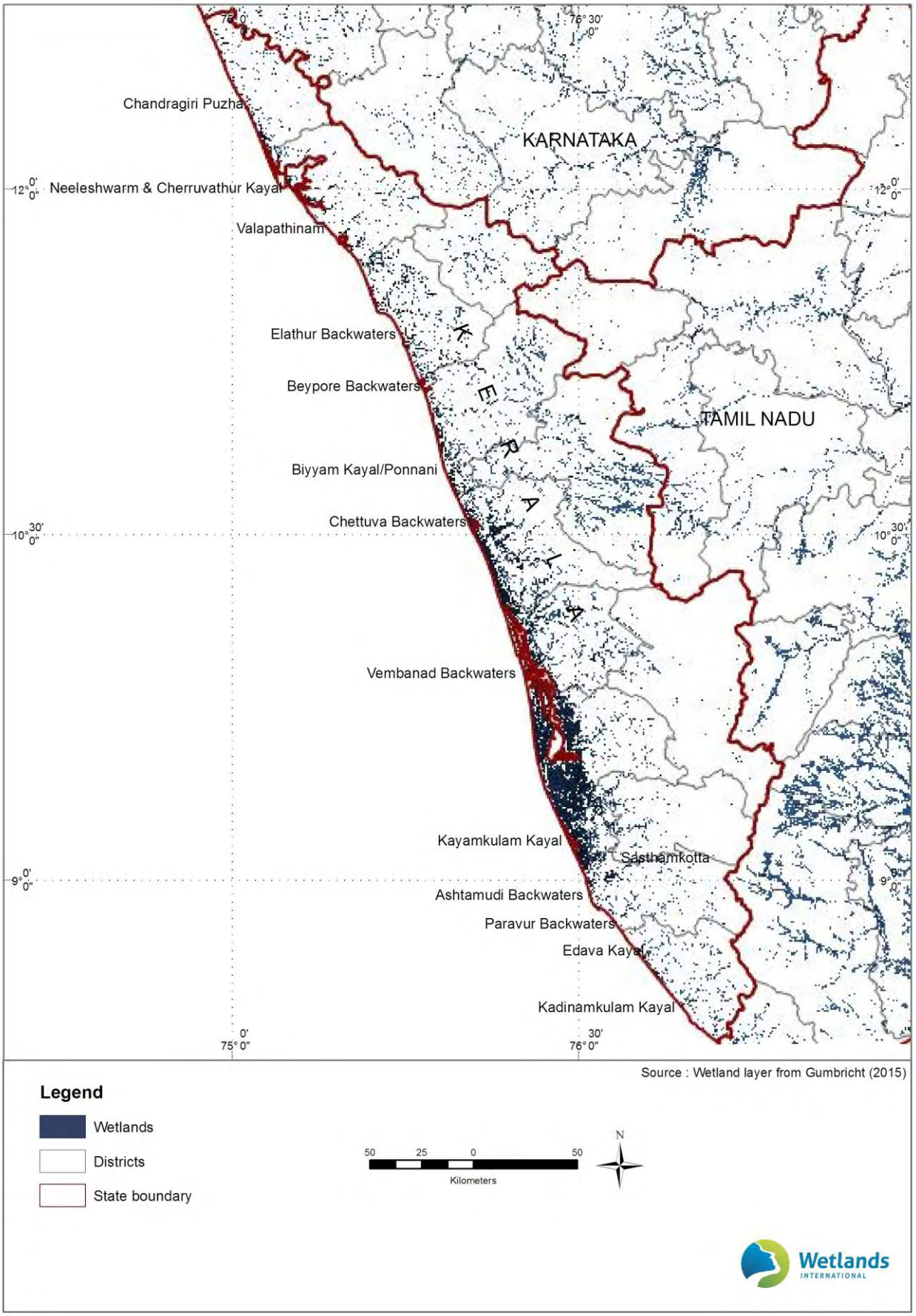
1.1 Background

Kerala is bestowed with a range of inland and coastal wetlands which form the core of the state's ecological and economic security. While accounting for only ~ 5% of the state's geographical area (SAC, 2010), the 0.16 M ha wetlands linked with its 44 rivers and 587 km long coastline provide a range of ecosystem services as fisheries, agriculture, inland navigation, tourism, groundwater recharge, buffering floods, besides being inextricably linked with people's culture and belief systems (Map 1.1). The wetlands also provide habitat to a range of species, including atleast 189 fish (57 endemic to Kerala), 136 amphibians (36 endemic to Kerala) and 160 birds, including over 100 waterbirds migrating within Central Asian Flyway. Three significant wetlands of the state, namely Vembanad-Kol, Ashtamudi and Sasthamkotta have been designated by the Ministry of Environment, Forest and Climate Change (MoEFCC) as Wetlands of International Importance under Ramsar Convention.

Located in Kunnathur Taluk of Kollam District, Sasthamkotta is the largest freshwater lake of Kerala (Map 1.2). Spanning 373 ha, the lake is the principal source of water for nearly 0.5 million people living in Kollam City and its suburbs. Sastha temple, from which the lake is believed to have got its name is an important religious and cultural centre for the region. The striking beauty of Sasthamkotta's placid waters surrounded by lush green hills have earned it the distinction of 'Queen of Lakes'. Sasthamkotta was designated Ramsar Site in 2002, thereby underlining the commitment of National as well as State Government for its conservation and sustainable management.

Sasthamkotta is evolving towards a marsh dominated stage due to frequent drying out of its lake bed. Rapid land use intensification within the catchments, unregulated mining within the floodplains and increasing spread of macrophytes has greatly impaired the lake ecosystem's health. Waste management practices in the shoreline villages are far from being comprehensive. Continued prevalence of these trends is only likely to adversely impact ecosystem functioning and increase water insecurity for the dependent communities.

A management plan for Sasthamkotta was drafted in 2001, and approved for implementation by MoEFCC. Limited funding was provided for implementation of the plan by the MoEFCC under the National Wetlands Conservation Programme (presently consolidated into National Plan for Conservation of Aquatic Ecosystems). The lake, however, went through a prolonged dry phase in 2009 – 10, thus necessitating a review of management. The State Government, responding to series of political representation made by the Panchayat and civil society organizations in 2010, called on the services of Centre for Water Resource Development and Management (CWRDM) to conduct hydrological assessments to identify the reasons of shrinkage in inundation regime, and consolidate the recommendations into a revised management plan (CWRDM, 2010). Following a review of the management plan at various levels, it was felt that the required level of sectoral integration was not achieved in the document. The document also did not conform to the requirements of management planning for Ramsar Site as outlined in the various guidance prescribed by the Ramsar Convention. The Department of Environment and Climate Change therefore initiated a reformulation of management plan, by entrusting the assignment jointly to Wetlands International South Asia and CWRDM. The present management plan is a response to this decision.



Map 1.1 | Wetlands of Kerala

Map 1.2 | Location of Sasthamkotta Lake

1.2 MANAGEMENT PLANNING PURPOSE AND OBJECTIVES

The overall purpose of management planning is to outline a strategy and specific actions for maintaining full range of wetland ecosystem services and biological diversity values. The management planning process addresses the following specific objectives :

- Development of a baseline inventory of wetland features and governing factors
- Assessment of status and trends in ecosystem components, processes and services, and risks of adverse change
- Participatory appraisal with communities to reflect their views, rights and capacities in the context of integrated management
- Evaluation of sectoral plans and management practices, and identification of interlinkages and coordination needs for integrated management
- Development of management planning framework ensuring linkages with existing sectoral plans being implemented by various government agencies
- Estimation of financial resources required for integrated management
- Recommending an effective institutional mechanism with clear cut roles and responsibilities of participating institutions supported by appropriate policies and regulations
- Designing an effective monitoring and evaluation framework for sustainable management

1.3 APPROACH AND METHOD

The 'wise use' approach of Ramsar Convention is globally recognized as the central tenet of wetland management. This approach recognizes that restricting wetland loss and degradation requires incorporation of linkages between people and wetlands, and thereby emphasizes that human use of these ecosystems on sustainable basis is compatible with conservation (Finlayson et al., 2011). The wise use approach aligns well with the fact that a certain level of natural variation and disturbance is important to maintain resilience within wetland ecosystems.

The Ramsar Convention on Wetlands defines wise use as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". Ecological character is "the combination of ecosystem components, processes and benefits/services that typify the wetland at a given point in time". Ecosystem services has been drawn into the definition of ecological character as a means of bridging wetland ecosystem functioning and their human use for well-being (Finlayson, 2012).

Ecosystems approach requires consideration of the complex relationship between various ecosystem elements and promotion of integrated management of land, water and living resources. Wise use, through emphasis on sustainable development, calls for resource use patterns which can ensure that human dependence on wetlands can be maintained not only in the present, but also in the future. Seen in totality, wise use is about maintaining wetland values and functions in order to ensure maintenance of flow of benefits from wetlands (their ecosystem services) from inter-generational equity point of view.

The approach adopted for management planning of Sasthamkotta is in line with the New Guidelines for Management Planning endorsed by the Eighth Meeting of Contracting Parties to the Ramsar Convention (Ramsar Convention Secretariat, 2010a). The guidelines call for adoption of diagnostic approaches for assessing management needs, based on systematic evaluation of wetland features and their governing factors. The guidelines also call for integrating site management plans into public developmental planning system at local, regional and national levels. In order to safeguard sites and their features, the guidelines recommend adoption of an adaptable management process which allows wetland managers to respond to the legitimate interest of others, adapt to an ever-changing political climate, accommodate uncertain and

variable resources, and survive the vagaries of the natural resources.

Management of Sasthamkotta thus far has been aimed at maintaining its capacity to support water supply for the inhabitants of Kollam City and its suburbs. The limitations of current management are apparent in frequent exposure of lake bed, pollution, and community resentment on deteriorating evirons. Wise use of Sasthamkotta entails putting in place management arrangements which can ensure provision of societal benefits from the lake on long term basis without compromising ecosystem health and integrity. Therefore, integrated management planning is aimed at providing a programmatic framework for achieving wise use of Sasthamkotta through restoration of ecological character in a 'healthy state' and embedded within the environmental and socio-economic sustainability objectives pursued through the on-going developmental programming in the State of Kerala.

The process of development and implementation of management plans for wetlands need to be accompanied with governance improvements at basin level. Such an approach underpins Integrated Lake Basin Management framework which calls for achieving 'sustainable management of lakes through gradual, continuous and holistic improvement of basin governance, including sustained efforts for integration of institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technological possibilities, and funding prospects and constraints (RCSE-SU and ILEC, 2014). Achieving close relationship between planning and governance is critical considering multiple stakeholder and sectoral interests which underlie and to a large extent structure wetland biodiversity and ecosystem service values, and the need to secure people's involvement and participation in basin scale management for considerably long periods of time.

Management planning for Sasthamkotta thus draws upon the six governance pillars for Integrated Lake Basin Management (RCSE-SU and ILEC, 2014), namely:

- Institutions : development of effective organizations and governance frameworks
- Policies: setting broad directions and specific rules
- Participation: expanding circle of involvement
- Technology: possibilities and limitations
- Information: pursuing sources of knowledge and wisdom, and
- Finance: seeking for sustainable sources at appropriate level

The management planning approach adopted herein is also in line with the National Environment Policy (2006) of Government of India which recommends integration of conservation and wise use of wetlands into river basin management involving all relevant stakeholders, in particular local communities. The policy further recommends integration of wetland conservation into sectoral development plans for poverty alleviation and livelihood improvement, and link efforts for conservation and sustainable use of wetlands with all on-going rural infrastructure development and employment generation programmes. Guidelines of MoEFCC's flagship programme for wetlands, NPCA (National Programme for Conservation of Aquatic Ecosystems) also recommend integration of wetland conservation in developmental programming by emphasizing convergence opportunities, stakeholder engagement and diagnostic evaluation approaches. The National Water Policy (2012) also espouses river basin scale planning, and integrated approaches in water resources management.

The need for integrated approaches are equally stressed upon in various policies of the State Government. Kerala Water Policy (2007) calls for multidisciplinary and holistic approach for management considering water as part of ecosystem for the benefit of all and not for the profit of few. Conservation and sustainable use of wetlands adopting a basin approach, while systematically addressing the drivers of degradation, namely pollution and unsustainable water harvest is listed as priority area within

Kerala State Environment Policy 2009. Kerala is also a front runner in putting in place a regulatory mechanism for wetlands in the form of Kerala Conservation of Paddy Land and Wetland Act (2008) which restrict conversion and reclamation of wetlands.

The management plan also responds to the requirements of Wetlands (Conservation and Management) Rules, 2010. These rules require specification of wetland boundary and a zone of influence, and enforcing a number of prohibitions and regulation of developmental activities detrimental to wetland ecosystem health.

In line with available international and national guidelines and best practices, the management plan for Sasthamkotta has been developed using a diagnostic approach (Fig.1). Status and trends in hydrological, ecological and socio-economic features have been assessed to determine key factors limiting integrated management. An evaluation of institutional arrangements (including sectoral programmes, policy and regulatory frameworks and stakeholder arrangements) has been carried out to identify coordination opportunities. An integrated and hierarchical assessment, monitoring and evaluation system has been recommended to enable adaptive management. These analyses form the basis of an action plan, with well-defined objectives and outcomes, to achieve wise use.

The management plan has been prepared by a team of experts of Wetlands International South Asia and CWRDM drawn from disciplines of hydrology, ecology, watershed management, sociology, and economics. Data on hydrological and ecological aspects was collected from various State Government departments, agencies and research institutes. Detailed socio-economic surveys and participatory assessments were conducted in villages located around the lake and its command areas to determine wetland

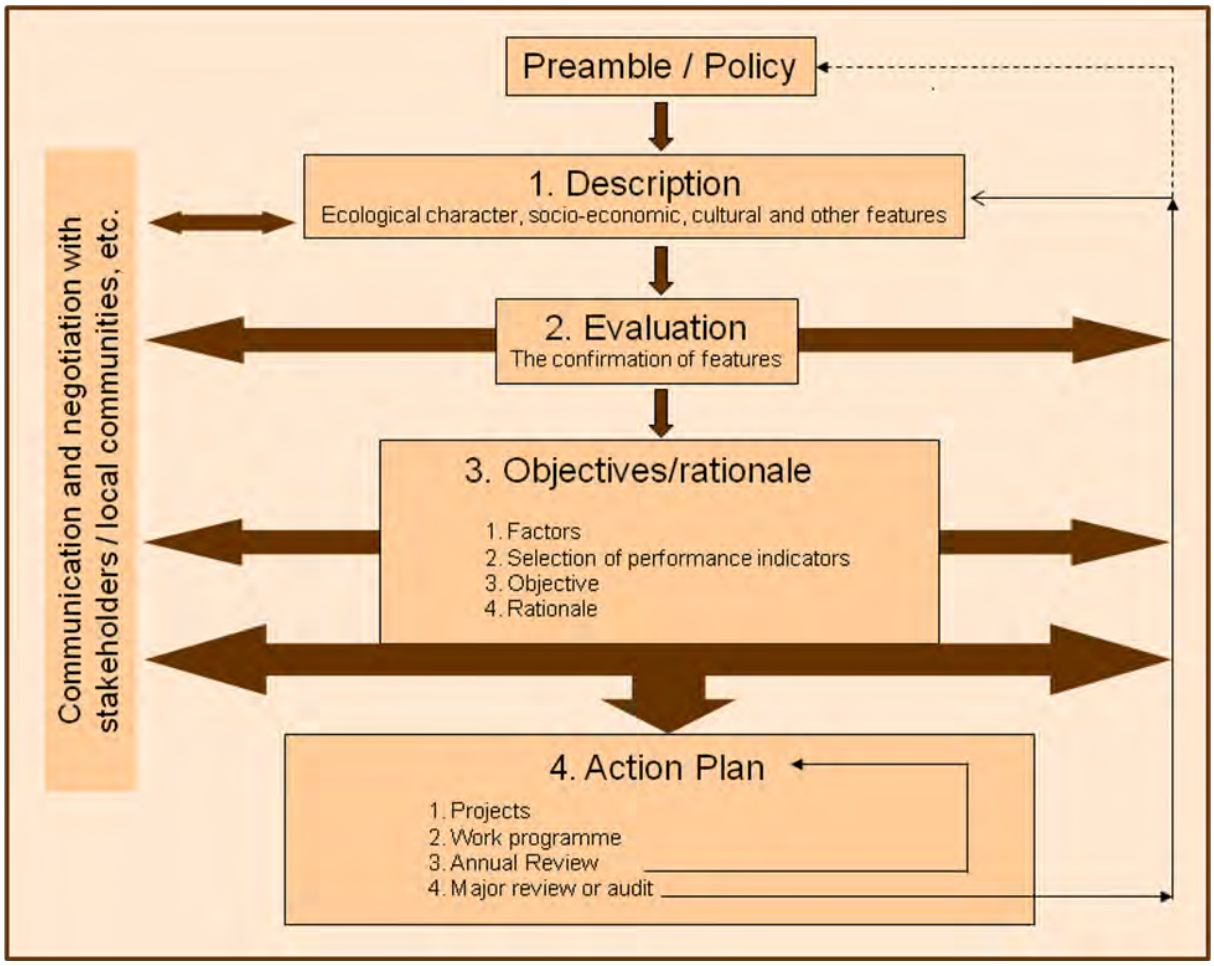


Fig. 1 | Management Planning Framework for Wetlands (Source : Ramsar Secretariat 2010a)

livelihood interlinkages. Secondary literature was also collated to establish status and trends in wetland features. To the extent possible, all available data has been presented in the form of thematic maps. The action plan has been developed with due consideration of existing departmental plans, as well as stakeholder consultations.

1.4 MANAGEMENT PLAN STRUCTURE

The management plan is presented in seven chapters. The first chapter sets the management planning background, approach and method. Chapter 2 contains description and evaluation of wetland features. Chapter 3 includes a review of existing institutional arrangements and a proposal for integrated management. An evaluation of ecological character is presented in Chapter 4. A monitoring and evaluation framework for Sasthamkotta is discussed in chapter 5. Chapter 6 and 7 include detailed action plan, budget and resourcing opportunities.

2. Review of wetland features

2.1 Location and extent

Sasthamkotta forms part of an extensive wetland regime formed on the alluvial deposits of River Kallada. These open water bodies and marshes systems are conspicuous between the Bharanikavu Town and the confluence of River Kallada with Ashtamudi Estuary at Kovilli. Besides Sasthamkotta, Karali, Velanthara, Veliyapadam, and Kadapuzha are significant marsh dominated areas flanking the right bank of Kallada River. Sasthamkotta is isolated by marginally elevated ridges, rising sharply from the average lake level of 13.5 m amsl to nearly 35 m amsl on the northern, western and southern flanks. The south-eastern margins, which would have naturally drained into River Kallada was embanked in the 19th century. The earthen embankment was made permanent in 1956 under the Quilon Water Supply Scheme supported by Indo-Norwegian Foundation. The embankment at most places is about 20 m amsl elevation.

Sasthamokotta is easily accessible from the Kerala state's extensive road network. Kollam City, the nearest urban center is located at a distance of 26 km from the lake. The Kollam-Theni Highway NH 220 runs parallel to its eastern margin. The Adoor-Sasthamkotta-Chhavra Road and the Kadapuzha-Karalimukku Road run respectively along the lake's north-western and southern margins.

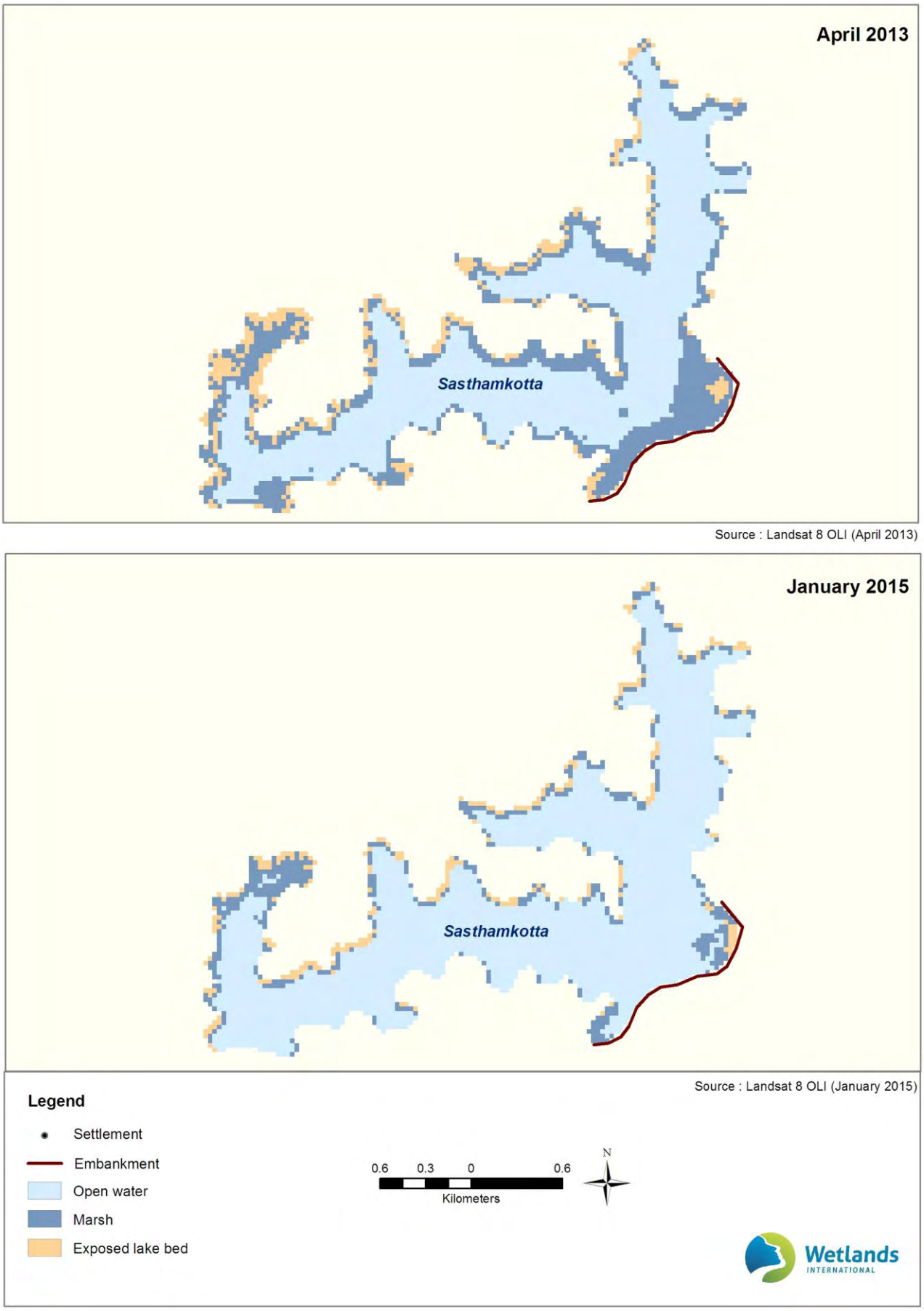
The inundated area within Sasthamkotta reaches its peak during the month of October, post southwest monsoon, spanning nearly 360 ha. This gradually recedes by the end of April, wherein large parts of inundated area along the embankment, and northern shorelines transforms into marshes. A delineation of wetland boundary was done in 2007 by Kerala Water Authority and Revenue Department. Based on the survey 387 boundary pillars were fixed 50 m away from the peak inundation area. The area of the wetland has been delimited to 373 ha (roughly corresponding with 16 m amsl water level), which includes open water area, marshes and fragments of exposed lake bed. Seasonal transitions in land use and land cover within the wetland is presented in Table 2.1 and Map 2.1.

Table 2.1 Seasonal transitions in land cover within Sasthamkotta

Land cover	April 2013	January 2015
Water	229.86	306.18
Marsh	108.45	47.07
Exposed lake bed	34.69	19.75
Total Area(ha)	**373.00**	**373.00**

(Data source: Analysis of Landsat 8 OLI Imagery of dates April 25, 2013 and January 12, 2015)

A panoramic view of Sasthamkotta Lake from Ambalakadavu



Map 2.1 | Land cover change within Sasthamkotta Lake in various seasons

2.2 WETLAND CATCHMENTS

Wetlands are the primary resources from which water and its benefits for humans are derived, and they constitute a major and critical component of the hydrological cycle that keeps us supplied with water (Ramsar Convention Secretariat, 2010b). River basins or river catchments (and the coastal and marine areas influenced by catchment discharges) are important geographical units for considering management of wetlands and water resources, as these ecosystems act as the connecting links between land and water systems within a river basin. Integrated River Basin Management (IRBM) reflects the principal philosophy of coordinated, collaborative decision-making across multiple land and water use sectors on multiple, connected scales, in order to ensure that the social and economic benefits of land and water resource use can be sustained and shared equitably, while still protecting vital ecosystems and their services.

Developmental planning, particularly land and water use changes within the basin of Kallada have a significant bearing on the status of Sasthamkotta. Within this basin, a direct catchment spanning 629 ha is isolated by moderately elevated ridges all around the lake except in the southern side, wherein an embankment has been constructed. This section of the management plan presents a description of the wetland catchments and land use and land cover changes therein. The analysis is primarily based on remote sensing images supplemented with secondary information derived from published reports.

Kallada River Basin

River Kallada originates as the Chendurni River in Papanasam range of the Western Ghats, at an altitude of 900 m amsl. Just after the source, Chendurni is joined on its right bank by three major seasonal streams, namely the Aruvi, the Uruli and the Narat. At Parappar, before which the river channel is joined by Kalathuruthy on right bank and Kulathupuzha on the left bank, a 335 m dam has been constructed (completed in 1986), leading to formation of reservoir with gross storage capacity of 504.92 Mm^3. Five kilometre further downstream of the dam, a pick-up weir has

View of Kallada River from NH220 near Kadapuzha

been constructed at Ottakkal with a capacity of 17 Mm^3, wherein the right and the left branch canals take off for irrigating a cultivable command area of 53,514 ha. Water from the reservoir is also used for generating 15 MW hydropower with the tailrace being reconnected to irrigation channels.

River Kallada exhibits a dendritic drainage over terrain with uniform rock structure. The river has an average gradient of 12.6 m/km, exhibiting high sinuosity, particularly in its middle and lower reaches, forming several incised meander loops flowing over tertiary and quaternary sediments (CGWB, 2013). The River is vertical eroding river and at places the channel bed lies as low as 8 m from the adjoining river banks, a characteristic observed in rivers in their upstream regions.

Before its confluence with the Ashtamudi Estuary, the Kallada flows for a length of 121 km, drains 1,598 km^2 catchment area[1] and is joined by 47 tributaries, generating an average annual stream flow of 3,374.86 Mm^3 (CWRDM, 1995). Majority of the basin area (84%) lies within Kollam District. The basin has 26 sub-watersheds which have been further sub divided in to 107 micro-watersheds. The direct drainage basin of Sasthamkotta lies within the watershed 5A1A7d2 (Map 2.2), and spans an area of 1002 ha (inclusive of 373 ha lake area).

Sasthamkotta is part of several fresh water bodies separated by natural ridge features that dot the landscape of Kallada basin. The Kallada basin exhibits a typical linear valley and ridge type topography with a number of freshwater bodies and floodplains formations. At least fifteen floodplains can be identified on Google Earth © images located on either side of the Kallada River. The elevation difference between the river bed and river banks and adjoining lands on the left and right banks of the river result in inundation of several low lying valleys which are also fed by rainfall from the surrounding hills. These lakes and floodplains have direct hydrological linkages with the Kallada River or had such linkages in the past. Natural sedimentation process has severed the riverine connection of many of these wetlands and floodplains. A few lakes such as Sasthamkotta, Chelurpola Kayal located very close to Ashtamudi because of low elevations are influenced by sea conditions during dry summer months and interventions were made to maintain fresh water conditions and bunds were constructed separating these water bodies from the Kallada River.

[1] The basin area has been delineated using the elevation data of Shuttle Radar Topography Mission 3, Version 2.1, collected in February 2000 by NASA. The basin area reported by WRIS is however 1,699 km^2.

Climate

The basin is located within the warm humid tropical climatic zone, characterized by hot and wet summers and mild dry winters. Annual rainfall ranges between 2,225 mm and 4,038 mm, with peaks exceeding 3,000 mm especially at the head of the basin. Over half (53 %) of the rainfall is received during southwest monsoon period (June – September). Another 27 % rainfall occurs during the retreating northeast monsoon (October – December). The period between January-March remains more or less dry, however, summer rains are received during the months of April and May. The normal daily mean temperature varies between 26.1°C and 29.1°C.

Physiography

In a west to east progression, the basin of River Kallada can be divided into three distinct units viz. the coastal plains, the midlands and the highland regions. The coastal plains with an elevation ranging between 0-6 m amsl occur as narrow belt parallel to the coast. Here the areas with nearly level slope characteristics constitute the wetlands and the marshes. The midland region has altitudes ranging between 6-100 m amsl, and is mostly characterized by undulating topography formed by small laterite hills separated by valleys. The midlands have gentle to moderate slopes. The upper reaches of the Kallada Basin catchments lie in the Western Ghats, and have elevations between 100– 1,763 m amsl, the highest point being Karimalaikodkal (Map 2.3). Large parts of the highlands form a part of the Papanasam Reserve Forests, the Courtallam slopes Reserve Forests and

the Chendurni Wildlife sanctuary. These areas have steep to very steep slopes. Table 2.2 and Map 2.4 include details of slope categories for the Kallada Basin.

Table 2.2: Slope characteristics of Kallada Basin

Slope categories	Area (km^2)	% of total
Nearly level (0-1%)	121	8
Sloping (2-10%)	797	50
Steep (11-25%)	539	34
Very steep (> 25%)	141	9
Total Basin Area	**1598**	**100**

Elevations within the direct drainage basin of Sasthamkotta range between 15– 40 m amsl characterized by hillocks, valley hills and gently sloping alluvial floodplains. Lower elevations (16-18 m amsl) on the west of Sasthamkotta, mark the place where the wetland bears connection with adjoining Karali marshes.

The state highway 37 (The Adoor-Sasthamkotta), the NH 220 and the Chavara-Sasthamkotta road run along ridge features around the lake, in the north, east and west of the lake. At a point below the embankment near the Thiruvatta - Mahadevar temple where the river takes a small U turn after flowing southwards for some distance, the left bank of Kallada River is depressed by as much as 3-4 m as compared with its right bank and its adjoining floodplains and probably marks the area of spill of Kallada water in to the connecting marshes and subsequently in to the lake. The surface water connectivity is presently hindered by the Karalimukku-Kadapuzha Road which runs along the right bank of the River (Table 2.3).

Table 2.3: Slope characteristics of Sasthamkotta drainage basin

Slope categories	Area (ha)	% of total
Nearly level (0-1%)	230	23
Sloping (2-10%)	651	65
Steep (11-25%)	120	12
Very steep (> 25%)	0	0
Total catchment area*	**1002**	**100**

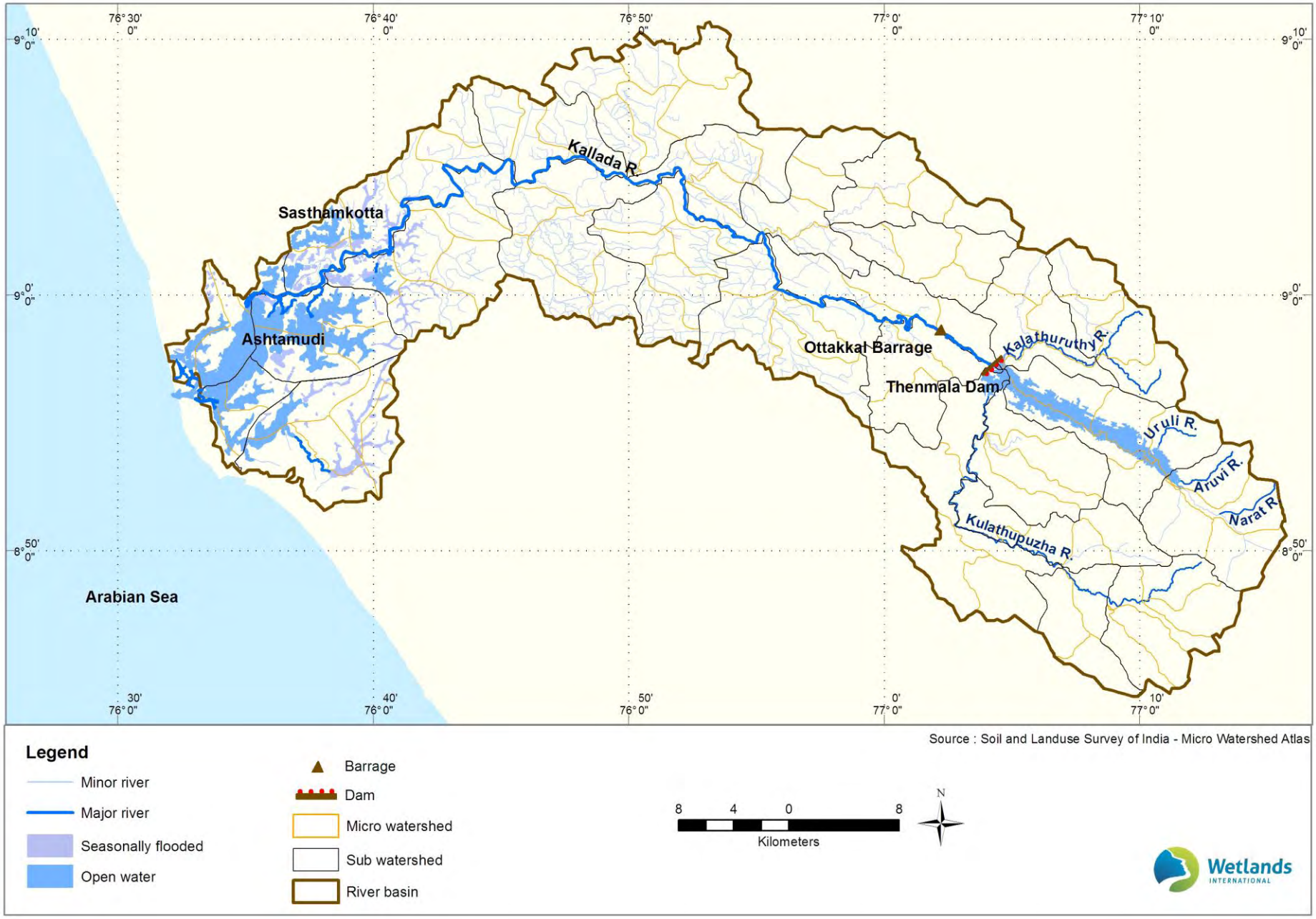
(*Catchment area includes 373 ha of lake area)

Geology and Geomorphology

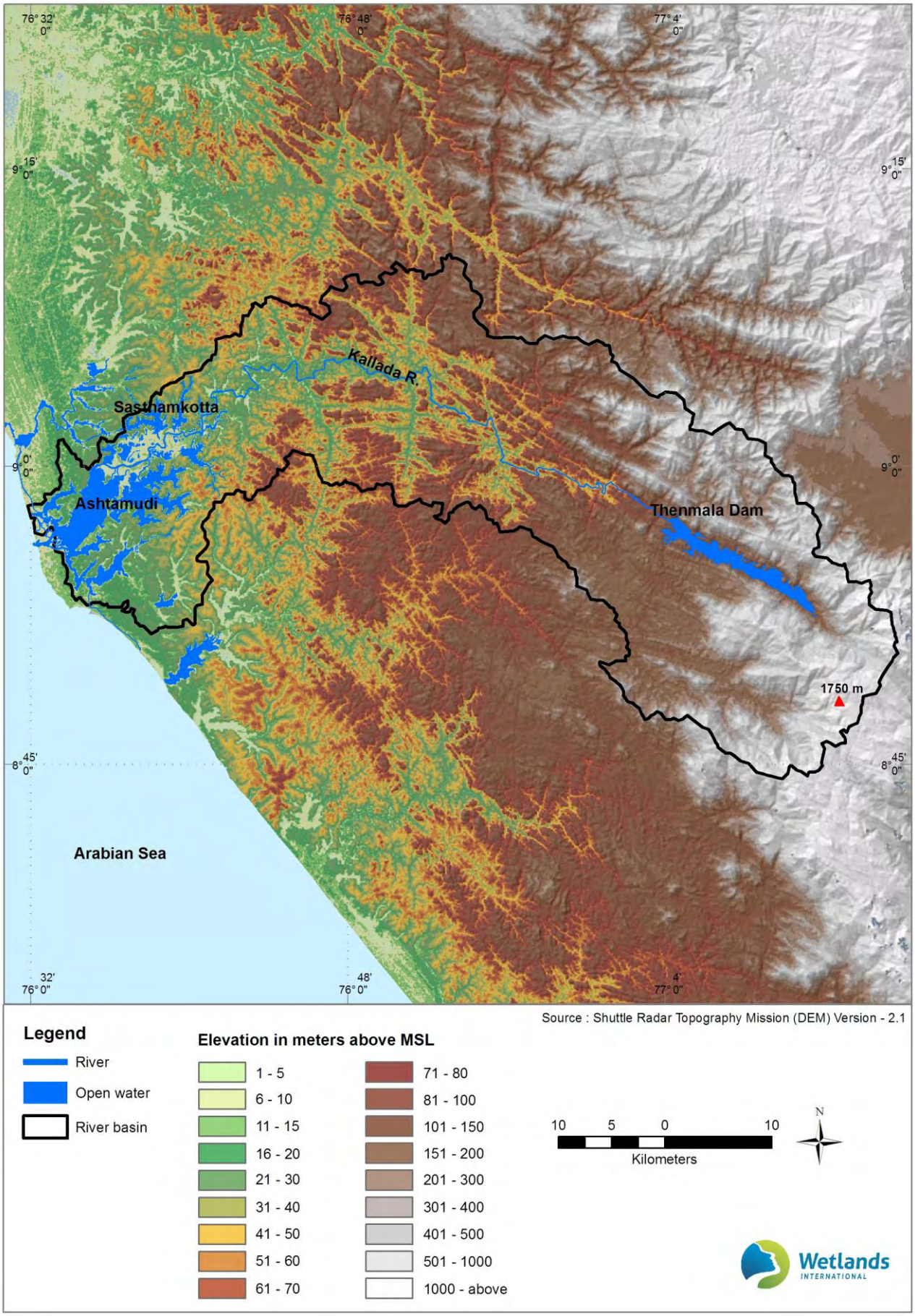
The Kallada Basin is made up of the Archaean crystalline basement, with overlying tertiary and quaternary sedimentary sequences. The rocks of Archaean age are exposed in the Western Ghats. The crystalline formations that occur here are khondalites, charnockites, granite gneisses and intrusives. For a good part of its initial course, Kallada River flows aligned to the Achen-Kovil Shear Zone (AKSZ), a major ductile shear zone separating two contrasting geological domains that separate the Southern Kerala Khondalite Block from the Northern Madurai Granulite Block. The AKSZ trends NW–SE with a width of ~ 15 km and extends for more than 120 km strike length (Rajesh and Chetty, 2006).

The Southern Kerala Sedimentary Basin was formed by crustal thinning (Qureshy, 1982), during Late Oligocene or Early Miocene. The basin has a sediment fill of approximately 700 m thickness with 600m of the sediments of early to middle Miocene and the remaining 100 m of quaternary age (Nair et al., 2010). The Cenozoic sedimentary succession in the onshore part of the Kallada Basin is dominated by siliciclastic sediments with interbedded lignite seams (Reuter et al., 2010). The sources for siliciclastics are the Western Ghats sediments deposited by the rivers in marginal lagoons (refer Text Box).

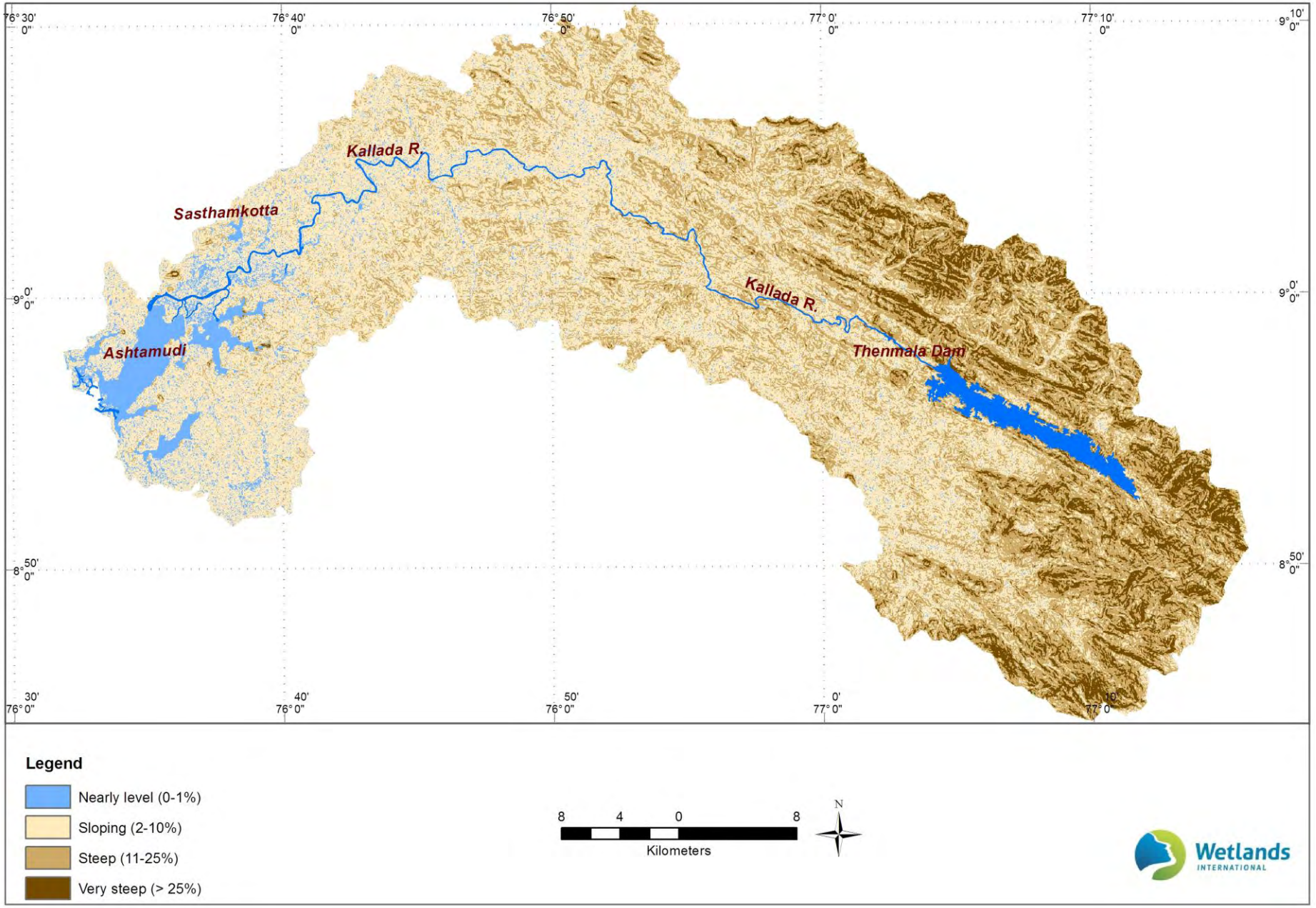
Sasthamkotta has developed on the uplifted South Kerala Sedimentary Basin (SKSB) (Nair et al., 2006). Tertiary sediments found within the direct drainage basin belong to Quilon and Warkalli Formations of Lower Miocene age. The laterite hillocks surrounding the Sasthamkotta are part of the Warkalli formation composed of sandstones and variegated clays and lenticular seams of lignite in certain pockets. This is underlain by more compact marly-sandstone with shell fragments and thin horizons of limestone, as known as the Quilon Formation.



Map 2.2 | Watersheds of Kallada River Basin



Map 2.3 | Elevation profile of Kallada River Basin



Map 2.4 | Slopes in Kallada River Basin

Evolutionary history of Sasthamkotta

Extending along the coast between Kollam and Kondungallur, the Southern Kerala Sedimentary Basin (SKSB) is the landward extension of Offshore Kerala Konkan Basin (Nair et al., 2006). The basin has a fill of about 700 m of sediments of which about 80 m are made up of Quaternary sediments. A characteristic feature of this basin is presence of largest coast-perpendicular estuary (Ashtamudi) and several marshes and lakes in a similar fashion. The formation of these wetlands is closely linked with the Quaternary geology of the basin (Map2.5).

During the Pleistocene period that ended about 11,700 years ago, the climate of the basin was drier and cooler. The rivers that flowed in the region, had established extensive riparian floodplains and swamps forests. The evidences of these swamps, particularly *Myristica* swamps can be seen at present as far as Chendurni Wildlife Sanctuary within the basin. These swamps are regarded as relic habitats and are one the most primitive of angiosperms with the family believed to have originated before the break up of Gondwana land. The tree exhibits physiological adaptations for waterlogged conditions such as protrusions, stilt roots, flying buttresses, aerial adventitious roots. These adaptations made them ideal species to establish and proliferate along the entire western coast.

During the early Holocene, as the Earth started warming up, heavy rainfall was experienced which flooded the existing river valleys. This flooding which occurred around 8,500-5,500 years ago, submerged the thick riparian forests with bank sediments derived from the nearby lateritic hills. Thus, the extensive Pleistoscene forests were converted into swamps, marshes and lakes. As sea levels receded about 4,000 years ago, sediments were deposited at the head of the river mouths, forming the Kerala Bay Head Delta. The Bay Head delta propagated seawards, filling up half of the Ashtamudi. River meandering and migration together with rapid sedimentation, as revealed by the sedimentary records of boreholes, was responsible for cut off of many broad, scoured valleys into freshwater bodies like Sasthamkotta Lake, Chelupola Lake, Chittumala Lake, etc.

The Quilon Formation, occurring below the Warkalli Formation is represented by fossiliferous limestones and sandy carbonaceous clays. Found in Parvoor and in the neighbourhood of Kollam, this is popularly known as the Kollam or Quilon limestone and is extensively exploited. Incidentally, Kollam District produces 36 % of crude clay and 43.5 % of processed clay in the state which accounts for 9.08% of the country's total China Clay production. The areas around the Sathamkotta Lake have rich reserves of China clay.

In most regions of Kerala, bauxite is associated with laterite and occurs as cappings over the crystalline and tertiary sedimentary rocks and forms lateritic plateau rising from 50 to 150 m above the msl. At Chattannur and Kundara in Kollam District, a zone of about 2 m thick bauxite is recognised at the contact between the crystallines and the overlying sedimentary rocks. The bauxite at the base of the sedimentaries indicates an earlier pre-Warkalli spell of lateratisation.

Soils

The National Survey of Soil Survey and Land Use Planning, Nagpur has identified mainly seven types of soils from the Kallada Basin. These are spread along a longitudinal north-south alignment and represent the geological sequence of formation of these soils from the Western Ghats to the coast. Textural analysis of soil samples indicates that the soil belongs to clay, sandy clay and sandy clay loam class.

Low lying coastal areas around the Ashtamudi Estuary mouth have very deep imperfectly drained clayey soils with shallow water table (Fine, Mixed Typic Dystropepts along with Fine, Mixed Aeric Tropaquepts) which are on level lands with valleys with slight erosion.

Map 2.5 | Ashtamudi and Sasthamkotta wetland complex

Small patches of well drained to imperfectly drained, clayey soils with moderately shallow water table - Typic Dystropepts and Typic Tropaquepts (hydromorphic alluvial soils) are found in narrow valleys and level lands to the west of Sasthamkotta and along Kallada River. These alluvial hydromorphic soils have been formed as a result of transportation and sedimentation of material from adjacent hill slopes and also through deposition by rivers. The development of the soil profiles has occurred under impeded drainage conditions. These soils, therefore, exhibit characteristic hydromorphic features like grey horizons, mottling streaks, hard pans, organic matter depositions, iron and manganese concretion, etc. (Map 2.6)

Heavy rainfall and high temperature in south Kerala are conducive for laterisation. Extensive laterite soils poor in available Nitrogen and Phosphorus with high clay content and low Cation Exchange Capacity are found in Kallada basin over coastal laterites and lateritic mounds in midlands and hilly areas. Very deep, well drained, gravelly clay soils occur on coastal laterites. Kaolinitic clays in coastal stretches west of Sasthamkotta belong to these categories. These kaolinitic, skeletal, clayey soils belong to the type Typic Kandiustults along with Typic Kanhaplustults. A major part of middle basin of the Kallada River beginning from mid of Sasthamkotta till Punalur is characterized by very deep, well drained, gravelly clay soils with moderate surface gravelliness formed on gently sloping midland laterites.

Very deep, well drained gravelly clay soil with moderate surface gravelliness are found on moderately sloping laterite mounds and on gentle slopes around Sasthamkotta and the middle and upper reaches of the basin. It is found around Bharanikavu, spreading to Pattazhy, Maloor and Edamon that is situated in the foothills of Western Ghats. These comprise the Clayey, Kaolinitic, Ustic Kanhaplohumults and the Clayey, Kaolinitic, Typic Kandiustults soil types.

Forest loams are restricted to upper catchments of the basin. These are the products of weathering of crystalline rocks under forest cover, and have immature profiles with shallow soils, followed by gneissic parent material in various stages of weathering.

Exposed lateritic soil near pump house

Map 2.6 | Soil types around Sasthamkotta Lake

Very deep, well drained gravelly loam soils (Ustic Humitropepts) are found on steeply sloping medium hills with thick vegetation in the basin of Kalathuruthy River, areas north of the Thenmala reservoir and along the Kulathupuzha River. These soils found around Ayiranalloor are subject to moderate erosion. They are also associated with well drained clayey soils on slopes (Ustic Palehumults).

Land use land cover change

The highlands of Kallada Basin form part of biodiversity rich Western Ghats (one of the 18 global biodiversity hotspots). The upper catchments form part of the core area of Agasthathyamalai Biosphere Reserve, which is famous for the endangered Lion Tailed Macaque (*Macaca silenus*) amongst other noteworthy flora and fauna. These areas are mostly forested, comprising the Thenmala Forests located on north of the Parappar Reservoir, Kulathupuzha Reserve Forests on its south, the Courtallam Reserve Forests of Tamil Nadu on its east and Yeroor Reserve Forests and Achenkovil Reserve Forests on the west of the reservoir. Chendurni Wildlife Sanctuary established in 1984, covers an area of 171 km^2 on either side of the Parappar Reservoir. Biodiversity within the sanctuary is noted for high level of endemism.

The ridges and valleys of the basin, within 800 m to 1200 m amsl elevation are mostly forested. Southern hilltop evergreen forest constitutes the major forest type. The higher slopes are covered by dense multi-storeyed tropical evergreen vegetation with abundant lianas and epiphytes. The semi-evergreen forests occur at lower elevations and in areas with lesser rainfall. The Chendurni Sanctuary is believed to be named after a tree species found in these forests, the *Gluta travancorica* locally called *Shenkurinji*.

The lower slopes of the hills below 600 m are covered by moist mixed deciduous forests. Myristica swamps which have a characteristic edaphic formation occur in the valley bottoms in areas subjected to inundation almost throughout the year. Grasslands and reed and cane breaks are also found in valleys and along streams and rivers. Myristica swamps are characterized by the presence of the primitive angiosperm family Myristicaceae or nutmeg family. Three major genera are found within the Western Ghats of India, namely *Gymnacranthera* (*Gymnacranthera*

Rubber plantation near Muthupilakadavu

canarica), *Myristica* (*Myristica magnifica, Myristica malabarica and Myristica canarica*) and *Knema* (*Knema attenuata*).

Some of the tree species found in these forests are *Dipterocarpus indicus, Strombosia ceylanica, Canthium pergracile, Hopea racophloea, Vateria indica, Aglaia lawii, Calophyllum polyanthum, Syzygium* sp., *Terminalia bellirica, Alstonia scholaris, Cullenia exarillata, Palaquium ellipticum, Dysoxylum malabaricum, Bischofia javanica, Humboldtia decurrens, Litsea oleoides, Holigarna grahamii, Antidesma menasu, Messua ferrea, Semecarpus auriculata* .

Grasslands are observed bordering the semi evergreen and deciduous forests, wherever there are open spaces. These are created as a result of degradation pressures caused by fires and grazing. Tall coarse grasslands comprising *Imperata cylindrica*, *Andropogon* sp. is interspersed with sporadic tree growth of *Emblica officinalis, Careya arborea*, *Pterocarpus marsupium* among others.

Forest plantations of teak, *Acacia auriculiformes, Acacia mangium* and other species occupy an area of approximately 135 km^2 in the Thenmala, Punalur and Achenkovil Forest divisions in the catchment (Kerala Forest and Wildlife Department, 2010). In the midlands, extensive rubber and eucalyptus plantations mark the landscape of hills tops and sides. The hill slopes are fairly thickly vegetated mostly with mixed crops and plantations.

The valley areas between the lateritic hills are rich in soil nutrients. These low-lying floodplains are used for paddy cultivation and multi–tier cropping of coconut and other crops with a ground tier of paddy. These areas are densely populated. Cultural diversity within the upper reaches of the basin is marked by the presence of atleast eight tribes (the Mala Pandram, Malayadiar, Malavedan, Kochuvelan, Malaluravar, Knaikkar, Ulladan, and Uraly). Remarkably, remnants belonging to Mesolithic period of the Stone Age was excavated from a large cave situated at the north-western part of the Chendurni River

An analysis of land use land cover change within the basin for the period 1988-2015, derived from remote sensing imagery indicates a decline in dense and open forest, and with almost a commensurate increase in plantation. The area under agriculture did not show any significant change, whereas marshes have declined. The area under settlements has increased significantly (Fig. 2.1 and Map 2.7)

The Kallada Basin has undergone a reduction in forest cover, with extensive patches converted for agriculture and plantation.[2] Coffee plantations were raised in Kulathupuzha and Chendurni valleys as early as the first decades of the 19th century, and later converted to tea or abandoned. Large moist deciduous and semi evergreen forests have been converted, even under state sponsorship, to raise eucalyptus plantations in Kulathupuzha and Anchal. In 1972-73, rubber plantations were raised in over 2,000 ha of clear forests in Kulathupuzha and Ayiranallur so as to enable resettling of 0.6 million repatriates from Srilanka. Construction of railway and roads have been also indicated for degradation of extensive forest tracts of the Kulathapuzha, Aryankavu, Nedumangad and Thenmala region.

Within the direct catchment, plantations form the major land use accounting for 66% of the area. These plantations constitute mostly of coconut based homestead agro-forestry system, intermixed with mango (*Mangifera indica*), cashew (*Anarcardium occidentale*) and jackfruit (*Artocarpus heterophyllus*). Major crops grown in the area include cashew, coconut, tapioca, jackfruit and areca nut (Fig 2.2 and Map 2.8).

Land use and land cover change within the direct drainage basin of Sasthamkotta indicates conversion of natural vegetation into plantation, as well as expansion of settlements. There are no forest patches left in the catchment, any more, as

[2] Bourdillon's plot, named after then Conservator of Forests of Travancore, is the world's first stump planted plantation of teak which is located near the Palaruvi water falls in Aryankavu forest range.

all of it has been reclaimed for plantation and agriculture. During the 80s, the shoreline areas were planted with *Acacia* under a World Bank sponsored social forestry project. However, post 2010, when the lake exhibited frequent drying and efforts are being made to remove the plantation and restore native vegetation. In certain areas, wild pineapple varieties have been planted to increase soil stability. There have also been extensive construction of roads and related infrastructure. The slopes have been encroached for tapioca, rubber and other plantations, and run-off and sedimentation enhancing agricultural practices.

Key issues

Land use within Kallada River Basin as well as Sasthamkotta's direct catchment has intensified over a period of time. Several of these changes have a bearing on hydrological connectivity and inundation regime stability of the lake.

Many of the marsh areas around Sasthmakotta have been converted to agricultural paddies along with conversion of mixed cropping plantations to paddies. Replacement of natural forest with plantations and reclamation of land for agriculture

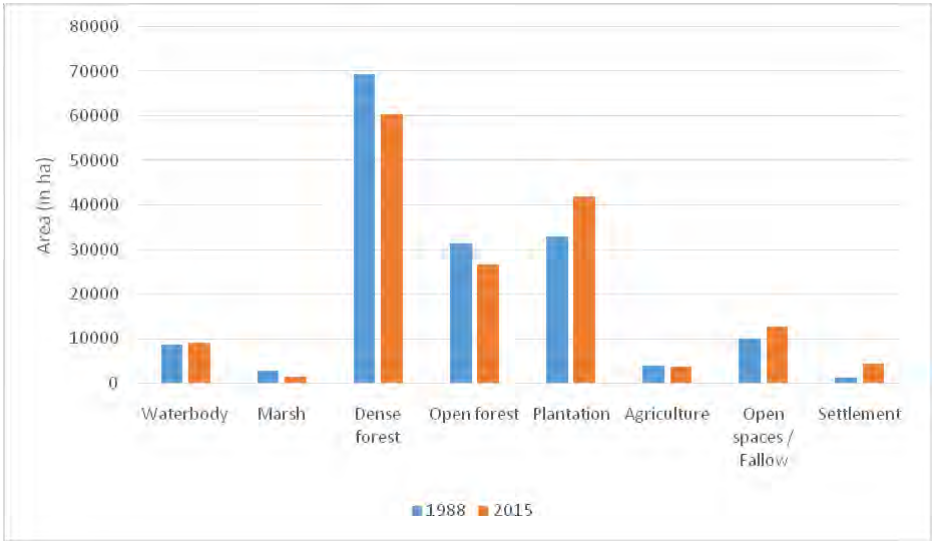


Fig. 2.1 | Land use land cover within Kallada River basin

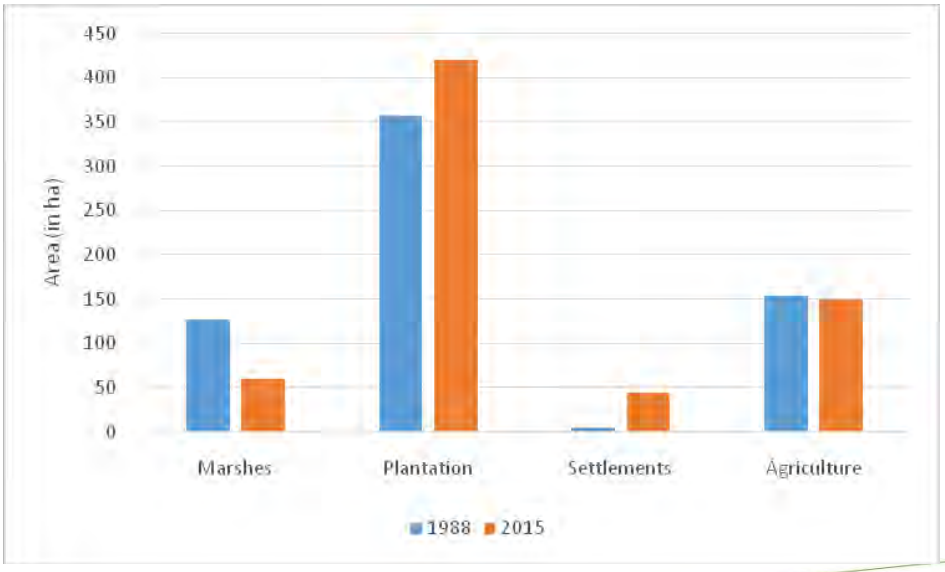
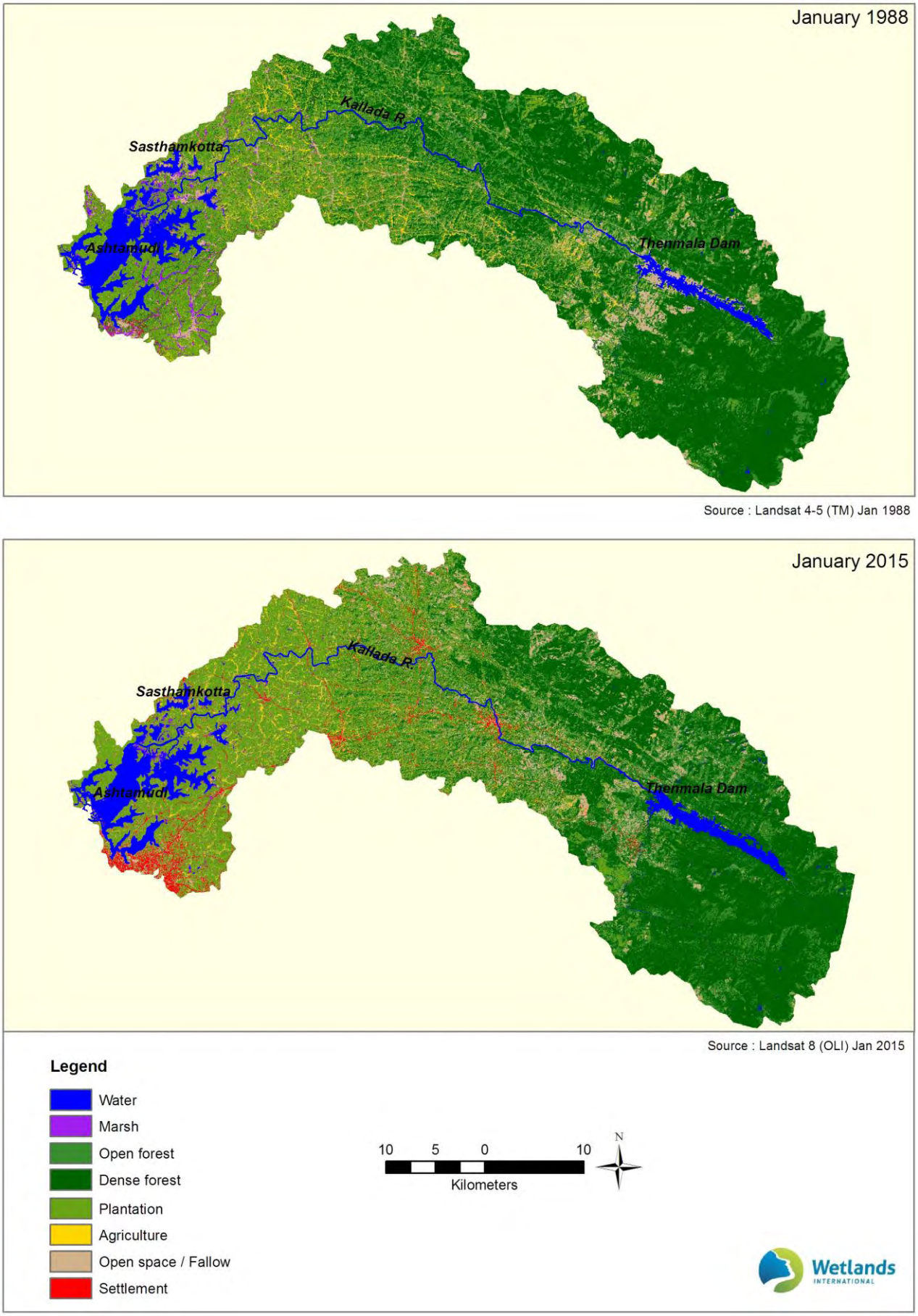
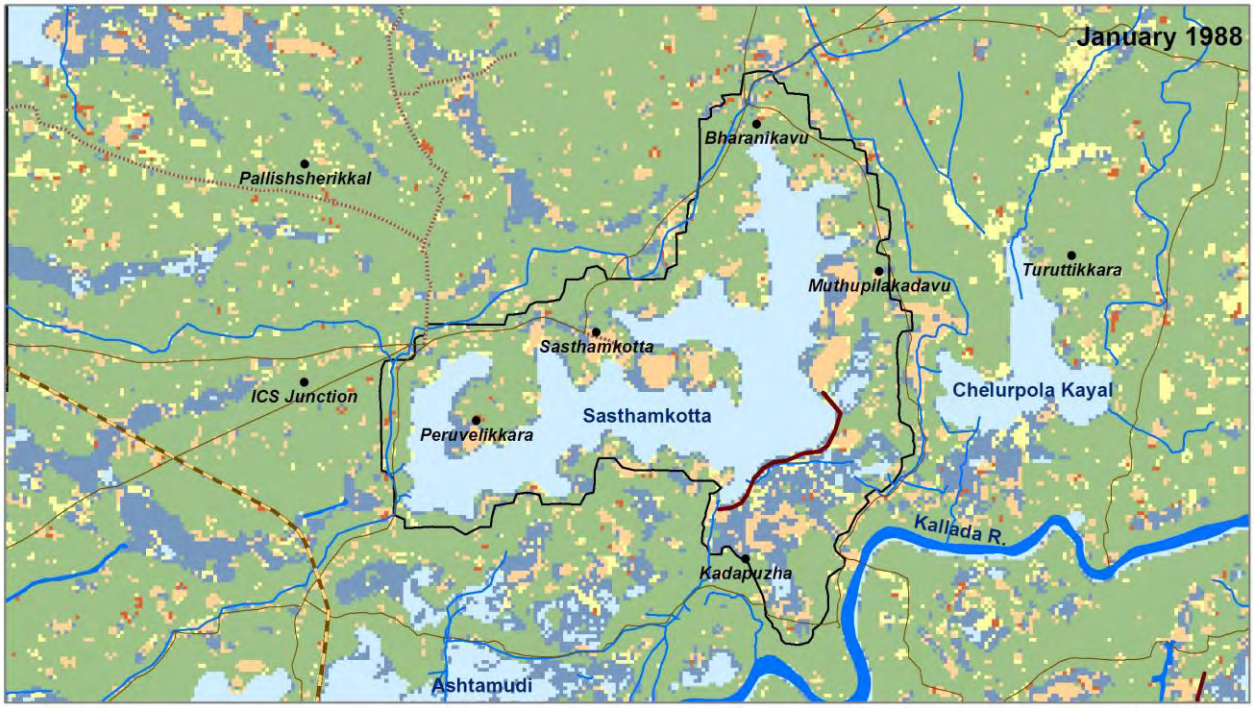


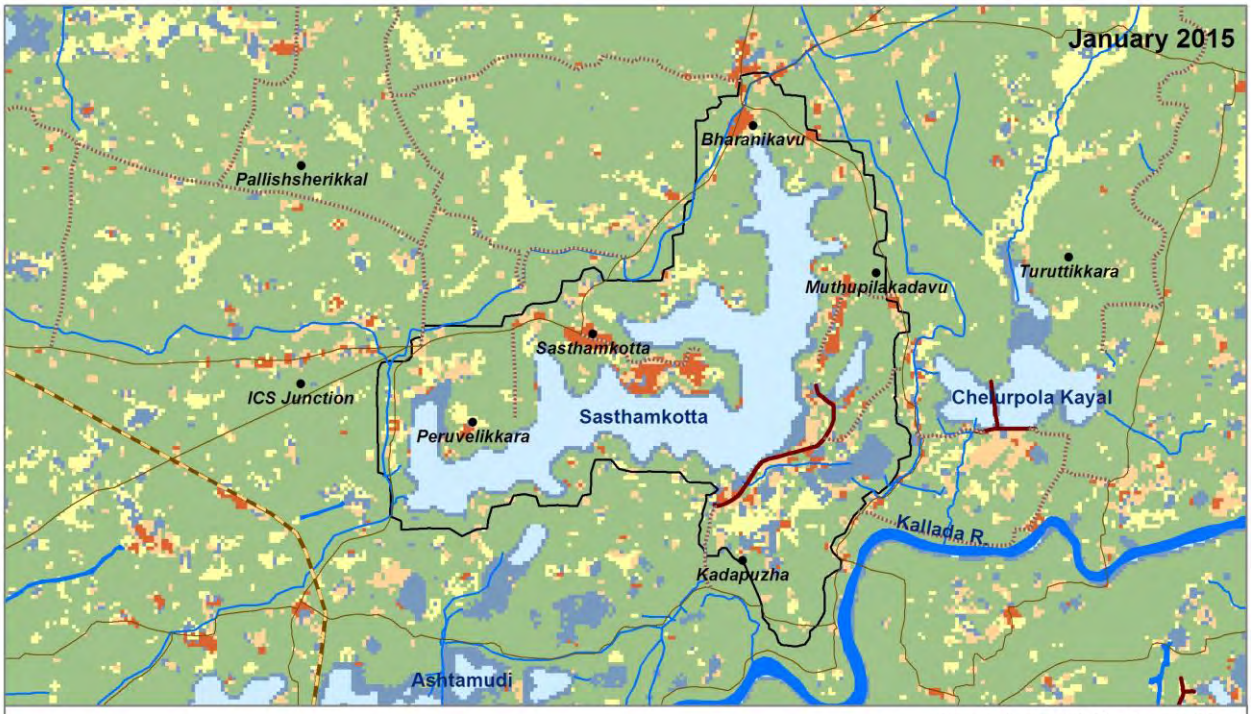
Fig. 2.2 | Land use land cover change in direct catchment of Sasthamkotta



Map 2.7 | Land use land cover within Kallada River Basin



Source : Landsat 4 - 5 TM (January 1988)



Source : Landsat 8 OLI (January 2015)

Legend

- Minor road
- Major road
- Railway
- Embankment
- Channel/Canal
- River
- Catchment boundary
- Open water
- Marsh
- Plantation
- Agriculture
- Open space/Fallow
- Settlement

0.8 0.4 0 0.8
Kilometers

N

Wetlands INTERNATIONAL

Map 2.8 | Land use land cover change within Sasthamkotta direct catchment

Eroded soil near D. B. College

Many of the marsh areas around Sasthmakotta have been converted to agricultural paddies along with conversion of mixed cropping plantations to paddies. Replacement of natural forest with plantations and reclamation of land for agriculture in the Kallada catchment have enhanced soil erosion. Replacement of native vegetation with *Acacia* and *Eucalyptus* trees has skewed the natural soil moisture regimes.

Many plantation companies are located in Punalur along the banks of Kallada River.[3] Pulp and paper mills are considered one of the most polluting industries. Paper making process demands large amount of fresh water and produces enormous quantities of wastewater that is contaminated by a number of organic and inorganic chemicals which generally have low biodegradability due to the presence of recalcitrant compounds. Disposal of such wastewater in aquatic bodies can have severe adverse impacts on the physicochemical characteristics and the biodiversity they support.

A significant pressure on wetlands is created due to mining within the floodplains. Along River Kallada, there are over 108 mining sites and the landscape is marked by the presence of several deep pits. Alluvial plains near the river being a rich source of clay and sand are exploited extensively. After digging out the clay from the surface layers, the alluvial river sand present underneath is extracted. It has been reported that very deep mining up to the extent of 90 to 100 metres below the surface is being carried out.

It is reported that at least one-third of the total area of West Kallada panchayat has been mined for sand thus, often using heavy-duty motors. The craters left at many locations are at a lower level

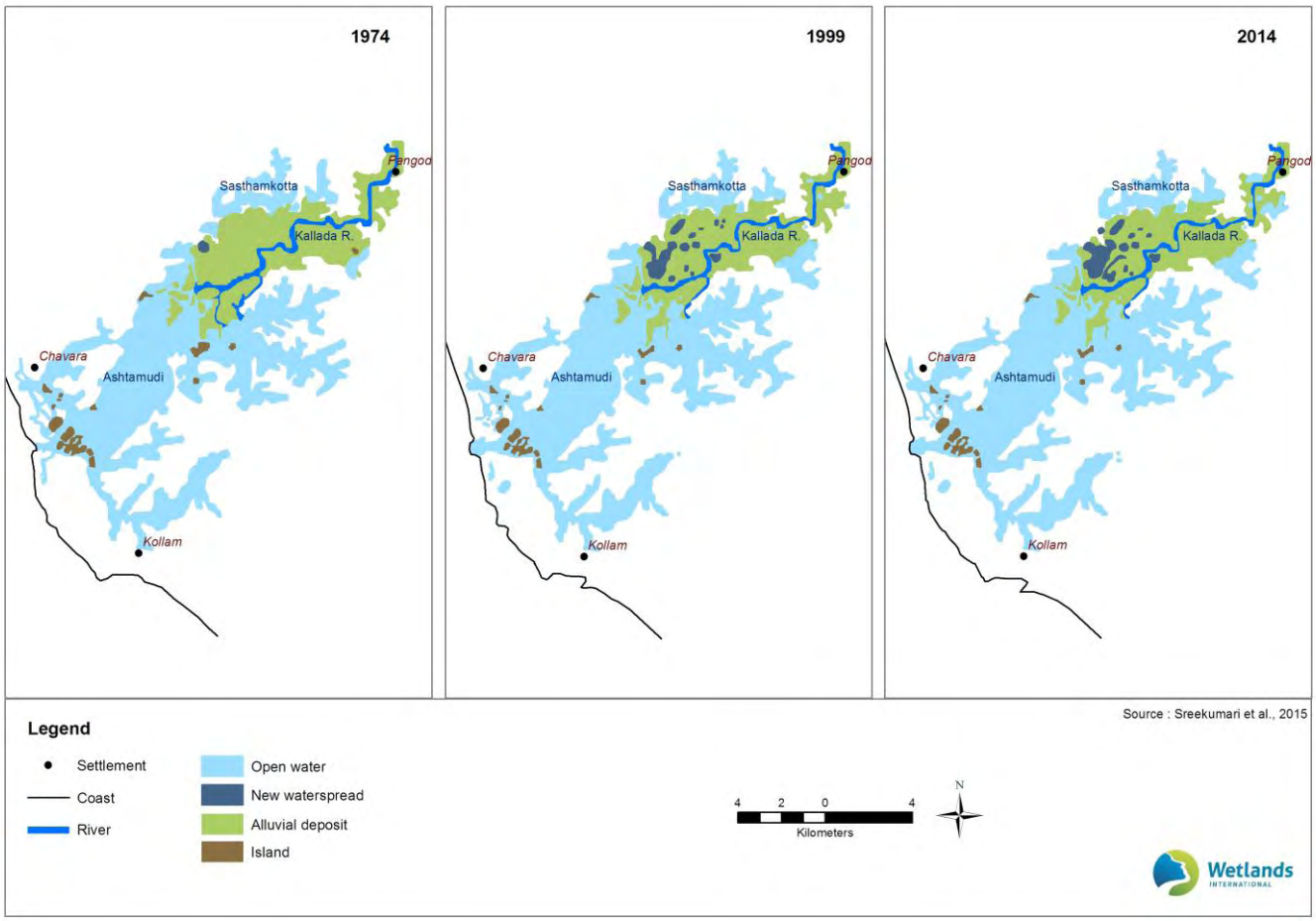
[3] The Punalur Paper Mills and the Rehabilitation Plantations Limited are located in Punalur. The latter is a joint venture company of the Government of India and Government of Kerala set up in 1972 with the objective of rehabilitating repatriates from Sri Lanka. It is involved in manufacture of ammoniacal latex and rubber sheets.

than the nearby Sasthamkotta Lake. Despite a State Government ban on sand mining for three years from Kallada in 2015, illegal sand mining is a great concern along the banks of the Kallada River which makes the banks more vulnerable to erosion and floods. Incidentally, mining of sand and clay from the river and paddy lands have received support from local self government institutions, because of high economic returns which makes management difficult and contested.

Besides sand, there is extensive laterite mining as well. Moist, laterites can easily be cut with a spade into regular-sized blocks which hardens upon exposure making it ideal construction material. Several of the lateritic hillocks surrounding Sasthamkotta have been mined for construction purposes.

Large scale conversions of paddy fields has also been observed for clay mining. It has been reported by local dailies that 820 acres of paddy field was converted for clay-mining and only 400 acres of agricultural land remained in the village (Irshad, 2015).

Map 2.9 indicates changes in alluvial floodplain structure on account of mining. A significant consequence, further elaborated in the discussion on hydrological regimes, is impeded sub-surface connectivity of the river with wetland, thus altering hydrological regimes, and making the ecosystem more vulnerable to variability in monsoon.



Map 2.9 | Changes in alluvial floodplain structure due to sand mining in lower reaches of Kallada River basin

2.3 HYDROLOGICAL REGIMES

Water creates wetlands. The biotic and abiotic composition of wetlands depend on the ways water moves within these ecosystems. The amplitude and frequency of water level fluctuations are probably the most important factors affecting ecological structure and functioning of wetlands.

Characterization of hydrological regimes of wetlands should ideally be done using long-term data on inundation regimes, water inflow and outflow patterns, sedimentation, water quality and the way water is managed. Current hydrological monitoring of Sasthamkotta is, however, limited to recording of lake levels, and select water quality parameters by the Kerala Water Authority (KWA). The analysis contained in this section is based on the following datasets, is of indicative nature, and primarily intended to highlight issues relevant for management of hydrological regimes:

- Rainfall data from Kollam Station of Indian Meteorological Department (IMD) for 100 years (1905 – 2015)
- Lake levels data made available for 18 years (1997-2015) by KWA. The level is gauged at the Authority's pump house used for water withdrawal.
- Lake Bathymetry for 2003 conducted by Centre for Earth Sciences (CESS)
- Water quality for select parameters obtained from Kerala State Pollution Control Board for the period 2011-2014. Additional data from published literature has also been used.

The hydrological information contained in this section of the report need to updated using a systematic Wetland Inventory, Assessment and Monitoring System, detailed in Section 5 of this management plan.

Inundation regimes

Sasthamkotta displays a significant inter-annual variation in inundation regime. During a normal rainfall year, the entire lake bed is inundated by November after the two spells of south-west and north-east monsoon. The lake levels at this juncture reach to 16 m amsl. Post monsoon, the inundation shrinks reaching its minimum by April, wherein levels dips to around 13 m amsl. At this level, the inundated area shrinks to around 210 ha. The lake bed thus exposed gradually transforms into marshes, with some parts remaining dry and devoid of any vegetation. Fig 2.3 captures the probability of exceedance of various lake levels for the lake.

The known long term trend in lake levels are presented in Fig 2.4. Post 2012, there was a conspicuous decline in levels. The period also coincided with decline in rainfall and increase in withdrawal of water from the lake on account of commissioning additional water supply projects. In May 2013, the lake levels dipped to 11.7 m amsl, at which over half of the lake bed was exposed, causing serious concerns on tenability of water uses which are dependent on Sasthamkotta.

Lake level monitoring stationat pump house

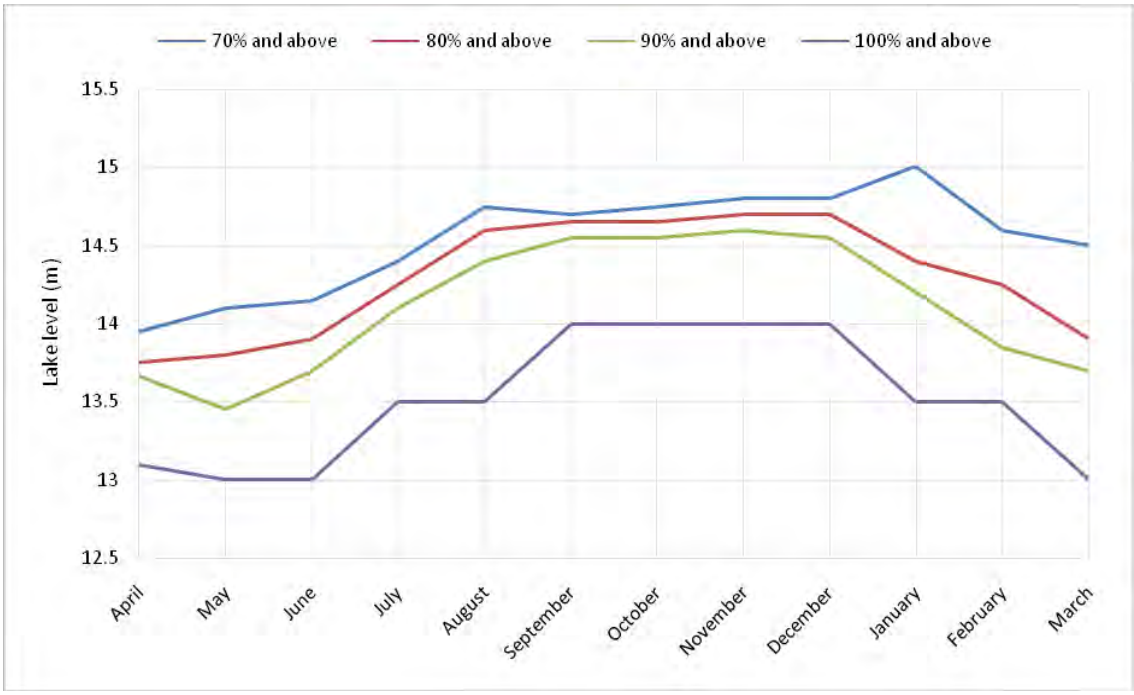


Fig 2.3 Probability of exceedance of lake levels during different months

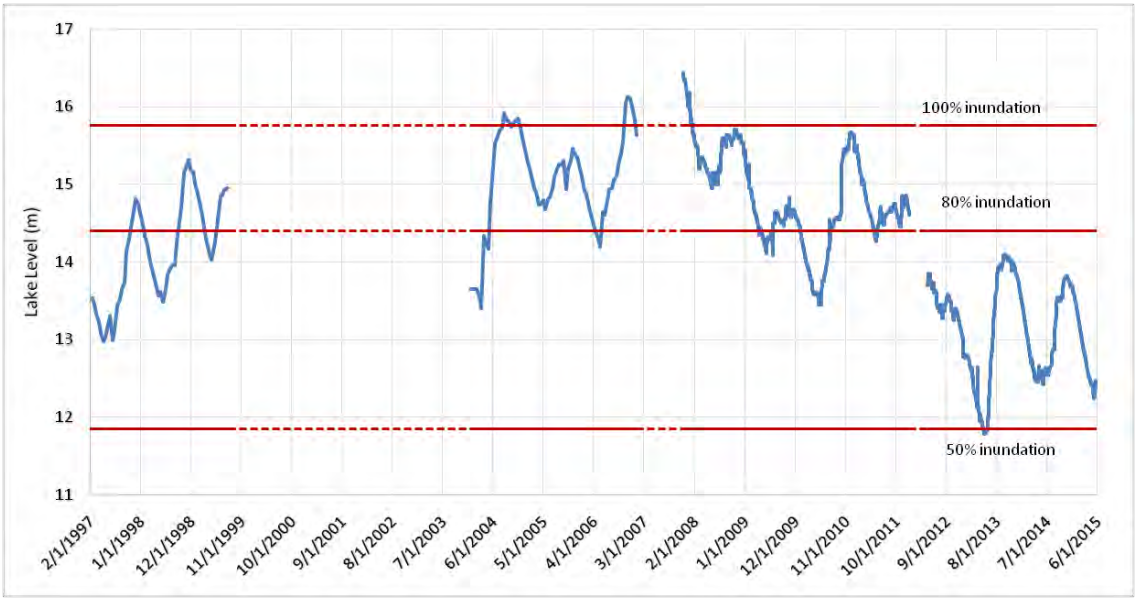


Fig 2.4 Trends in lake levels (1997 – 2015)

Water inflow, outflow and balance

Sasthamkotta has a direct drainage basin of 625 ha. Surface run-off from rainfall within this drainage basin, as well direct rainfall on the lake bed constitute the major sources of inflow. Water from Sasthamkotta is withdrawn by the Kerala Water Authority for supply to Kollam City and its suburbs. Evaporation from the lake bed also constitutes a significant proportion of water outflow.

Located at the gateway of Indian monsoon (general reference to Kerala as being on the southernmost tip, it is the first state to receive monsoon rainfall), Sasthamkotta receives high rainfall. As per the records of 1905-2015, the lake

and its surrounding receive an average annual rainfall of 2,251.57 mm (maximum being 4160.2mm in 1952 and minimum of 692.2mm in 1969). Rains are received in two spells, south-west (during June and August) and north-east (between September and November). The two seasons contribute 81% of the total annual rainfall. Rainfall during south-west monsoon is the predominant component, accounting for 48% of the total rainfall.

Present withdrawal of water from Sasthamkotta for Quilon Water Supply Scheme (WSS) is around 30 million litres per day (equivalent to 10.95 Mm^3). An additional 33.5 MLD (equivalent to 12.22 Mm^3) is withdrawn for meeting the water requirements of 4 water supply schemes (WSS for Chavara-Panmana, WSS for Sasthamkotta, Sooranad (S) and West Kallada; and WSS for Thevalakkara – Thekkumbhagam).

A monthly water balance has been computed to assess the water inflow and outflow patterns. For estimating the catchment run-off, a factor of 0.6 has been used. Rainfall and evaporation have been computed from the IMD Data.

The groundwater exchange is a derived estimate, based on the lake levels at the beginning and close of every month. Bathymetric data (Map 2.10), based on surveys conducted in 2003 indicate the waterholding capacity of the lake at 16 m amsl to be 15.63 Mm^3 (Fig. 2.5).

The water balance analysis indicates the total inflow of 29.1 Mm^3, of which run-off from the catchment and direct rainfall on the lake bed contribute 27% and 25% of the inflow respectively. The net groundwater exchange accounts for the 47% of the total inflow.

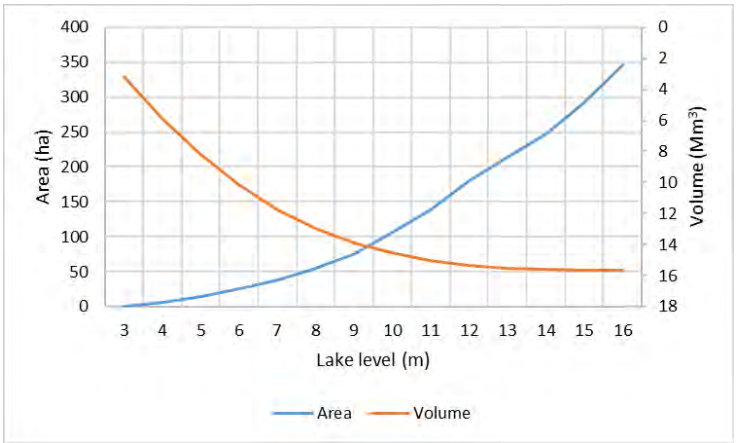
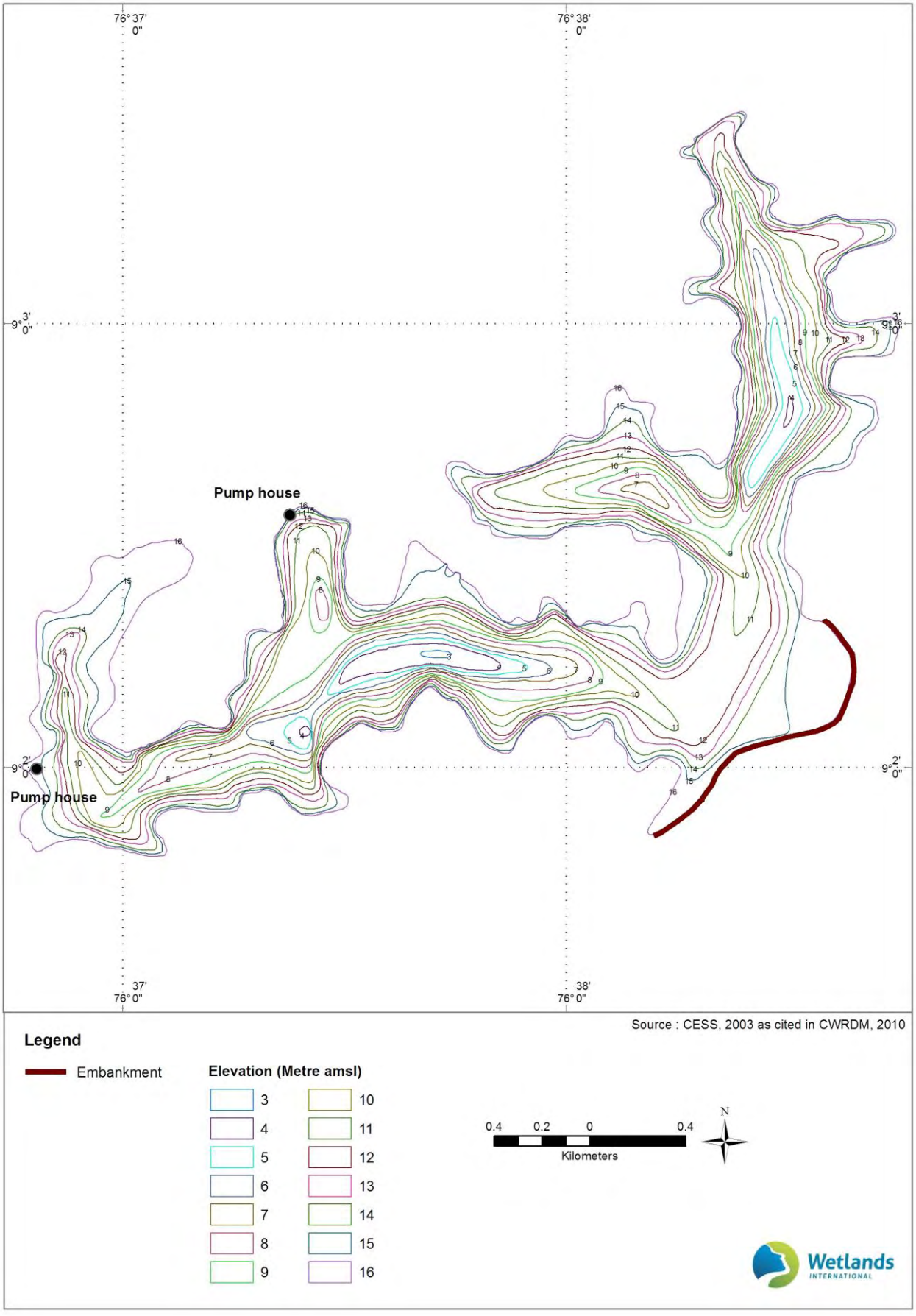


Fig 2.5 : Area capacity curve for Sasthamkotta

Pumphouse for water supply to Kollam City



Map 2.10 | Bathymetry of Sasthamkotta Lake

The outflows are on account of withdrawal for water supply (23.18 Mm^3, or 80% of total outflow) and the rest lost to evaporation. The monthly water balance and contribution of different components to inflow and outflow are presented in Fig 2.6 and 2.7 respectively.

The connectivity of Sasthamkotta with River Kallada has an important bearing for water balance of the lake. Studies conducted on lithological characteristics of borehole cores indicate the presence of an upper sand dominated layer, intervened by comparatively thin, silt and clay dominated sediments. This layer rests over clay or mud dominated organic rich sediments, deposited on an erosional surface (Sreekumari et al., 2015). This sand bed acted as a hydrological conduit between the river and the lake. Surface flows between the river and lake were received in the form of flood pulses during the south-west and north-east monsoon. This connection has been impeded by construction of Velanthra embankment. As discussed in the previous section of wetland catchments, extensive sand mining within the floodplains has led to fragmentation of sub-surface pathways (Fig 2.8). Studies based on isotopes indicate the river water no longer reaches the lake through surface or sub-surface pathways (Joseph et al., 2003).

Fig. 2.6 | Contribution of different component to a) Inflow, b) Outflow

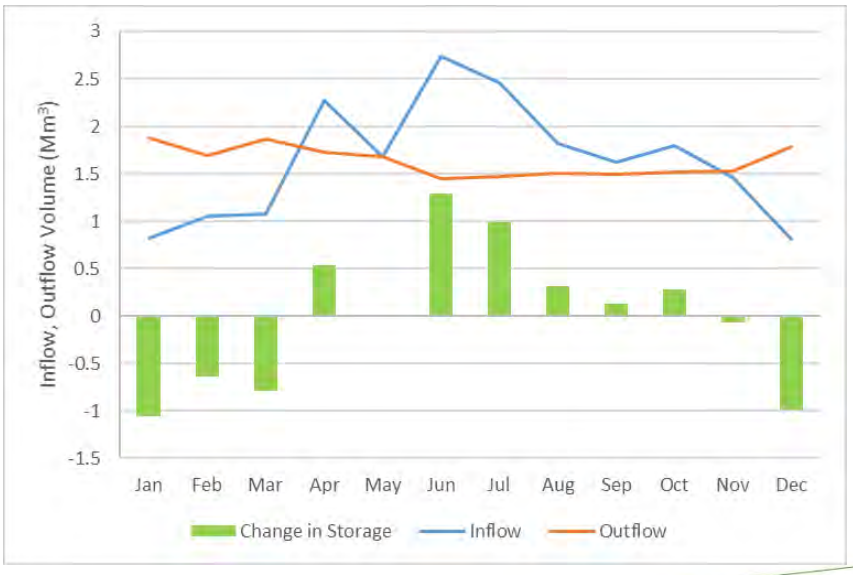


Fig 2.7 | Monthly water balance

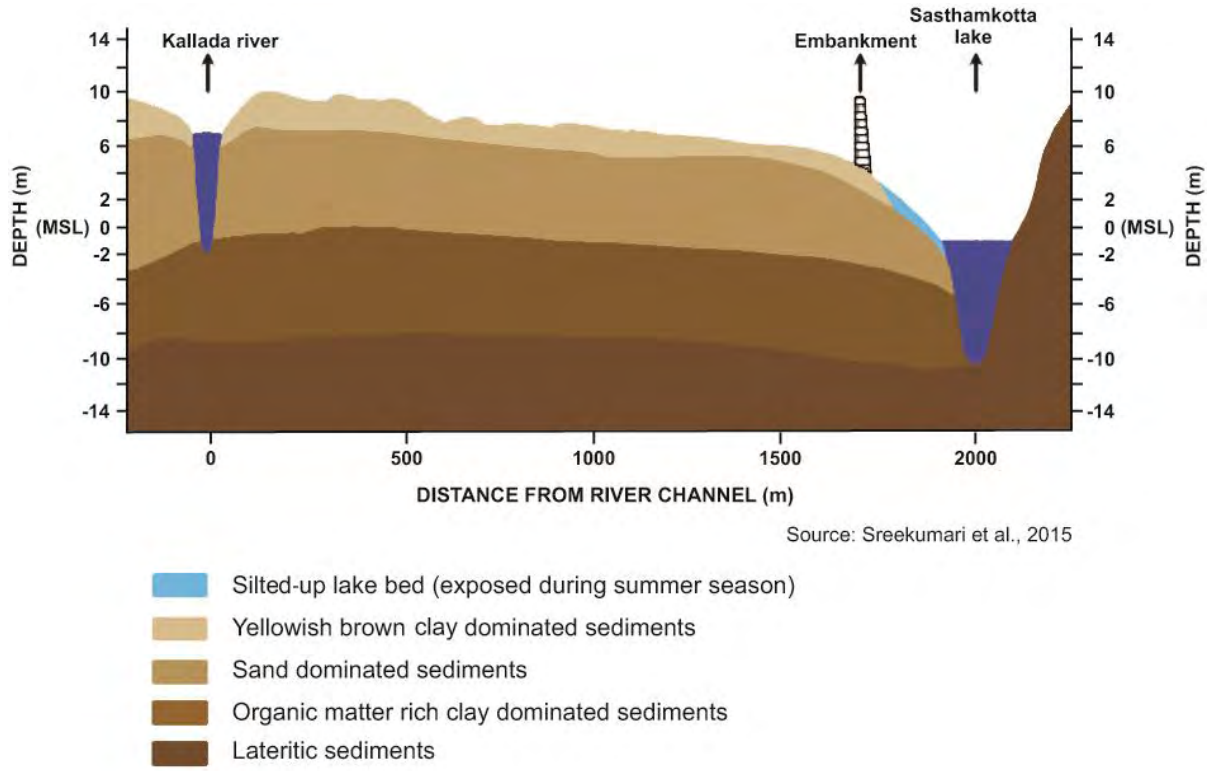


Fig. 2.8 | Sub-surface profile of River Kallada floodplains

Sedimentation

Wetlands act as sediment traps; however, continual sediment accumulation impacts the overall hydrology and hydraulics of the ecosystem. While some sedimentation takes place naturally within any given basin, of particular concern is the contribution of human interference which needs careful management. In the case of Sasthamkotta, excessive rates of sedimentation are likely to have an implication for overall water availability as in absence of an outflow, there is no means of natural flushing of sediments.

Hydrological investigation in the drainage basin of Sasthamkotta Lake, carried jointly by Bhabha Atomic Research Centre and CWRDM, Kozhikode using environmental isotopes (D, ^{18}O, ^{3}H, ^{137}Cs), has indicated that the recent sedimentation in the lake ranges from ~0.18 to 1.81 cm/year, with higher values very close to the Velanthara Bund.

Recent investigations on sediment quality have not been taken up. Sediment quality assessed in 2007 indicated clay to be the major constituent (47 – 72%), followed by silt (26% - 52%) with minimum contribution of sand (Girijakumari, 2007). The pH of surface sediment ranged from 4 to 7, indicating acidic to neutral character. Organic carbon was found to be low (0.034 – 2.64 mg g^{-1}). Sediment phosphorus was observed to low and ranging between 0.005 – 0.204 mg g^{-1}. These values corresponded with low primary productivity (ranging between 0.072 – 4.5 mg/C/m^3/day). Assessments of 1998 indicate similar concentrations of Phosphorus (Prakasam and Joseph, 1991) indicating selective absorption in water, with Iron and Manganese being released into interstitial waters (Sreejith, 1998).

Water quality

Sasthamkotta maintains a low salt, well oxygenated and low nutrient water, despite severe anthropogenic stresses on the lake, including extensive catchment degradation, discharge of sewage, community bathing and washing, and prolonged dipping of coconut leaves for thatching. Several explantations have been made, including presence of large numbers of *Chaoborus* sp. larvae which is known to feed voraciously on smaller zooplanktons (eg. Pillai, 1981) and locking

up of phosphorus in sediments (Prakasam and Joseph, 1991 and Sreejith, 1998). Recent assessments however indicate a progressive degradation of water quality.

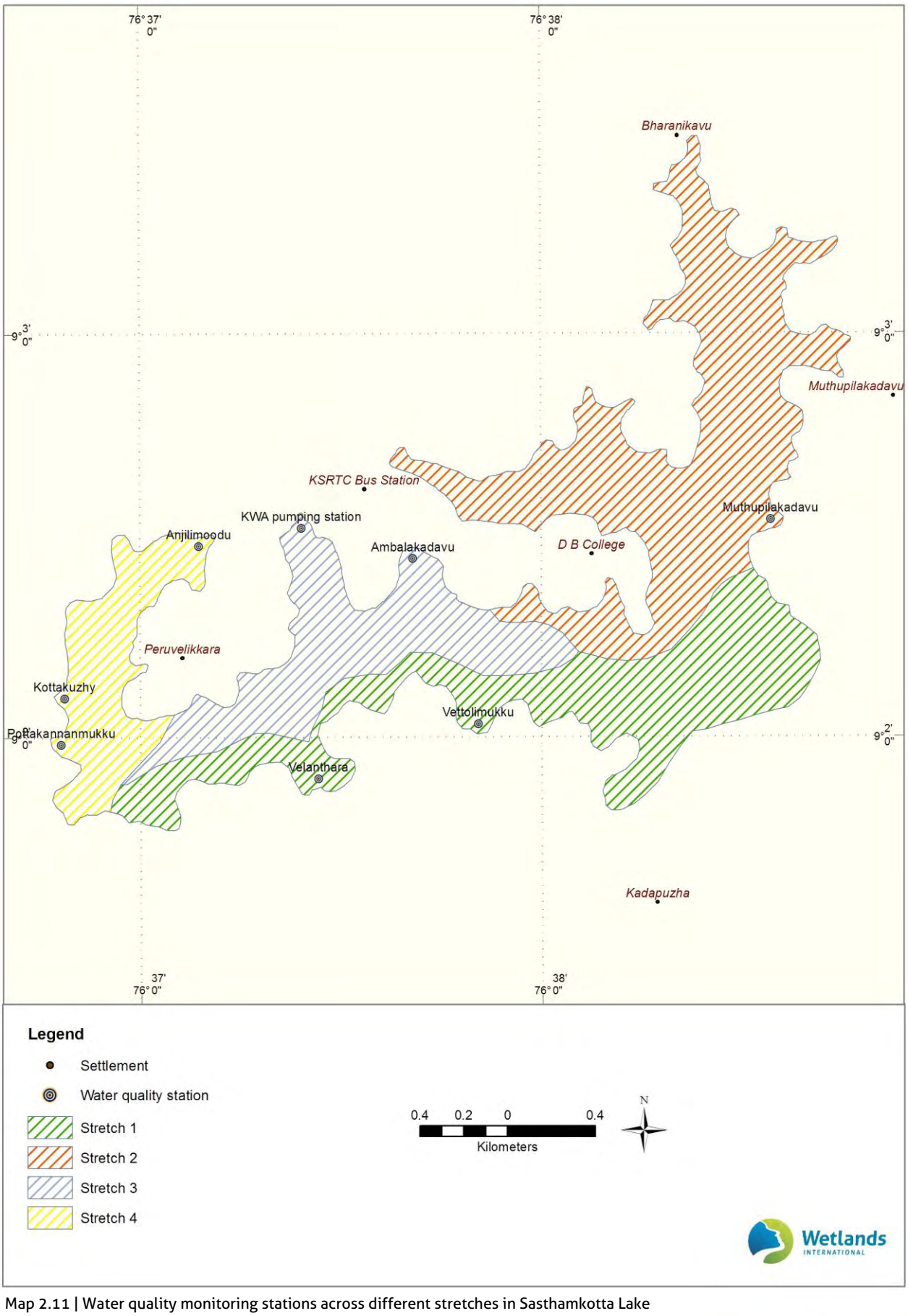
The overview of status and trends of the water quality of the lake presented in this section is based on the available information. Girijakumari (2007) and George and Koshy (2008) provide an overview of lake water quality during the period 2005-08. During 2006-2007, algal biodiversity and related physicochemical parameters of the lake were assessed by Chaudhary and Pillai (2009). CWRDM (2010) conducted a water assessment study of the entire lake area in 2008 to identify the source of pollution. Data from various water quality sampling stations have been grouped into 4 stretches to enable better correlation of the observations with various anthropogenic activities taking place around the wetland. These stretches are indicated in Map 2.11.

Stretch 1 constitutes the southern area of the lake which gradually transforms into marshy conditions as the monsoons recede. Stretch 2 in the north receive untreated wastewater from Sasthamkotta town and Bharanikavu town. Stretch 3, in the centre is the deepest portion from which water is withdrawn. This stretch also receives effluent of wastewater treatment facility. Stretch 4 on the west is in the vicinity of rubber factories.

The most recent data on water quality is that of 2013-14 (Table 2.4), which indicate the lake to be well-oxygenated, nutrient-poor and neutral to weakly alkaline. Low dissolved oxygen values were recorded in select pockets near Stretch 1, during pre and post monsoon periods. Biochemical oxygen demand (BOD) levels frequently cross 3 mg /l threshold for category B water quality of Central Pollution Control Board.

Dissolved oxygen (DO) levels of the lake water during pre-monsoon, monsoon and post monsoon seasons were found to be sufficient at all stations except at Vettolikkadavu station during post monsoon where the lowest concentration of DO (1.7 mg/l) was recorded. BOD levels during pre-monsoon season were recorded to be high in comparison to monsoon and post monsoon levels.

Sediment deposition near Velanthara Bund



Map 2.11 | Water quality monitoring stations across different stretches in Sasthamkotta Lake

Table 2.4 | Seasonal variations of the water quality of Sasthamkotta Lake

Parameters	2013-2014								
	Stretch 1			Stretch 3			Stretch 4		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
pH	6.9-7.8 (7.6)	6.5-7.8 (7.2)	6.3-7.8 (7.15)	6.7-7.7 (7.15)	6.6-7.8 (6.9)	6.4-7.8 (6.9)	6.4-7.9 (7.4)	6.6-8 (7.15)	5.3-7.6 (7)
Alkalinity (mg/L)	20-40 (22)	10-26 (16)	10-34 (18)	16-26 (21)	10-30 (18)	10-24 (16.5)	18-120 (22)	8-44 (19)	10-26 (14)
Conductivity (µs/cm)	60.2-235.2 (114)	63-114 (100)	60.1-116 (97.5)	57.2-165 (101)	63.7-143 (95.5)	60.1-114 (98.5)	60-303.6 (104)	79-235 (101.5)	58.4-119 (98)
DO (mg/L)	3.3-8.2 (6.1)	5.3-7.9 (6.9)	1.7-7.9 (6.85)	5.6-7.6 (6.65)	5.1-8.1 (6.5)	5.9-8.7 (7.25)	5.5-7.8 (6.5)	4.5-8.5 (7.05)	5.5-8 (7.4)
BOD (mg/L)	0.6-4.8 (1.5)	0.4-2 (1.6)	0.4-2.4 (1.2)	0.7-4 (1.8)	0.4-3.2 (1.2)	0.4-2.8 (1.3)	0.4-2.8 (2.3)	0.4-2.8 (1.4)	0.4-3.2 (1.2)
Total Dissolved Solids (mg/L)	43-98 (78.5)	44-79 (68)	43-82(69.5)	40-110 (70.5)	48-102 (67)	43-81 (68)	41-202 (73)	49-196 (72)	42-85 (70)
Total Suspended Solids (mg/L)	12-312 (21.5)	24-53 (33)	18-51 (35)	9-48 (24.5)	12-36 (26.5)	19-62 (34)	11-40 (32)	20-52 (28)	19-66 (35)
TotalHardness (mg/L)	12-32 (21)	14-30 (20)	14-32 (20)	14-30 (18)	18-28 (21)	15-32 (22)	12-100 (24)	18-40 (22)	14-24 (22)
Nitrate (mg/L)	0.22-1.3 (0.32)	0.8-9.9 (1.1)	0.07-1.9 (0.59)	0.31-5.5 (0.59)	1.1-6.1 (2.35)	0.16-7.7 (0.985)	0.41-2.5 (0.565)	1.7-4 (3.15)	0.21-2.5 (0.765)
Chloride (mg/L)	16-36 (25)	18-32 (24)	16-28 (22)	15-32 (24)	18-32 (22)	14-28 (22)	17-38 (26)	18-40 (25)	18-32 (22)
Calcium (mg/L)	3.2-16 (9.8)	6-20 (12)	3.6-18 (12)	1.2-24 (7.8)	8-18 (14)	4-16 (12)	2.1-22 (16)	10-24 (14)	4.8-18 (12)
Magnesium (mg/L)	0.24-16 (6)	2-24 (8)	1.2-16 (7)	0.7-14 (4)	4-14 (8)	0.7-20 (8)	1.2-14 (8)	4-16 (8)	0.9-12 (8)

Parameters	2013-2014								
	Stretch 1			Stretch 3			Stretch 4		
	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Iron (mg/L)	0.013-0.91 (0.215)	0.021-1.8 (0.3)	0.1-1.1 (0.27)	0.1-1.7 (0.285)	0.15-1 (0.315)	0.022-1.1 (0.255)	0.036-0.9 (0.22)	0.032-1.1 (0.225)	0.037-0.57 (0.2)
Total Coliforms (MPN/100 mL)	200-1000 (480)	100-1400 (500)	260-910 (540)	200-1300 (390)	110-700 (290)	200-1210 (390)	130-540 (400)	180-580 (400)	400-600 (500)
Faecal Coliforms (MPN/100mL)	80-320 (210)	60-600 (200)	90-420 (240)	90-410 (150)	80-350 (135)	80-420 (180)	90-190 (140)	70-320 (140)	90-290 (220)

Coliforms levels exceeded way beyond the permissible limit throughout the seasons with the maximum total coliforms of 1400 MPN/100 ml and faecal coliforms of 600 MPN/100 ml recorded during the monsoon season. The reason for presence of high levels of coliforms during monsoon season can be attributed towards the monsoon run-off from the catchment and the surrounding areas which are being drained directly into the lake.

Available data from various sources have been collated in five year intervals (Table 2.5). The available data indicated that the DO levels were high at all stations, barring a few stations at Stretches 1 and 4. The low levels of DO at some stretches of the lake can be attributed towards the direct discharge of domestic waste along with the agricultural and chemical run-off from the rubber plantation and surrounding areas. As a result, there is reduction in the metabolic activities of the aerobic aquatic life forms leading to low fish productivity of the lake over the years. BOD levels of the lake water were comparatively low during 2011-2014 at all stretches with a minimum value of 0.1 mg/l recorded at Stretch 3.

The levels of coliforms (both total and faecal) were found to be beyond the permissible limit across all the stretches. Maximum total coliforms value of 5200 MPN/100 ml was reported from Stretch 4 during 2011-2014. Stretches 2 and 3 recorded the highest values (2400 MPN/100 ml) during 2006-2010. The high values of coliforms in the lake water can be attributed towards the increase anthropogenic activities in the catchment and the nearby areas of the lake. Sprawling households in the catchment area without proper sanitation facilities leading to direct discharge of domestic waste water into the lake have contributed largely to the faecal contamination of the lake.

Groundwater

The region around Sasthamkotta has phreatic as well as confined to semi-confined aquifers. The weathered crystallines, laterites and the alluvial formations form the major phreatic aquifers; while the deep fractures in the crystallines and granular zones in the tertiary sedimentary formations form the confined to semi-confined aquifers.

The drainage basin of Sasthamkotta contains mostly very deep, well drained clayey soil on gently sloping coastal laterites. The clay is basically Kaolinite which does not allow much infiltration through it from the surface.

Decadal average ground water level for Sathamkotta block for the period 2001-11 was observed to be 8.02 m bgl pre monsoon and 7.19 m bgl post monsoon (CGWB, 2013). An isotope study on groundwater movement conducted by CWRDM, it was observed that the wells on the south-eastern margins of the lake were getting recharged by the lake, whereas the rest contributed water into the lake (Warrier, 2007). The assessments further confirm significant surface-groundwater exchange which is critical for maintaining hydrological regimes of Sasthamkotta.

Mining of sand and laterite has led to altercation in the hydrological regimes of Sasthamkotta. In 2003, instances of land subsidence and earth fissure were reported along the embankment, which has been attributed to mining of groundwater aquifiers (Kuriakose, 2013).

Water use patterns

Water withdrawal for supply to Kollam City and its suburbs forms the principal water use of Sasthamkotta. Any significant reduction in inundation regime directly impinges on water availability to meet this purpose, and is of immense significance to management. The water supply project was conceived in the 1960s, to meet the drinking water requirements of City. The population has since increased to 0.3 million, with the lake being still the principal water source. The increasing frequency of drastic shrinkages in inundation levels and dips in water levels has raised concerns of planners and decision makers on sustainability of such use.

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Table 2.5 | Stretch-wise variations in the water quality of Sasthamkotta Lake

Parameters	Stretch 1			Stretch 2			Stretch 3			Stretch 4		
	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014
Temperature (°C)	28.5-30.45 (29.5)	-	-	27.85-30.38 (29.63)	-	-	27.63-31.5 (29.83)	-	-	27.63-30.23 (29.63)	-	-
pH	6.45-7 (6.77)	6.16-7.3 (6.87)	6.3-8.1 (7.1)	6.64-7.06 (6.88)	6.1-6.86 (6.69)	6.3-8.1 (6.95)	6.8-7.36 (6.955)	7	6.4-7.8 (7)	6.78-7.17 (6.85)	6.43-6.9 (6.53)	5.3-8.1 (7.085)
Conductivity (µ mhos/cm)	44.13-49.73 (44.45)	33.6-63.98 (49.23)	44-235.2 (66)	44.9-57.88 (46.13)	34.7-58.88 (47.33)	44.6-86.3 (54.45)	42.05-62.03 (47.875)	33.8	44-165 (65.5)	42.5-57.55 (47.6)	34.5-56.45 (52.96)	44-303.6 (61.1)
Transparency (cm)	130-140.5 (137.5)	-	-	129.75-143.25 (133.25)	-	-	124.25-141.25 (133)	-	-	125-135.5 (130.75)	-	-
Turbidity (NTU)	3.05-4.93 (3.5)	2-4 (2.5)	1.09-1.7 (1.2)	1.83-5.75 (3.38)	1-5 (1-4)	0.8-1.4 (1.15)	2.75-5.1 (3.815)	4	1.02-1.6	3.55-5.13 (4.98)	1	1.1-2.5 (1.2)
Hardness (mg/l)	7.35-10.55 (8.93)	6-14 (8)	8-32 (18)	8.18-10.68 (8.93)	6-14 (8)	8-22 (14)	8-10.85 (9.755)	7.2	9-32 (18)	8.65-10.3 (9.18)	7.2-20 (10)	9-100 (18)
Alkalinity (mg/l)	11.4-13.75 (11.48)	4-49.8 (29.88)	10-40 (18)	11.23-12.23 (11.75)	4-39.89 (19.92)	12-24 (16)	11.9-15.1 (12.94)	6	9-30 (18)	11.08-14.1 (11.43)	8-39.8 (29.8)	-18
Salinity (o/oo)	2.78-3.13 (2.91)	-	-	2.88-3.23 (2.96)	-	-	2.95-9.78 (6.325)	-	-	2.6-3.07 (3.04)	-	-
Carbon dioxide (mg/l)	3.28-5.08 (3.83)	4.312	-	3.3-5.4 (3.9)	4.312	-	3.03-5.5 (3.85)	-	-	3.43-5.53 (3.78)	4.312-8.624 (8.624)	-
DO (mg/l)	6.43-8.06 (7.95)	6.842-9.93 (8.131)	1.7-8.2 (6.9)	6.08-8.05 (8)	5.99-9.47 (8.2)	5.7-7.9 (7.1)	5.72-8 (7.8)	8.27	5.1-8.7	6.64-8 (7.7)	6.842-9.67 (7.704)	2.1-8.5 (6.8)
BOD (mg/l)	4.1-4.93 (4.5)	1.07-3.4 (2.265)	0.4-4.8 (0.8)	4.45-5.45 (4.48)	0.2-5.93 (1.87)	0.4-0.9 (0.66)	4.1-4.95 (4.45)	1.93	0.1-4 (0.8)	4.15-4.83 (4.45)	2.87	0.4-3.2 (0.8)
COD (mg/l)	5.58-9.5 (8.35)	-	-	5.83-9.38 (8.23)	-	-	5.58-9.5 (8.315)	-	-	5.58-9.2 (8.3)	-	-

Parameters	Stretch 1			Stretch 2			Stretch 3			Stretch 4		
	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014
Total Organic Carbon (mg/l)	2.78-3.2 (3.08)	-	-	2.88-3.8 (3.08)	-	-	2.75-3.45 (2.98)	-	-	2.75-3.1 (3.05)	-	-
Nitrite (mg/l)	0.03-0.05 (0.03)	-	-	0.03-0.04 (0.03)	-	-	0.03-0.05 (0.04)	-	-	0.03-0.04 (0.03)	-	-
Nitrate (mg/l)	0.04-0.49 (0.05)	0.98-2.16 (1.48)	0.01-9.9 (0.16)	0.03-0.4 (0.08)	1.19-2.47 (1.5)	0.01-2.1 (0.14)	0.03-0.18 (0.07)	0.62	0.01-7.7 (0.195)	0.02-0.12 (0.04)	0.67	0.01-4 (0.14)
Phosphate (mg/l)	0.0018-0.0028 (0.0024)	0.02-0.03 (0.02)	-	0.0012-0.0018 (0.0018)	0.03	-	0.0012-0.0559 (0.00195)	-	-	0.0013-0.0023 (0.0022)	0.09	-
Sulphate (mg/l)	-	0.48-0.68 (0.52)	-	-	0.6-1.04 (0.8)	-	-	0.6	-	-	0.52	-
Silicate (mg/l)	98.11-136.46 (129.84)	-	-	96.26-135.43 (130.68)	-	-	99.31-137.28 (128.93)	-	-	97.57-133.74 (133.06)	-	-
Potassium (mg/l)	1.5-2.08 (1.63)	0.9-2.6 (0.95)	-	1.5-2.08 (1.63)	0.7-1.6 (0.9)	-	1.15-2.4 (1.83)	0.9	-	1.5-2.08 (1.63)	1.4	-
Chloride (mg/l)	-	14.04-22.72 (17.04)	14-36 (21)	-	18.46-31.24 (18.46)	14-22 (19)	-	-	12-32 (21)	-	19.88-21.3 (19.88)	15-40 (22)
Sodium (mg/l)	-	6.93-8.25 (7.26)	-	-	6.93-7.26 (6.93)	-	-	7.26	-	-	7.92	-
Calcium (mg/l)	-	1.6-2.88 (2.08)	2.4-20 (4.8)	-	1.6-2.56 (1.92)	2.4-5 (3.4)	-	1.92	1.2-24 (4.8)	-	1.6	2.1-24 (4.6)
Magnesium (mg/l)	-	0.39-0.97 (0.585)	0.24-24 (1.9)	-	0.78-0.97 (0.78)	0.24-2.9 (1.45)	-	0.58	0.48-20 (2.4)	-	0.78	0.24-16 (1.9)
Iron (mg/l)	-	0.14-0.22 (0.195)	0.013-1.8 (0.23)	-	0.11-0.2 (0.18)	0.09-1 (0.22)	-	0.23	0.022-1.7 (0.215)	-	0.4	0.01-1.6 (0.224)
Manganese (mg/l)	-	0.002-0.009 (0.0035)	-	-	0.026 (0.009)	-	-	-	-	-	-	-

Parameters	Stretch 1			Stretch 2			Stretch 3			Stretch 4		
	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014	2001-2005	2006-2010	2011-2014
Colour (Hazen)	-	5.9-10.3 (7.15)	5	-	9.9-17.7 (12.5)	5	-	8.6	5	-	10.2	5
Total Suspended Solids (mg/l)	15.03-17.85 (16)	-	8-312 (17)	13.45-17.68 (15.68)	-	8-22 (10.5)	13.43-20.33 (17.275)	-	6-62 (15)	12.98-17.85 (14.68)	-	6-66 (18)
Total Dissolved Solids (mg/l)	-	21.5-24.19 (22.175)	30-98 (44)	-	22.21-23.74 (23.13)	30-60 (39)	-	21.63	32-110 (45)	-	22.08	32-202 (42.5)
Total Coliform (MPN/100 ml)	1100-1299.5 (1200.3)	12-240 (17)	60-1400 (380)	300-2500.5 (800.5)	10-2400 (10)	80-750 (295)	240-1700.5 (850.15)	2400	60-1300 (305)	450.3-899.8 (499.8)	17-240 (17)	60-5200 (355)
Faecal Coliform (MPN/100 ml)	200.5-300.5 (239.8)	9-240 (240)	20-600 (150)	169.8-1200.5 (399.5)	23-2401 (43)	20-450 (90)	39.8-1400.3 (405.05)	2400	20-460 (120)	150-280 (157.8)	43	20-1200 (120)

As per information provided to the management planning team, the Authority withdraws 13.68 Mm^3 (30 MLD) from the lake through its pumping station located on the northern shore along the Chavara - Adur road. The water is filtered and sterilized at the station and conveyed through 28" diameter concrete pipe to Kollam town, located at a distance of 25 km from the lakeshore. An additional 33.5 MLD (equivalent to 12.22 Mm^3) is withdrawn to meet the water requirements of 4 water supply schemes, thus making the total withdrawal to 63.5 MLD (equivalent to 23.18 Mm^3).

A scenario analysis was carried out in order to assess the sensitivity of lake levels decline to that of rainfall (Results presented in Annex 1). The analysis uses the monthly water balance as the basis. Rainfall is varied while keeping water withdrawals and groundwater exchange as unchanged, and the lake levels assumed to be at 16 m amsl at the beginning of the month of September (ensuring complete inundation of the lake bed). Nine scenarios, corresponding with 10%, 20% and 30% decline in rainfall during south-west and north-east monsoon separately, as well as cumulatively were estimated. The outcomes of the scenario analysis is presented in Fig 2.9. As can be seen, the decline in rainfall lead to significant deficits in water balance, ranging from 0.47 Mm^3 for a 10 % decline in rainfall during north-east monsoon, to upto 3.6 Mm^3 when the rainfall both during the south-west and the north-east monsoon decline by 30%.

In order to compensate for the reduction in rainfall, the only way to keep water levels aligned with the natural variation is to reduce the water offtake. Such adjustment would be equivalent to a minimum of 2% reduction in withdrawal during December – May, to upto 15.5 % reduction. Given that there is general declining trend in south-western rainfall, the alignment of water withdrawal with rainfall needs to be considered urgently. An alternate mechanism would be to consider an additional source of water for the Kollam City such that the dependence on Sasthamkotta can be reduced rationally.

The risk of reduction in rainfall is fairly high for Sasthamkotta. The analysis of 100 year rainfall for IMD Kollam Station distinctly indicates a gradually declining rainfall during south-west monsoon, and as a result total rainfall (Fig 2.10). Krishnakumar et al. (2009) confirm a similar trend for the Kerala State.

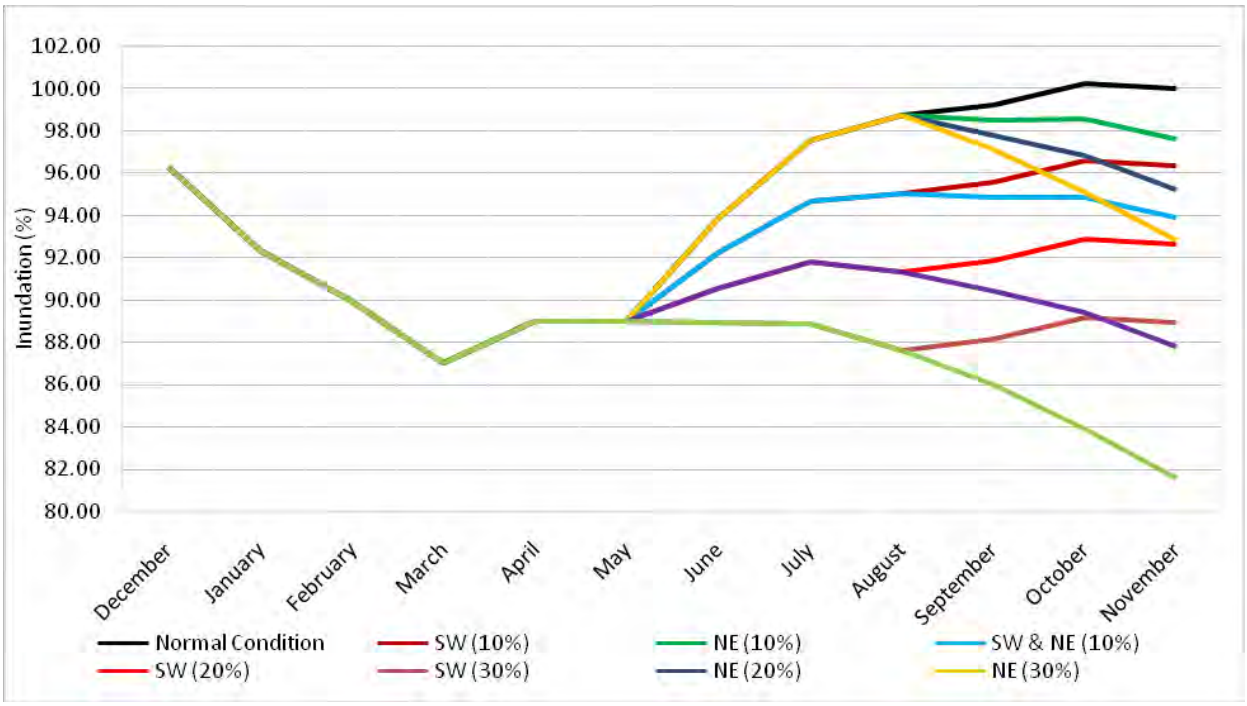
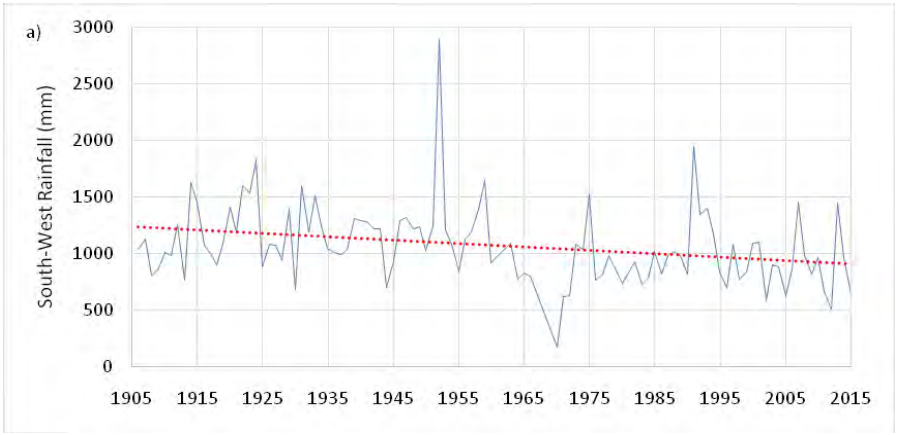
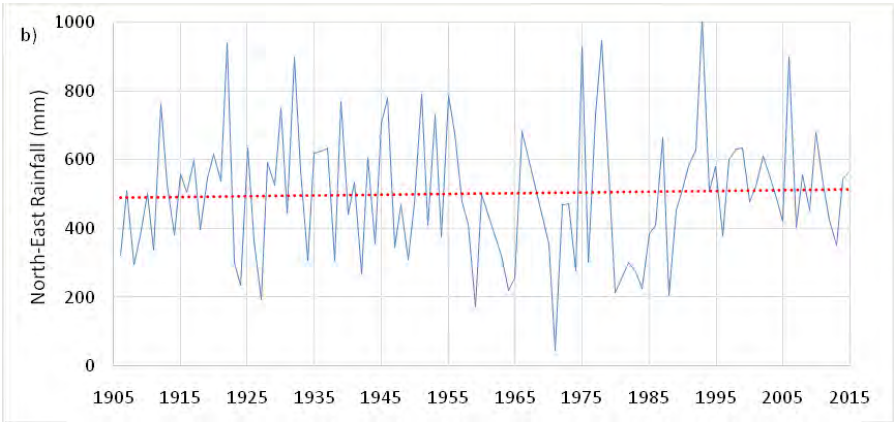
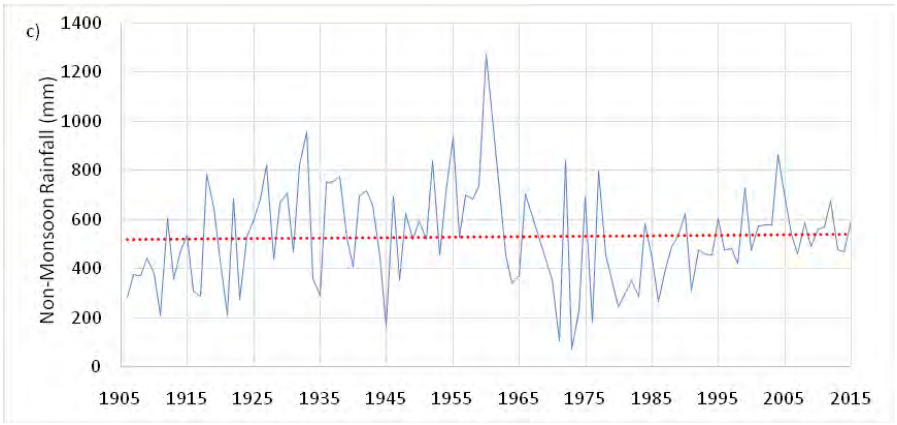


Fig 2.9 | Scenario outcome on the inundation pattern of the lake







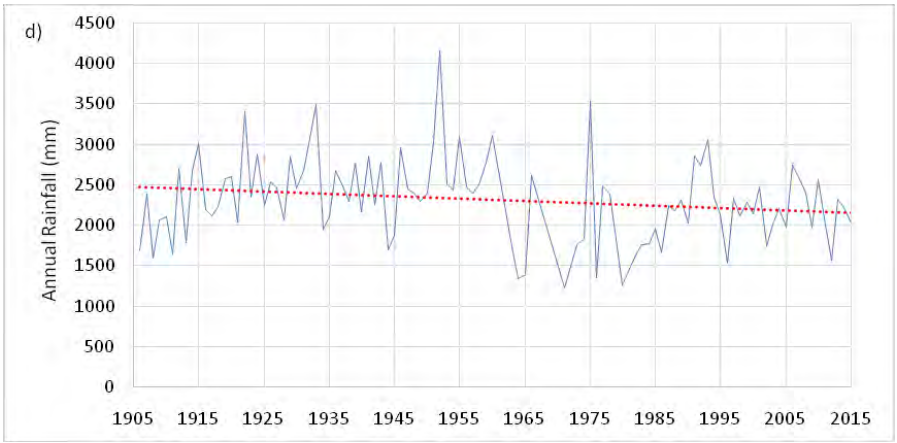


Fig 2.10 | Rainfall trend from 1905-2015

a) South West monsoon rainfall

b) North-East monsoon rainfall

c) Non-Monsoon rainfall

d) Annual rainfall

Key issues

Changes in natural hydrological regimes

Water levels in Sasthamkotta were traditionally maintained by a mix of surface and groundwater interactions. The sand layer between Sasthamkotta and River Kallada, embedded within the alluvial sediments of Late Quaternary age, played a major role in hydrology of the entire region by acting as conduit of freshwater flows from the river to the lake. Excessive sand mining within this region has led to complete breakdown of this connection to an extent that the two systems have become hydrologically isolated. Construction of embankment of the surface has limited flood pulse interactions with surface waters.

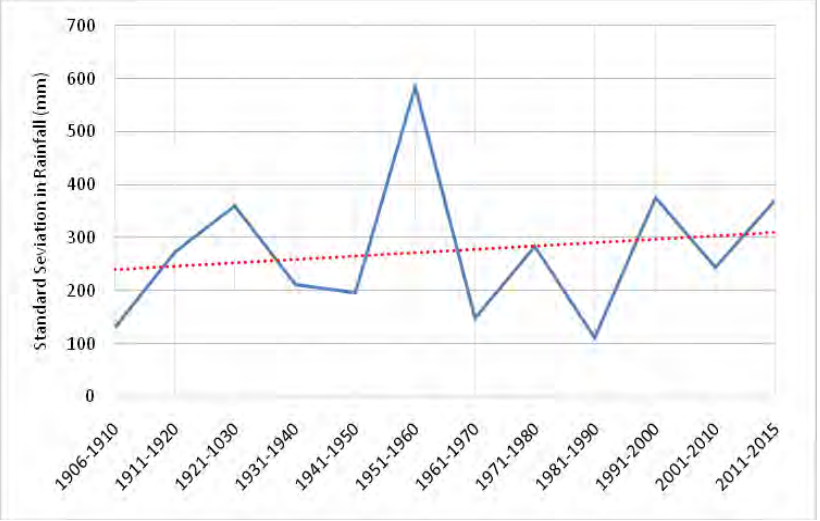


Fig. 2.11 | Variability in South-west monsoon

Hydrologically, Sasthamkotta is presently governed primarily by rainfall and any surface run-off from its relatively small drainage basin. It is highly susceptible to significant changes in inundation regimes in response to any changes in rainfall. Notably, the variation in South-West monsoon has shown an increasing trend. (Fig. 2.11)

Unsustainable water extraction

The level of water withdrawn from Sasthamkotta far exceeds the inflow received from direct rainfall and run-off. With interactions between river floodplains limited due to hydrological fragmentation, the current abstraction levels are not tenable even in the short run. It is pertinent to limit withdrawals based on detailed assessment on overall water availability.

Pollution

Despite significant sanitation coverage, the high levels of fecal coliform within the lake waters indicate substantive leaching. Water quality has also been observed to be degraded in select pockets. Also washing of clothes and devotees to the Sastha temple attributes to water quality deterioration. Any degradation of water quality within Sasthamkotta has public health consequences, as it is a major drinking water source.

Clothes being washed in the lake at Vettolikadavu

2.4 BIODIVERSITY

Fragmented attempts at documenting the biodiversity and ecology of Sasthamkotta Lake have been made since the 80s. Aspects of primary productivity and water sediment interactions were investigated by Thomas et al. (1980) and Prakasam and Joseph (1991). A summary of these information was used to develop a profile of Sasthamkotta for inclusion in the 'Directory of Indian Wetlands' published in 1993 (WWF-India and AWB, 1993). A project entitled 'Ecology, Biology and Pollution of Sasthamkotta Lake' was implemented in 1991 through the support of MoEFCC (the then MoEF). Biodiversity and ecological information used for Ramsar Site designation and preparation of Ramsar Information Sheet is mostly based on this information.

Subsequently, partial inventories were published in 2003, which covered Sasthamkotta as a part of larger set of wetlands of Kerala. The Environmental Resources Research Centre, an autonomous research and development centre of the state, implemented a project on biodiversity management and conservation of Sasthamkotta Lake with financial assistance from the MoEFCC. The study covered planktons, fish, hydrophytes and terrestrial vegetation (published as Nayar et al., 2011). In 2011, the Kerala State Biodiversity Board initiated consolidation of a Biodiversity Register for Sasthamkotta, as per the framework of the Biological Diversity Act, 2002. Specific studies on fisheries (as Kurup et al., 2004 and Girijakumari, 2007) and waterbirds (under the Asian Waterbird Census framework) provide complementing information on biodiversity of Sasthamkotta. The information presented in this section is based on the analysis of aforementioned literature, field assessments and community consultations conducted in March-April 2015.

An overview of available information on species richness and their conservation status is summarized in Table 2.6.

Plankton

Planktons play a crucial role in the food chain within an aquatic system. Available information on planktons in Sasthamkotta indicate presence of at least 37 species of phytoplankton belonging to 30 genera (Girijakumari, 2007) (Annex 2). The zooplankton communities are represented by six phyla (ibid).

Table 2.6 | Conservation status of flora and fauna in Sasthamkotta Lake

Biodiversity	Group	No. of Species	Source	Status						
				CR	EN	VU	NT	LC	DD	NE
Flora	Phytoplankton	37	Girijakumari, 2007							37
	Macrophyte	18	Nayar et al., 2011 and Field Survey, 2015					15		3
	Terrestrial vegetation	158	Nayar et al., 2011		1	1	1	19	3	133
Fauna	Zooplankton	information available only at phylum level								
	Insect (Butterfly)	23	Nayar et al., 2011					2		21
	Fish	36	Girijakumari, 2007 and Nayar et al., 2011			1	3	27	2	3
	Waterbird	35	CWRDM, 2010; Nayar et al., 2011; AWC Records, 2012 and Field Survey, 2015				2	33		

CR-Critically Endangered; EN-Endangered; VU-Vulnarable; NT-Near Threatened; DD-Data Deficient; LC- Least Concern; NE-Not Evaluated

Phytoplanktons are most abundant during post-monsoon with higher percentages in the areas adjoining Sasthamkotta Town, and minimum around the western margins Bacillariophyceae is the dominant group followed by Chlorophyceae, Cyanophyceae and Dianoflagellata. Notably, Chlorophyceae was indicated to be the dominant class in studies done in 1994 (Joseph, 1994 as cited in Girijakumari, 2007). This transition may be related with increase in pollution loading within the waterbody. *Cocconeis* sp., *Fragilaria* sp., *Melosira* sp., *Nitzschia* sp., *Navicula* sp. and *Synedra* sp., reported presently to be abundant are tolerant forms of diatoms that sustain well even in polluted waters (Palmer, 1980).

Zooplankton in Sasthamkotta are majorly from group Nauplius, Rotifer and Copepod with a small component of Cladocerans. The overall count was reported to be low (28 counts/litre). The count of Nauplius builds gradually from pre-monsoon period to predominate during monsoon. Rotifers do not exhibit much variability, and increase only marginally during monsoon. Copepods at their peak form around 5% of the zooplankton population. The overall trend in composition for the year 2008 (Nayar et al., 2011) is presented in Fig. 2.12. Peaks of zooplanktons and phytoplankton were observed to occur simultaneously.

Primary productivity assessed during 2004-05 (Girijakumari, 2007) showed low concentrations, ranging from 0.072 - 4.5 mg/C/m^3/day. Primary productivity increased during post monsoon gradually and decreased during pre-monsoon. Lake area near Velanthara bund showed highest productivity throughout the year. Low primary productivity has also been reported by Thomas et al. (1980) and Prakasam and Joseph (1991).

Macrophyte

Available studies and field assessments indicate the presence of at least 18 macrophytes of 12 families in Sasthamkotta (Annex 3). Their distribution is largely confined in the regions adjoining Velanthara embankment, Rajagiri, Bharanikavu and Sasthamkotta Town. These areas are also significant point sources of pollution into the lake. *Vallisneria, Salvinia* and *Blyxa* are the dominant amongst submerged macrophytes, whereas, *Ipomoea* and *Nymphoides* form the dominant floating forms (Map 2.12). *Monochoria* and *Hygrophila* often mix with *Colocasia* and *Pandanus* to form thick vegetation growth.

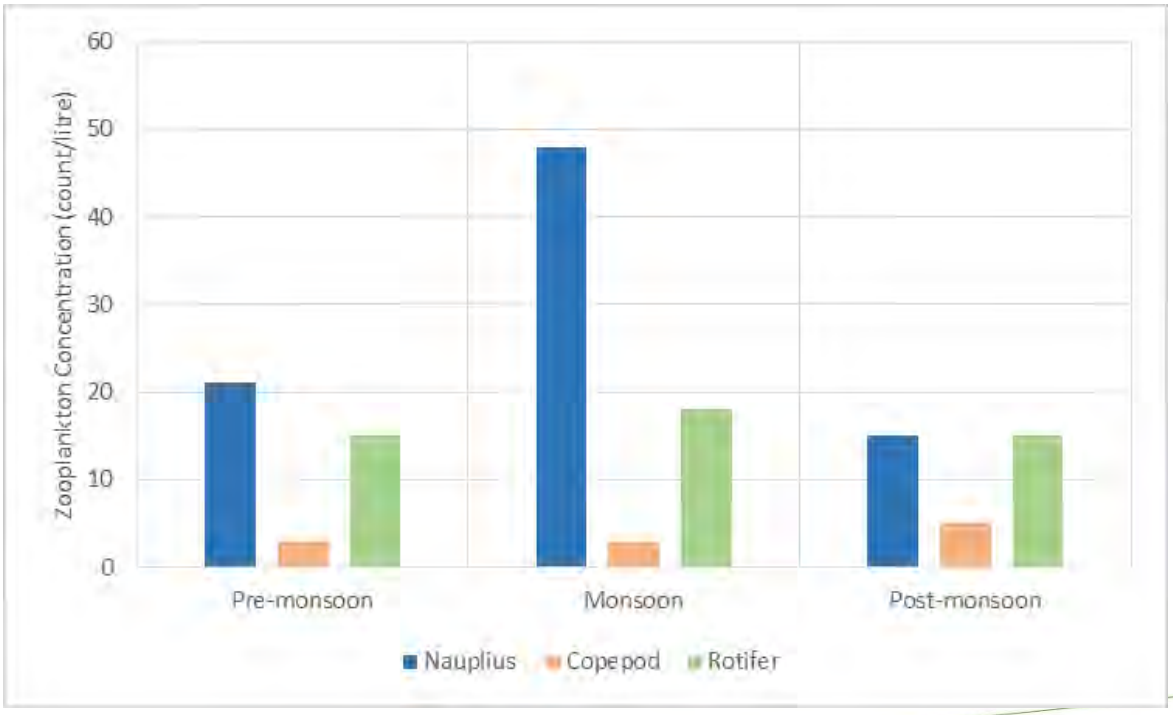
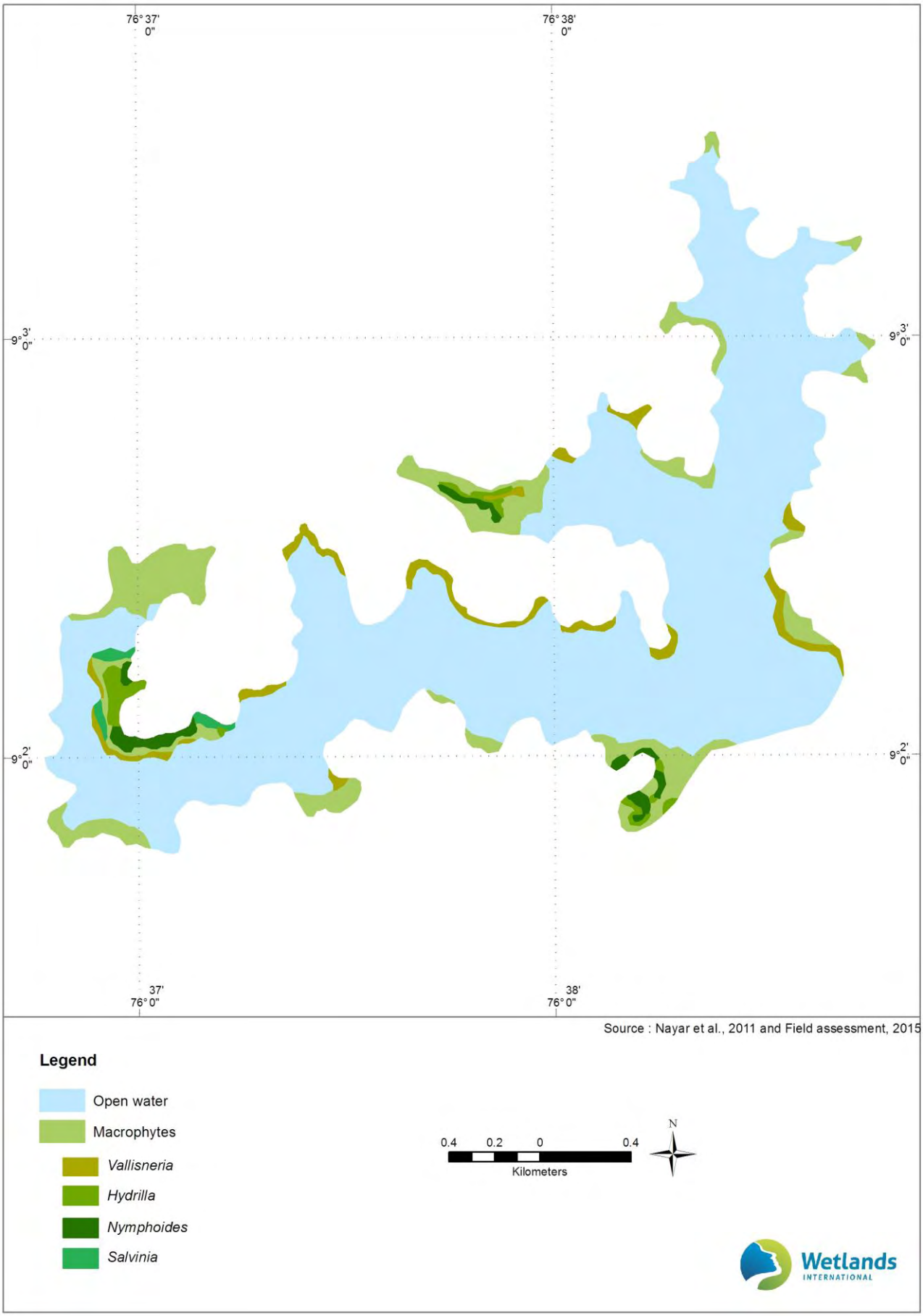


Fig. 2.12 | Seasonal variation in zooplankton groups



Map 2.12 | Macrophytes in Sasthamkotta Lake

Mats of Salvinia adjacent to Rajagiri area

Mats of *Salvinia* and *Eichhornia crassipes* (water hyacinth) were observed near Rajagiri old fish hatchery. Notably, 12 ha under these invasive was manually removed from this area in 2010 but has re-emerged. Agglomeration of free floating plant *Pistia* sp. was also observed during post monsoon period in areas adjoining D.B. College and Rajagiri.

Nayar et al. (2011) report choking of Valiyapadam marshes, once connected with Sasthamkotta, with *Salvinia*. Apparently, growth of macrophytes within Sasthamkotta is kept in check due to the dynamic inundation regime and low nutrient status. However, continued discharge of untreated sewage, agriculture run-off, silt from catchments and shrinkage of inundation regime is highly likely to create conducive conditions for proliferation of invasive macrophytes.

Terrestrial Vegetation

Nayar et al. (2011) report presence of 11 species occurring along the shorelines of Sasthamkotta and 60 species within the overall catchment area. Patches of Screw Pine (*Pandanus odoratissimus*) exist near the Velanthara embankment. The eastern shoreline has patches of insectivorous plant, Indian Sundew (*Drosera* sp.). The hinterland has at least 97 species, whereas, the homesteads have 21 species. Collating the information on the terrestrial species yields a list of 158 species growing around Sasthamkotta Lake (Annex 4). In some areas, wild pineapple varieties have been planted for increasing soil stability and prevent soil loss. The micro watershed around the lake has mainly coconut based agroforestry system with trees such as *Mangifera indica, Anacardium occidentale,* and *Artocarpus heterophyllus.*

Acacia plantations all along the fringes of Sasthamkotta

The shorelines were planted with *Acacia* under a social forestry project of the World Bank during the 80s. However, much of the plantations were removed post-2010 after the lake exhibited frequent drying, and *Acacia* was considered as one of the causative factors. The Department of Forest is working with village Panchayat on removal of the species in the lake's direct drainage basin.

Insect

At least 23 species of butterflies have been reported from the lake (Annex 5). Majority of these belong to two families - Nymphalidae and Papilionidae (Nayar et al., 2011). Maximum concentration can be seen near the Velanthara Embankment area which has relatively higher number of grasses and herbs species. Studies done in the 80s (eg. Pillai, 1981) indicated presence of large numbers of *Chaoborus* sp. larvae which is known to feed voraciously on smaller zooplanktons. Studies need to be taken up on the present status of the species in Sasthamkotta and its overall water quality contribution.

Fish

Compilation of available species richness records indicate presence of at least 38 species of fish belonging to 19 families in Sasthamkotta (Annex 6 and Map 2.13). The list includes *Horabagrus brachysoma*, classed as Vulnerable in the IUCN Red List of Threatened Species. Two families (*Cyprinidae* and *Bagridae*) account for 11 species. *Etroplus suratensis*, the State Fish of Kerala is commonly found in the lake. *Etroplus maculatus* another species of the same genus has also been recorded in the lake. The species is largely confined to South India and Sri Lanka.

Six of the recorded species (*Dayella malabarica, Horabagrus brachysoma, Macrognathus guentheri, Mystus oculatus, Ompok malabaricus* and *Parambassis dayi*) are endemic to the country.

Map 2.13 | Active fishing zone in Sasthamkotta Lake

Disruption of flood pulse through construction of embankment along Sasthamkotta has impeded species exchange between River Kallada and the lake. Kurup et al. (2004) indicate that, several species (*Etroplus maculatus, Horabagrus brachysoma* and *Ompok bimaculatus*) are common between the two, but the lake population has been isolated.

During community surveys, fishers of Rajagiri identified breeding and spawning habitats along the embankment and the southern margins of the lake. Species abundance surveys done in 2004-05, indicated highest abundance of *Dayella malabarica, Puntius filamentosus* and *Parambassis dayi*. Most of these species were considerably smaller in size and did not contribute significantly to economic landings.

Waterbird

Assessments conducted under Asian Waterbird Census (for the year 2012), CWRDM (2010) and ERRC (2010) indicate the presence of at least 35 species of waterbirds in Sasthamkotta (Annex 7). Most of the reported species are shoreline foragers (egrets, herons and bitterns) and waders (sandpipers and lapwings). Marshes around the fringes of the lake serve as foraging grounds for both migratory and resident waterbirds.

Of the reported species, 2 species (Oriental Darter and Black-headed Ibis) are classed as Near Threatened as per IUCN Red List of Threatened Species (ver. 2016-3). A sporadic sighting of Asian Woolly Neck (*Ciconia episcopus*), a vulnerable waterbird species was reported in 2015 by Sasthamkotta Biodiversity Management Committee.

The number of species and counts in Sasthamkotta are apparently lower than adjoining Ashtamudi Estuary which has higher food availability and diversity of habitats. Yet, Sasthamkotta retains its significance as an important habitat in the network of wetlands used by waterbirds inhabiting the region.

Key Issues

Hydrological regimes have a significant influence on biodiversity of aquatic systems as Sasthamkotta. Low primary production, low nutrient concentrations and hydrological fragmentation constrain biodiversity within the lake to a fewer number of species as compared with other wetlands of lowland regions of Kerala. Exhaustive and systematic biodiversity surveys are likely to yield better insights into the entire range of species and their ecological interactions.

Flock of birds near Rajagiri fish hatchery

Screwpine on shoreline of Sasthamkotta. Waters under these trees are habiat for fish, especially Etroplus.

Available information indicates stresses on the limited biodiversity present in the lake. The plankton community is shifting towards a dominance of pollution tolerant species. Within fish species there is a significant decline in population of *Horabagrus brachysoma* and *Etroplus suratensis* which were once abundant. Species as *Tachysurus malabaricus* and *Macrobrachium* are believed to have been nearly eliminated from the lake due to disrupted exchange of fish species caused due to construction of Velanthara embankment along the southern margin of the lake. The already meagre fishery is under stress due to unsustainable fishing practices as harvest of broods and disturbance in breeding areas. During surveys, fishers indicated removal of natural shoreline vegetation as Screw Pine, as one of the significant reasons for declining fish populations as many species nested within their roots.

Invasive macrophytes as *Salvinia* and *Eichhornia crassipes* are increasingly occurring on the shorelines. As marshes adjoining Sasthamkotta are being increasingly cultivated, the waterbirds are preferring alternate habitats as Ashtamudi Estuary.

Continued discharge of sewage, silt, shrinkage in inundation regimes and shallowing of margins from catchments will only create conducive conditions for invasion. It is therefore, important that changes in biodiversity, especially those which are sensitive to stresses as pollution, is integrated within wetland monitoring system. There is also a need to continue a periodic updation of the community Biodiversity Registers.

2.5 Livelihoods

Livelihoods of communities living around the wetland have an important bearing on ecological character, and possibility of achieving wise use. Assessment of community livelihoods around Sasthamkotta, presented in this section, is based on socioeconomic survey of peripheral villages conducted during April to June 2015. The survey covered 118 households within 10 wards of 3 Panchayath located on the lake shoreline, namely Sasthamkotta, Mygnapally and West Kallada. The surveyed households accounted for 2 % of the total number of households of these Panchayat. Selection of households was done using stratified random sampling, using primary occupation as a selection variable. Focal Group Discussions were also conducted to understand communities' views, rights and capacities to engage in integrated management of Sasthamkotta.

Livelihood settings

Community livelihoods around Sasthamkotta have been under gradual transition, in the lines of the broader developmental planning within the region. Evidences indicate that the ecosystems services and biodiversity values of wetlands were hardly recognized in the planning processes, instead their transformation into productive agricultural lands was promoted throughout 19th century. Beginning 19th century, Colonel Munro, the erstwhile Prime Minister of Travancore, initiated various flood protected measures for promoting agriculture within Kollam District. The earthen embankment around Sasthamkotta was constructed during his tenure to prevent the lake from flooding nearly agriculture fields, and harness the water storage for drinking water purpose. By 1960s, a system of land tenure was implemented within the reclaimed marshlands, rents being largely fixed as per agricultural productivity. However, as complete exclusion of inundation and river flood pulses was not possible, winter paddy (Mundakan Paddy), sown after the monsoon months and harvested during winter remained the principal crop. Native vegetation within the direct drainage basin was

Focal group discussion with key stakeholder near Ambalakadavu

Mixed cropping of banana and coconut on the fringes of Sasthamkotta near Muthupilakadavu

gradually removed to pave way for plantations, and by 1980s almost no natural vegetation area could be discerned.

In 1956, the water storage within Sasthamkotta formed the basis of the Quilon Water Supply Scheme, supplying water to Kollam City. For this purpose, the earthen embankment was concretized and raised in height by upto 1.2 m, so as to enhance water holding capacity. As agriculture production increased, concurrent development of rail and road infrastructure was undertaken so as to facilitate easy movement of people and goods.

In 1961, unprecedented flood hit this area due to which the low lying areas of the Kallada River i.e. the East Kallada, West Kallada, and Munroe Island etc. got submerged, causing extensive damage to houses and assets. This promoted implementation of Parappar Reservoir within headwaters of Kallada, so as to provide flood protection downstream, and use the water thus stored for irrigation development. The entire river also became a hotbed for sand mining to meet the increasing demands from the construction industry. Water withdrawal from the lake intensified as additional drinking water supply projects were commissioned. Plantations of acacia was undertaken during the eighties under a World Bank Projects aimed at enhancing fuelwood availability.

A cumulative impact of developmental projects was decline in fisheries in Sasthamkotta, and since the last decade, rapid shrinkage in inundation regimes. Taking cognizance of the high adverse impact, sand mining from six rivers, including Kallada was banned in 2015.

While the environmental conditions around Sasthamkotta declined, several economic trends, common to entire Kerala, underpinned a gradual shift from a natural resources based economy to one driven by services sector. Immigration to Gulf countries begun in the 1970s and became very intensive towards the end of nineties. Infrastructure development brought along

increase in demand for sand, and thus employment opportunities in mining sector. Thus, there remained a comparatively small section of community of fishers around Rajagiri with livelihoods directly dependant on wetland resources. For the rest, the dependence is more in the form of water security and cultural aesthetics.

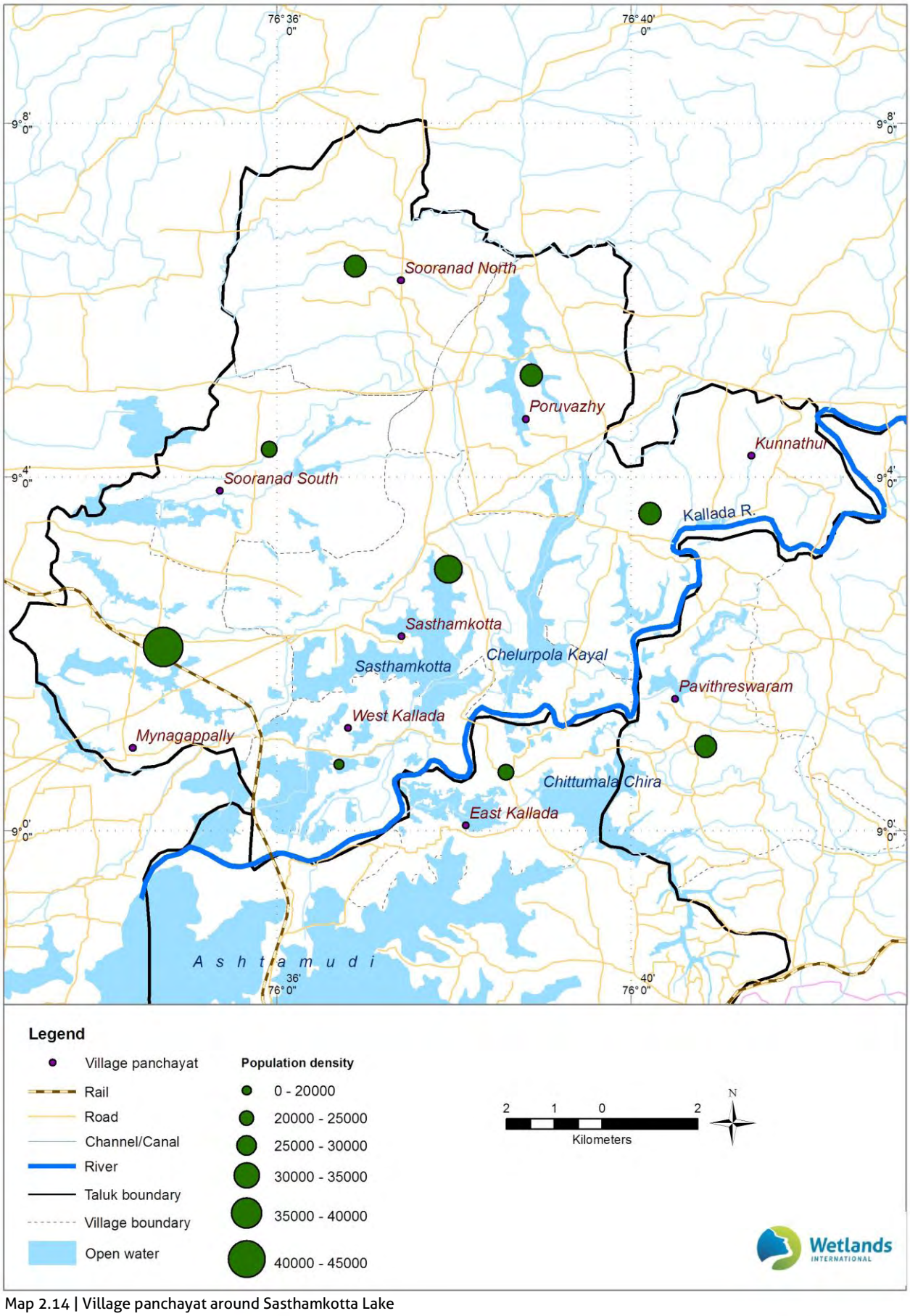
Profile of communities in and around Sasthamkotta

The shoreline of Sasthamkotta is inhabited by three village Panchayats, namely Sashtamcotta, West Kallada and Mynagapally, all of which form a part of Kollam District (Map 2.14). Over half of the shoreline falls under Sasthamkotta Panchayat, the rest being shared equally by Mygnapally (western shoreline) and West Kallada (southern shoreline). Of the 25,602 households (total population of 92,500) that inhabit the three Panchayat, 57% (13,400 households, total population of 53,300) inhabit the direct drainage basin of Sasthamkotta (Annex 8).

The shorelines have high population density, as is the case with the entire lowland region of Kerala. The density within the drainage basin, as per 2011 population census, at 1609 persons per square kilometre is double that of Kerala State. The northern shoreline has higher population density as compared to the south, as it has large settlements as Sasthamkotta and Bharnikavu Towns, the fishermen colony of Rajagiri, and settlements adjoining Sastha Temple.

The shoreline along West Kallada Panchayat has mostly lowland paddy fields. Settlements are relatively sparser here. The shoreline shared with Mygnapally has mostly rubber plantations, which extend till Karali marshes. Communities within Sasthamkotta Panchayat constitute mostly progressive farmers and traders. West Kallada and Mynagapally have a mix of farming and fishing communities. Majority of fisher belong to Ezhava and Latin Catholic community (DoF, 2011). A profile of primary and secondary occupations of the sampled households is presented in Table 2.7

Fisher with fishing gear in fishermen colony of Sasthamkotta



Map 2.14 | Village panchayat around Sasthamkotta Lake

Table 2.7 | Occupation profile of communities living around Sasthamkotta Lake

Occupation	% of total HH	Agriculture farming & Plantation	Fishing	Small Business	Service	Wage Labour	Others
Agriculture farming and plantation	2%	**100%**	0%	0%	0%	0%	0%
Fishing	16%	0%	**100%**	14%	8%	22%	0%
Small Business	12%	14%	0%	**100%**	5%	14%	0%
Service	17%	8%	0%	8%	**100%**	8%	19%
Wage Labour	30%	17%	0%	2%	0%	**100%**	0%
Migrants	24%	4%	6%	4%	46%	23%	**100%**

Over half of the households (54%) living around Sasthamkotta earn their livelihoods through wage labour (employed at construction sites, rubber plantations or in mining) or by migrating internationally for jobs. Natural resources based livelihoods (fishing, farming and plantation) provide the main base of sustenance for 18% of the households. The rest are employed either in formal sector, or own small business. The fishers fish mostly in Kallada River, and only meagrely in Sasthamkotta. The work force participation rate (percentage of adult population employed gainfully) at 42% is comparatively higher than that of Kollam district. Kerala on an overall is one of the top performers in gender equity in workforce participation, and similar trends can be seen in the sampled population. The overall literacy rate was assessed to be 85%, with male members having marginally higher rates (87%) than the females (84%).

The average per capita income of the drainage basin communities at Rs. 35,400 is significantly lower than that of state (Per Capita Net State Domestic Product of Kerala for 2014-15 was Rs. 103,820 at current prices. One of the significant reasons for this is exclusion of migrant income for the sampled households. Notably, Kerala has the highest remittance from international sources, forming almost a quarter of the per capita income. Wage labourers, fishers and farmers have significantly lower incomes than the average.

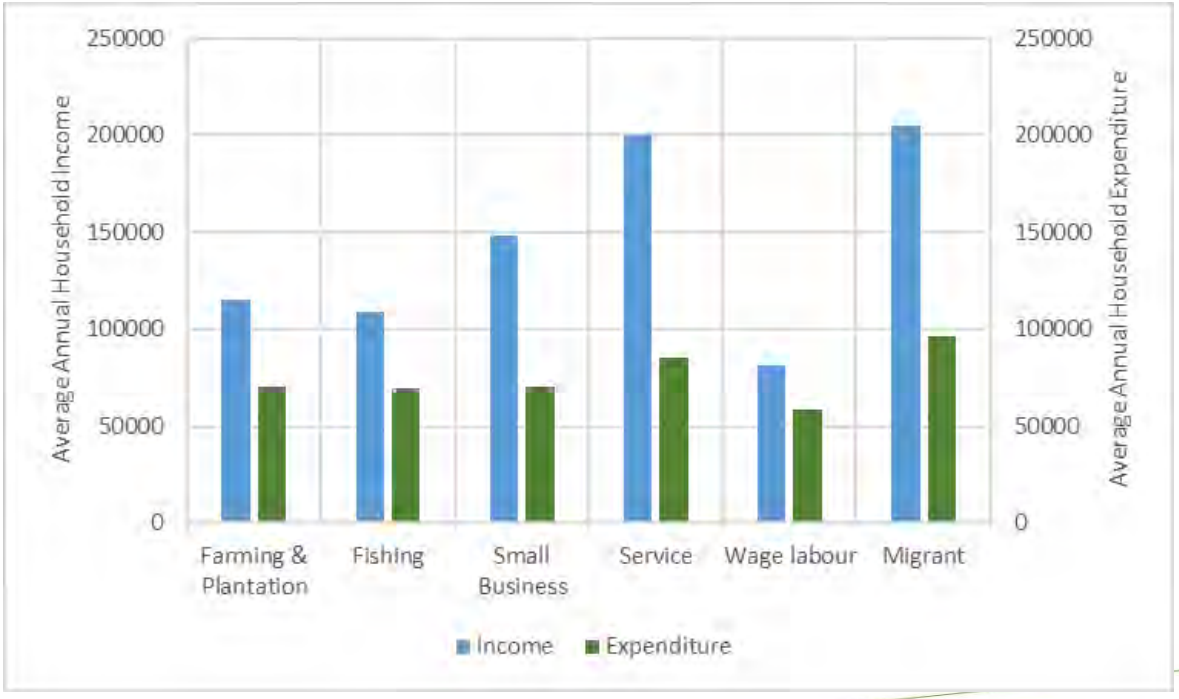


Fig. 2.13 | Income and expenditure profile of various stakeholder

While significant differences in incomes were recorded during the survey, household expenditures were almost similar across various occupation categories (Fig. 2.13). Nearly half of the sampled households reported being indebted, with an overage outstanding loan being Rs. 125,200. 40% of the households reporting indebtedness had accessed the formal banking system for credit. Loan is taken primarily to meet household needs (60%), health (12%) and education (10%).

Fig 2.14 captures the income inequality within various occupation categories. Households with migrants as key income earners have inequalities higher than the rest (Gini Coefficient = 0.475 as compared with 0.38 for the entire surveyed households). Communities dependent on fishing, agriculture and plantation have least inequality amongst all assessed.

A profile of access to basic amenities communities, segregated for various major stakeholder groups is presented in Table 2.8. As can be seen, fishers and wage labourers rank amongst the least within the surveyed communities. It is noteworthy that while Sasthamkotta provides water to a major proportion of urban population within Kollam City, only 39 % of the households living within the drainage basin avail the benefit of water supply from the lake. There is a near complete coverage of sanitation (99%), most of the toilets have single pit (70%), and there is substantive leaching of fecal coliform in lake waters, as indicated by the water quality observations.

Wetlands-livelihoods interlinkages

The most direct dependence of communities on Sasthamkotta is as a source of water supply. The Quilon Water Supply Scheme (QWSS) withdraws 30 million litres of water for supply to 0.3 million population living within Kollam City and its suburbs. In addition, 33.5 million liters are also withdrawn from the lake daily to provide for the water supply needs of communities living within Chavara, Panmana, Sasthamkotta, Sooranad, West Kallada, Thevalakkaora and Thekkumbhagam. The Sasthamkotta water treatment plant of KWA produces 30 MLD of water. Out of this, 13 MLD of water reaches Kollam Corporation, with the balance being supplied to neighbouring Panchayat. An estimated 5 MLD is also extracted from 35 tube wells located at various places within Kollam Municipal Corporation.

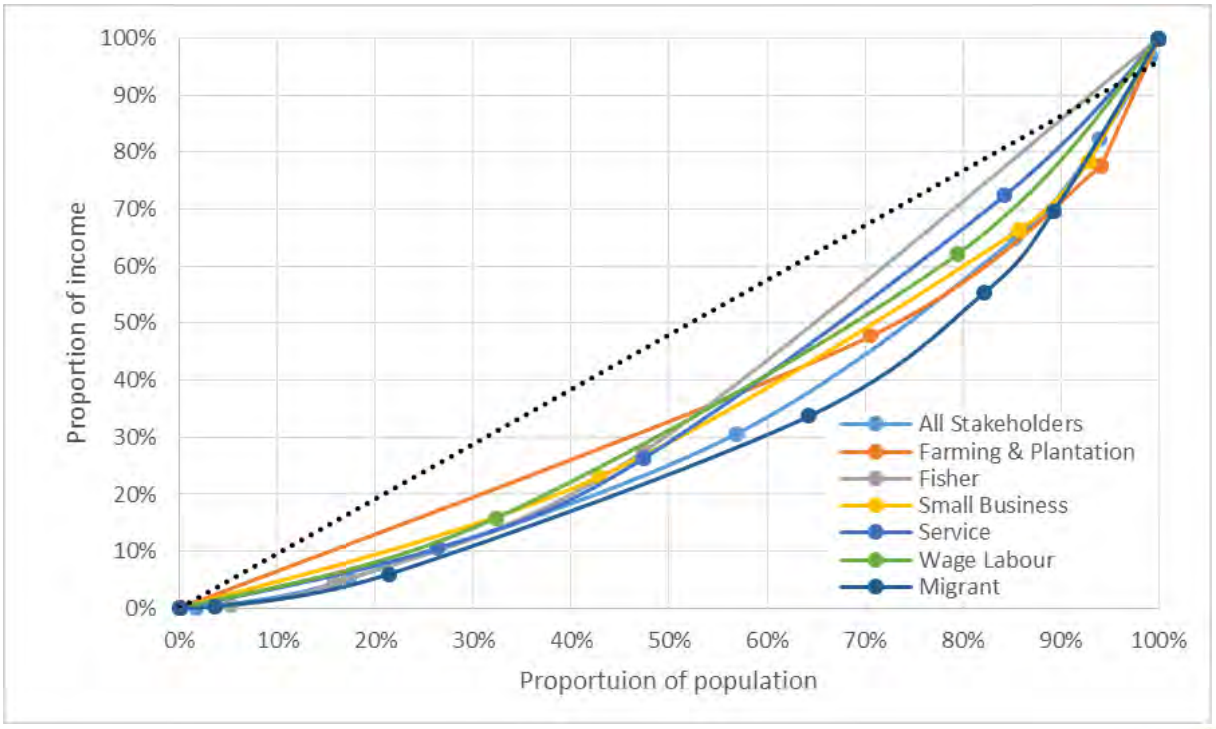


Fig. 2.14 | Pattern of income distribution

Table 2.8 | Asset holding by various stakeholder categories

		Household occupation							
		Unit	Total	Farming and Plantation	Fishing	Small Business	Service	Wage Labour	Migrant
Education									
Adult literacy	Male	% adult in household	99.53%	100%	100%	96%	100%	100%	100%
	Female	% adult in household	97.47%	100%	100%	96%	95%	96%	100%
Quality of housing									
Owned		% household	99%	100%	100%	100%	100%	97%	100%
Concreate house		% household	43%	50%	36%	50%	65%	25%	64%
Semi-Concreate house		% household	23%	0%	21%	28%	15%	34%	10%
Earthen house		% household	34%	50%	42%	21%	20%	37%	25%
Electricity	> 8 hrs	% household	99%	100%	100%	100%	95%	100%	100%
Drinking water	House piped water supply	% household	44%	50%	52%	43%	15%	28%	42%
	Well	% household	32%	50%	32%	29%	60%	31%	32%
	Public piped water supply	% household	4%	0%	5%	0%	0%	2%	0%
Energy for Cooking	Only LPG	% household	3%	0%	0%	0%	0%	0%	11%
	Only Fuelwood	% household	18%	0%	21%	7%	5.0%	43%	0%
	LPG and Fuel Wood	% household	78%	100%	74%	93%	95%	54 %	89%
	Fuel Wood and Kerosene	% household	2%	0%	5%	0%	0%	3%	0%
Toilets		% household	99%	100%	95%	100%	100%	97%	100%
	Single Pit	% household	96%	100%	90%	93%	95%	94%	96.%
	Double Pit	% household	4%	0%	5%	7%	5%	3%	4%
Agriculture land & livestock	Own Agriculture land	% household	32%	100%	11%	21%	40%	34%	43%
	Landholding	Average, acre	0.50	0.30	0.32	0.27	0.38	0.25	0.81
	Own Livestock	% household	12%	0%	16%	0%	5%	20%	11%
	Own Poultry	% household	9%	0%	0%	14%	0%	17%	11%
Annual Income		Average	143879	115000	108947	148571	200000	81471	205000
		SD	102395	49497	47830	99758	96321	39630	134976
Annual Expenditure		Average	74455	70000	69211	70000	85000	58636	96111
		SD	43611	28284	26471	23664	46233	22613	66511
Proportion of expenditure									
	Food	% of monthly Expenditure	41%	53%	41%	43%	30%	42%	44%
	Education	% of monthly Expenditure	10%	10%	8%	13%	14%	8%	8%
	Health	% of monthly Expenditure	18%	20%	16%	16%	18%	19%	17%
	Transport	% of monthly Expenditure	11%	10%	11%	13%	7%	12%	12%
	Repair and maintenance	% of monthly	9%	0%	8%	7%	16%	11%	9%

	of house	Expenditure							
	Main livelihood activity (fisheries, agriculture, etc.)	% of monthly Expenditure	12%	7.5%	17%	7%	16%	7%	10%
Indebted		% household	23%	0%	8%	1%	2%	11%	6%
Purpose	Occupational needs		6%	0%	11%	0%	0%	0%	14%
	Household needs		63%	0%	44%	100%	50%	69%	71%
	Education		19%	0%	22%	0%	50%	23%	0%
	Medicine/hospital		3%	0%	11%	0%	0%	0%	0%
	Other		9%	0%	11%	0%	0%	8%	14%
Main source of credit									
	Local money lander		0%	0%	0%	0%	0%	0%	0%
	Bank		78%	0%	89%	100%	50%	85%	57%
	SHGs		22%	0%	11%	0%	50%	15%	43%
Outstanding Credit		Average	115714	0.00	111111	900000	175000	107884	224285
		SD	110490	0.00	110698	0.00	170776	94911	189636
Membership to Kudumbshree		% household	44%	100%	89%	36%	25%	34%	39%
Role	General member	% household	40%	0%	82%	0%	40%	0%	36%
	Office bearer	% household	2%	0%	0%	0%	20%	0%	9%
	No role	% household	58%	0%	18%	0%	40%	0%	55%

Entrance to Sastha Temple

Sasthamkotta is also a source of rich recreational cultural values. Kollam District is historically significant as a trade destination. Every year, thousands of tourist visit the district to see its beaches and wetlands. According to Department of Tourism (DoT) 2014, Kollam District has registered high growth in tourist arrival as compared to Kerala State (9.13% for 2013 – 14 as compared to 7.71% for Kerala). The District Tourism Promotion Council (DTPC) lists Sasthamkotta as one of the 7 major touristic destinations. Some of other sites of Sasthamkotta such as Velanthara Embankment, Rajagiri, Punnakkad and Kunnampuram provide significant views of the lake. Connection with National Highway 220 and Kollam – Ernakulum rail network enhances ease of access to the district as well as the lake. Annually, Sasthamkotta receives over 2,000 visitors.

The region around the lake has high cultural value as well. The lake is believed to have been named after the local deity, Lord Sastha, who has a temple adorning the shoreline. The new moon day of each month is considered auspicious, drawing a large number of locals to the temple and to the lake. Besides, Ammankovil Devi or Bhadrakali temple situated in Sasthamkotta Mannakkara, Thalayinakkavu Shiva Parvathi Temple, Poruvazhy Peruviruthi Malanada Duryodhana Temple, and Anayadi Narsimhaswamy temple are significant religious sites located around the lake. Mount Horeb Ashramam, a monastic community of the Malankara Orthoodox Church, was established in 1991 on the banks of Sasthamkotta.

There is a ferry service connecting Ambalakadavu (Sasthamkotta) and Vettolikadavu (West Kallada) used by 30-40 persons daily. A nominal fare of Rs. 10 is charged per passenger for one-way trip.

Sasthamkotta does not support significant commercial fisheries due to several ecological factors as low primary productivity, and absence of riverine connection. Subsistence level fishing is done within the lake and adjoining river by 36 fishers. The catch from the lake has been

Feery service from Ambalakadavu to Vettolikadavu

declining, from nearly 10.5 MT in 1991 to less than .65 MT at present (Prakasham 1991, Nayar et al., 2011 and Field assessment 2015) Fig. 2.15. Inefficient food-chain, regulation of flood pulses and destruction of breeding grounds are some of the major contributing factors.

The fisher cooperatives engagement in Sasthamkotta has been on a decline as well. Padappakada Rural Fish Cooperative Society was first primary fisher cooperative society (PFSC) established in 1995. The society had 2000 members, covering fishing grounds within Sasthamkotta, Kundara and Ashtamudi Lake. Sasthamkotta Rural Fish Cooperatives Society was formed in 1997 with 155 members, for managing lake fisheries. However, the society has stopped functioning as resources have declined, and there is no capital available for meeting various operational requirements.

Sasthamkotta helps maintain the hydrological regimes of the entire drainage basin, supporting agriculture and plantation activities. Much of agriculture within the basin and adjoining areas has evolved on converted marshlands. A winter crop of paddy (locally termed as Mundakan paddy)

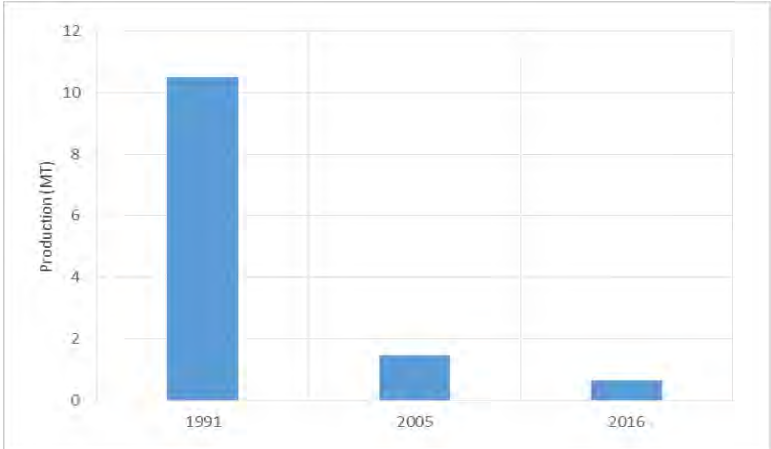


Fig. 2.15 | Fish production trends of Sasthamkotta Lake

followed by seasumum are the major crops. Around 24 ha of the lakebed is under permanent cultivation. Agriculture in Kerala on an overall has been impacted by rising costs of labour and inputs.

Community perspectives on wetland issues

There was unanimity amongst surveyed communities that the lake has been degrading. Shrinkage in lake area, siltation, and plantation of acacia trees around the shorelines were listed as the most significant adverse trends. These were closely followed by ranking placed on excessive water abstraction, sand and laterite mining within the direct drainage basin and increase in pollution loading. Fisher communities listed destruction of fish breeding grounds within the wetlands as a significant adverse change, however, scored it as the least important of the issues identified (Fig. 2 16).

A mix of management and regulatory measures were recommended by the communities to improve the health of the Sasthamkotta ecosystem. Desiltation of the lake bed, promoting rainwater harvesting and control siltation from the catchments were recommended as high priority actions. High emphasis was also placed on promoting community awareness on the significance of Sasthamkotta wetlands. Regulation of mining within direct catchments and groundwater abstraction and reduced water withdrawal were recommended as next in priority. Measures to improve hydrological connectivity with Kallada River, protection of fish breeding grounds, regulation of land use and development of ecotorism opportunities were also recommended. Fig 2.17 encapsulates various recommendations suggested by communities for restoration of ecosystem health of Sasthamkotta.

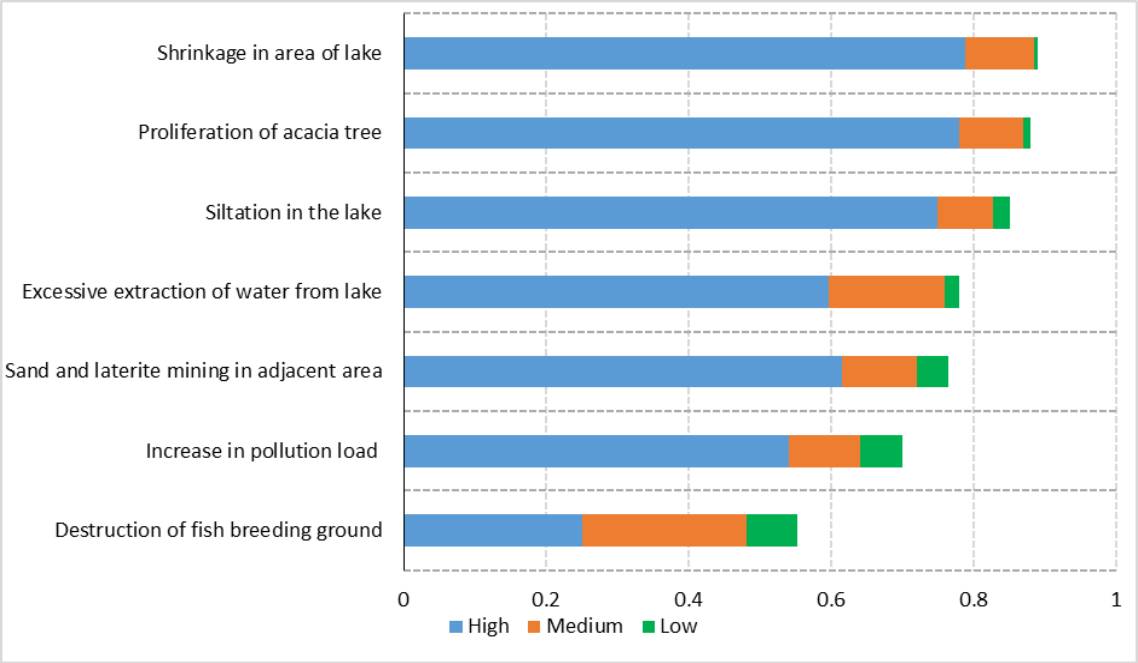


Fig. 2.16 | Community perception on key issues in Sasthamkotta Lake

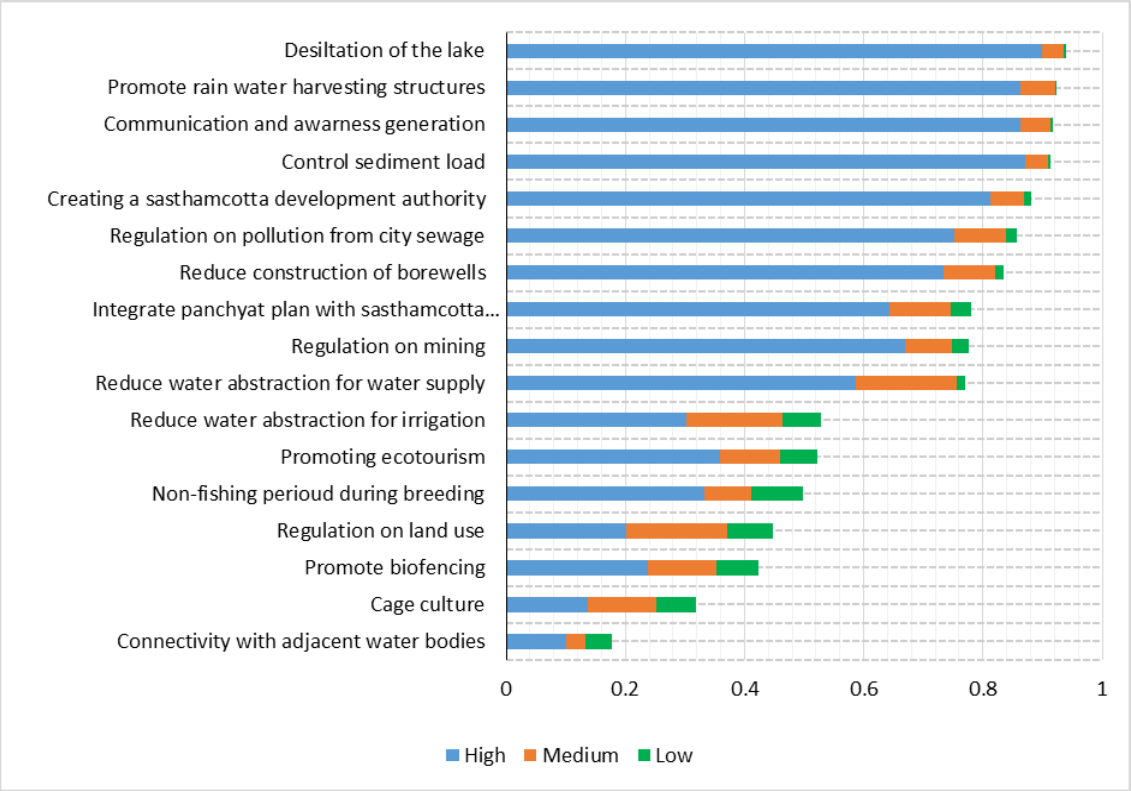


Fig. 2.17 | Key restoration measures identified

3. Institutional arrangements

3.1 Wetland Institutions : lessons and best practices

Addressing wetland degradation requires incorporation of linkages human societies have with wetlands within all spheres of management. Institutions and governance systems structure the relationship human societies have with wetlands, and thus, have an important bearing on ecosystem status.

Institutions encompass all formal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed. Various collections of institutions come together to form governance systems, that include interactions between different centres of power in the society at different scales from local to global. Institutions and governance systems determine, to various degrees, the access to, and the control, allocation and distribution of components of nature and anthropogenic assets and benefits to people. Formal institutions are often embedded in informal institutions, which collectively define the overall institutional environment. The ability of institutions and governance systems to deal with environmental change is closely related to the degree of fit achieved between biophysical systems, resource regimes and governance systems (Gehring and Oberthur, 2008).

Wetlands are subject to influence of a range of developmental planning and resources management decisions being implemented within their river basins and coastal zones. An important institutional pre-requisite is to ensure arrangements for cross sectoral coordination, so that various programmes pursued by different government departments as well as private agencies do not work for cross-purposes, and lead to adverse outcomes for wetlands. Institutions also need to be adaptable, so as to be able to accommodate new information and perspectives on wetlands, needs of diverse stakeholder groups,

A tourist boat in Sasthamkotta

and an uncertain political environment. Since communities living around a wetland have a direct bearing on the ecological state, and often have nuanced management systems based on traditional knowledge, institutional arrangements need to have adequate representation of such communities and knowledge systems. The institutions also need an adequate regulatory backing so as to enforce measures for conservation and sustainable management.

National scale efforts for wetland conservation in India started taking shape since the 80s coinciding with India's ratification of Ramsar Convention in September 1982. A dedicated scheme for financing wetland restoration was initiated by the MoEF in 1987 to provide financial assistance to the states for implementation of site management plans. An important building block of the scheme was a guidance to the State Government to constitute State Level institutions for enabling cross-sectoral coordination and management. Responding to these guidelines, several states have constituted specific institutions for management of wetlands.

Given the need to bring in multiple departments and stakeholders together to implement management plans, the State Governments have considered constitution of dedicated wetland authorities. The Loktak Development Authority (LDA) constituted in 1986 was one of the first wetland development authorities set up in the country. This was in the context of rapid degradation of Loktak Lake, one of the largest freshwater lakes in the northeast due to species invasion, shrinkage in area and reduction in water holding capacity, particularly after the commissioning of Loktak Hydro-electric Project in 1983. The Authority was initially placed under the aegis of Irrigation and Flood Control Department, but later on transferred under the administrative control of the Forest and Environment Department. In 1992, the Government of Odisha constituted the Chilika Development Authority (CDA) to address the pressures on Chilika Lake, the largest brackishwater lagoon on the east coast threatened by increasing silt load, declining fisheries and expansion of shrimp aquaculture. In 1997, the Government of Jammu and Kashmir constituted the Lakes and Waterways Development Authority under the Aegis of the Housing and Urban Development Department for restoration of Dal and Nigeen Lakes. Within the decade of 2000, separate wetland authorities were created for waterbodies of Madhya Pradesh, lakes within Bengaluru City, and East Kolkata Wetland. The Lake Conservation Authority of Madhya Pradesh initially focused on Bhoj Wetlands but was entrusted the mandate for conservation of all waterbodies of the state in 2004. The State of Odisha constituted a distinct wetland authority for the entire state in 2012.

The constitution of State Wetland Authorities was given a renewed push through a specific advisory to the State Governments in 2013. As on the date of writing this management plan, eight states had constituted such institutions.

The example of CDA indicates the value of wetland authorities in ensuring integrated management, particularly with the required degree of political ownership. At the same time, the authorities are also constrained by lack of adequate human and financial resources, limited powers of enforcement of regulatory regimes, and the ability to convene all sectors and stakeholders together. The case of Bhoj Wetlands clearly indicates that when not supported by adequate policy mandate and capacity, wetland authorities tend to lose their relevance. Ensuring fit between the ways wetlands function and the capability of wetland institutions remains a critical element of institutional design.

3.2 Existing Institutional and Governance Settings

Policy and regulatory frameworks

There is a wide gamut of policy and regulatory framework at the federal as well as state level to support conservation and wise use of Sasthamkotta. The framework draws strength from the Constitution of India, which in its Article 51-A (g) stipulates that "it shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and

wildlife and to have compassion for living creatures". Article 48A, part of the Directive Principles of State Policy obligates the State to protect and improve the environment.

The overarching policy framework for wetland conservation in India is set by the MoEFCC. The National Environment Policy (2006) identifies wetlands as 'freshwater resources'. Recommended policy actions include integration in developmental planning, management based on prudent use strategies, promotion of ecotourism, and implementation of a regulatory framework. Integration of wetlands in river basin management is also identified as a strategy for management of river systems.

The National Plan for Aquatic Ecosystems (NPCA) is the Ministry's flagship scheme for conservation of wetlands. The scheme amplifies Government of India's commitment to Ramsar Convention's wise use principle for conservation and sustainable management of all wetlands. NPCA also contributes to the commitments to the Convention on Biological Diversity (CBD)[1].

At state level, the **Kerala State Environment Policy** (2009) enlists conservation and sustainable use of wetlands for water and food security and economic benefit of people as a strategic area. Actions envisaged under the policy include prohibiting reclamation of wetlands, regulating unsustainable tourism and promoting sustainable utitlization without compromising biodiversity values. The **Kerala Water Policy** (2008) identifies ecosystem integrity as well as the physical, social and environmental background of the state while deciding on water allocation priorities. In 2015, the **Kerala State Action Plan on Climate Change** was approved for implementation by the Ministry. The plan includes wetland management as an action under the water management sector.

Wetlands (Conservation and Management) Rules, 2010, notified by the MoEFCC under the provisions of the Environment (Protection) Act 1986 provide the regulatory framework for wetlands in the country. All Ramsar Sites, including Sasthamkotta, have been placed under a specific category of wetlands notified under the rules. Under these rules, a range of activities are prohibited, key being hydrological fragmentation, conversion to non-wetland uses and discharge of untreated sewage and sewerage. A Central Wetland Regulatory Authority (CWRA) has been constituted for the purpose of enforcement of these Rules.

At the time of drafting this management plan, the Ministry had placed a revision of the Wetlands Rules for public consultation. Within the revised rules, the list of regulated and prohibited activities needs to be referenced to site's ecological character. The rules also require constitution of a State Wetland Authority as the nodal agency for policy making, regulation and management of wetlands of the state. The Indian Fisheries Act, 1987; The Indian Forest Act, 1927; The Wildlife (Protection) Act, 1972; The Water (Prevention and Control of Pollution) Act, 1974; The Environment (Protection) Act, 1986; and The Biological Diversity Act, 2002 contain specific regulatory provisions having relevance for management of Sasthamkotta. For example, Water (Prevention and Control of Pollution) Act, 1974 prohibits direct or indirect discharge of any poisonous, noxious or polluting matters in any waterbody and empowers the State Pollution Control Board to issue directions to ensure compliance of the same.

[1] In line with the CBD Strategic Plan 2011-2020, India has formulated 12 National Targets. Wetlands have direct reference in Target 3 (Strategies for reducing rate of degradation, fragmentation and loss of natural habitats are finalized and actions put in place by 2020), Target 6 (ecologically representative areas on land and in inland waters, as well as coastal and marine zones, especially those of particular importance for species, biodiversity and ecosystem services, are conserved effectively and equitably), and Target 8 (by 2020, ecosystem services, especially those related to water, human health and livelihoods and well-being are enumerated and measures to safeguard them are identified).

Lake bed inside demarcated area being used for plantation

The Government of Kerala has also enacted the Kerala Conservation of Paddy Land and Wetland Act, 2008 to conserve paddy lands and wetland ecosystems and restrict their conversion or reclamation. The act completely prohibits the reclamation of wetlands in the state. The reclamation of paddy land is restricted to ten cents in a Panchayat or five cents in a Municipality/Corporation. Any activity or construction in a paddy land in contravention to the provisions of the act is illegal[2].

The State Government has also notified The Kerala Protection of River Banks and Regulation of Removal of Sand Act (2001) to protect river banks and river beds from large scale dredging of river sand and to protect their biophysical environment. In 2015, the provisions of the act and

[2] The act stops local authorities to grant license or permit (under Kerala Panchayat Raj Act, 1994 (13 of 1994) or in the Kerala Municipality Act, 1994 (20 of 1994) for carrying out any activity or construction in a paddy land or a wetland converted or reclaimed in contravention of the provisions of this Act. As per the provisions of the act, a local level monitoring committee has to be constituted at Panchayat or Municipality level to prepare detailed guidelines for the protection of the paddy lands/wetlands under its jurisdiction and monitor compliance to the provisions of the act.

Any conversion in violation of the act invites penalties to the tune of imprisonment for two years and fine of one lakh rupees. This applies to person and companies as well. Authorised officers of Revenue Department have the powers to stop any such violation under the provisions of the Code of Criminal Procedure, 1973 (Central Act 2 of 1974) relating to search and seizure.

corresponding rules were used by the State Government to ban sand mining in six rivers of the state, including Kallada.

The Kerala State Pollution Control Board, under the powers vested by Water (Prevention and Control of Pollution) Act, 1974 has issued a notification of June 9, 2010 (Annex 9) prohibiting the following activities within all villages around the lake:

- Bathing, and washing clothes, animals and vehicles in the lake
- Discharge of wastewater from hotels, commercial establishments, industries, healthcare establishments and others into drains or pathways leading into the lake,
- Discharge of sewage into the lake or pathways leading into the lake,
- Mining of sand, granite, laterite, clay or soil from within 500 m from lake periphery,
- Storage of materials, polluted leachate from the which is likely to flow towards the lake, within 500 m periphery of the lake,
- Agricultural activities within 100 m periphery of the lake,
- Catching of fish from the lake using explosives,
- Construction of any sewage disposal facility (such as pit latrines) inferior to laid down minimum standards for septic tanks within 500 m periphery of the lake,
- Disposal of overflow from septic tank into land other than through soak pit with concreted bottom, perforated ring or honeycomb brick wall, within 500 m from the periphery of the lake,

Ownership and management arrangements

The boundaries of Sasthamkotta were delineated in 2007 through a joint survey by Kerala Water Authority and Revenue Department, and boundary pillars established on-ground at a distance of 50 m from the peak inundation area. The rights of the delineated area are vested with the Government, however, the revenue records indicate presence of private rights in some parts of the lake. Land within the direct drainage basin is under private ownership.

The Department of Environment and Climate Change is the designated state level institution for conservation and management of wetlands in the state. A key role of the department is to ensure coordination of various sectoral programmes on matters related to environment, including wetlands.

The department has constituted the State Wetland Authority Kerala (SWAK) vide Kerala gazette notification No. 49, dated 15 November 2015 (Annex 10). The Authority is registered as a society under the Travancore-Kochi Literary Science Charitable Society Registration Act, 1955.

SWAK is the designated regulatory authority for identified activities for management and wise use of wetlands. SWAK has been entrusted the role of policy development, enforcement of regulatory framework, and integrated management, implementation of action plans, research, awareness creation and mobilization of funds for wetland management. The Authority comprises a 11 member panel, chaired by the Environment Minister, with the Principal Secretary (Environment) as the Convener and officials from the Department of Water Resources, Science and Technology, Local Self Government, Agriculture as ex-officio members and four sector experts on limnology, hydrology, ecology and biodiversity.

Being a water infrastructure (or waterworks[3]), water abstraction and supply is looked after by the Kerala Water Authority (erstwhile the Kerala Water and Waste Water Authority). The Authority, since its constitution in 1984 (under the Kerala Water and Waste Water Ordinance, 1984 which

[3] "Water works" includes water channel (including stream, lake, spring, river or canal, well, pump, galleries, reservoir, cistern, tank), duct whether covered or open, treatment units, sluice supply main, culvert, engine, water-truck, hydrants, standpipe, conduit and machinery, land, building or other things for supplying or used for supplying water or for protecting sources of water supply or for treatment of water. This Act thus, entitles the KWA with the institutional ownership over the lake. KWA has demarcated its boundary after a survey.

subsequently, became the Kerala Water Supply and Sewerage Act, 1986) looks after the development and regulation of water supply and waste water collection and disposal in Kerala. The authority is a corporate body comprising a chairman appointed by the government, a Managing Director and Secretary, Public Health Engineering Department, Finance, Secretary, Local Administration, Secretary, Development Department and two representatives of local bodies as members.

The act vests all water supply and sewerage works with the authority. The authority has the power to abstract water for drinking purpose from any natural source, enter into contracts with other firms, lay down fees; acquire, possess and hold lands to carry water or sewerage works and can obtain specific information from local bodies to make provision for the supply of water and efficient sewerage services. The act also prohibits activities such as obstructing the flow of or flush, drawing off or diversion of water from water works belonging to the Authority or any water course by which any such water is supplied and the activities that pollute the water works.

Relevant sectoral programmes of Government agencies and departments

A number of State Government agencies and departments have programmes with bearing on the status of Sasthamkotta Lake (Annex 11).

Kerala Water Authority

Sasthamkotta, being a water supply project has been placed under aegis of the Kerala Water Authority. The Authority manages the abstraction and associated infrastructure.

Forests and Wildlife

The catchment of Sasthamkotta falls under the Kollam Social Forestry Range under the Department of Forests and Wildlife. Main functions of the Social Forestry division is conservation of biodiversity and promoting green cover at public places, maintenance of Compensatory Afforestation areas, spreading nature awareness through classes, film shows, farmers training etc.

Acacia plantations around Sasthamkotta were raised in available public lands under the Kerala Social Forestry project funded by World Bank that concluded in 1993. As *Acacia* is known to be water consumptive, a joint programme has been implemented since 2010 to replace the acacia trees with native vegetation. KSBB also launched a tree-planting drive to create a bio-fence around the lake.

Kerala State Pollution Control Board

The Authority is the nodal agency for implementing provisions of a gamut of laws and rules on environment, interalea:

- Water (Prevention and Control of Pollution) Act and the Cess Act, 1974.
- Environment (Protection) Act, 1986.
- Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 1989.
- Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-organisms, Genetically Engineered Organisms or Cells, 1989
- Biomedical Waste (Management and Handling) Rules, 1998
- Municipal Solid Wastes (Management and Handling) Rules, 2000 and
- Environmental Impact Assessment Notification, 2006.

The Authority also monitors a select set of water quality parameters of Sasthamkotta and has issued a notification in 2010 for regulating polluting activities.

Kerala State Biodiversity Board

Kerala State Biodiversity Board (KSBB) was constituted in 2004 under the provisions of the Biological Diversity Act 2002, Rules 2004 and Kerala State Biological Diversity Rules 2008. The KSBB is dedicated to conservation and protection of the agro, plant and fish diversity of the State. The major function of the State Biodiversity Board is to advise the State Government on any guidelines issued by the Central Government on

Office of Kerala Water Authority in Sasthamkotta town

matters relating to the conservation of biodiversity. The Board is headed by a Chairman, a Member Secretary and followed by a team of expert government officials.

Biodiversity Management Committee (BMC) have been constituted in all Local Self Government Departments including village Panchayats, Municipalities, and Corporations during 2011-2012 for the successful implementation of the Biological Diversity Act 2002. A joint Biodiversity Management Committee around Sasthamkotta, was constituted comprising members of three panchayats - Sasthamkotta, East Kallada, and Mayangapalli and Sasthamkotta block Panchayat president as the Chairman[4]. The committee is entrusted to take actions for protection of biodiversity and conservation and augmentation of the indigenous fish stock of Sasthamkotta Lake. In order to address the environmental problems faced by Sasthamkotta, a management plan focusing on massive afforestation and pollution mitigation measures has been proposed.

The Kerala State Biodiversity Board (KSBB) has published a Biodiversity Register for wetland ecosystem covering the catchment area of Sasthamkotta. The register is the result of a year-long mapping exercise carried out in association with a joint BMC comprising representatives of the gram panchayats.

Tourism Department

Sasthamkotta attracts many tourists because of its scenic beauty and religious significance. Kerala Tourism Department is the nodal agency managing tourist inflow in Kerala. Tourism department works with line departments, institutions and organization such as Kerala Tourism Development Corporation (KTDC), Tourist Resorts (Kerala) Ltd., District Tourism Promotion Council, Kerala Institute of Travel and Tourism Studies (KITTS) and Kerala Institute of Hospital Management Studies (KIHMS). Tourism department provides support to District Tourism Promotion Councils (DTPCs) in all districts of Kerala.

[4] As per Kerala Biological Diversity Rules 2008, Section 22 Sub Section (4) the Chairperson of the BMC shall be Chairperson of the Local body and the Secretary of the Local body shall be Member secretary of the Biodiversity Management committee.

The Kollam District Tourism Promotion Council has initiated a project to develop tourist facilities around the lake that includes a one kilometre road stretch, a rest room and places to sit and watch the lake[5]. A gateway is proposed as an entry to the lakeside at the Sri Dharma Sastha Temple end. An amphitheater along with a garden to beautify the lake premises is planned. The theatre is intended to stage various art forms of the state to attract tourists. Construction of a footpath has been planned alongside the shore with special canopies for the visitors to sit and relax.

Fisheries

The Department of Fisheries is the nodal agency for all affairs related to fisheries, including increasing production, conservation and sustainable exploitation of fisheries wealth, promoting cultivation of fish and prawns, development of fishing harbours and facilities for landing and marketing of fish, and for the upliftment and welfare of the fisher folk. The Department its allied agencies viz. Matsyafed, ADAK, KFWRB, FIRMA and FFDA implements the Government's visions and schemes in this sector.

The Department constructed a hatchery at Rajagiri for seed production of Karimeen (*Etroplus suratensis*). The hatchery is presently defunct.

Agriculture

The Department of Agriculture Development and Farmers Welfare deals with the formulation and implementation of various programmes to augment production of both food crops and cash crops in the state. It undertakes activities among farmers to promote scientific methods of cultivation, plant protection etc. and also arranges the supply of high yielding varieties of seeds, seedlings, planting materials and plant protection chemicals to farmers. The main function of agriculture department are agricultural research, education and extension.

The department functions through its district and Panchayat offices and has a presence in all the Village Panchayats through Krishi Bhavans. The Farm Information Bureau, established in 1969 acts as a single nodal agency to provide active and complete information support to accelerate the extension and developmental activities of the department of Agriculture, Animal Husbandry and Dairy Development. It works as a link between research stations and farming community by disseminating scientific knowledge and providing feedback to research stations.

A comprehensive District Agriculture Plan for Kollam district has been prepared for integrated and participatory action for the development of local area in general and agriculture and allied sector. The ultimate objective of the District Agriculture Plan is to attain substantial growth of agriculture sector with optimal utilization of the available resources.

The Department of Soil Survey and Soil Conservation which has a soil conservation wing and a soil survey wing undertakes investigation, preparation and execution of all the soil conservation work through its District Soil Conservation Offices. They have executed soil and water conservation activities under which about 456 ha of area have so far been brought under effective treatments where by erosion from catchment could be moderated to permissible limit.

Local self-government

The decentralization initiated by the 73rd and 74th amendment Acts of the Indian Constitution has given greater responsibility and powers to the local bodies for local planning, effective implementation and monitoring of various social and economic development programmes. Kerala State Government took to decentralized planning in 1996 and declared that 35 to 40 percent of the state plan fund would be utilized in the form of grant -in-aid to the Local Self Governments (LSGs) for formulating and implementing Local Development Plans. Over the years, the Gram Panchayat has appeared to put in more efforts to integrate sponsored programme into their Local Development Plans.

5 http://www.deccanchronicle.com/131228/news-current-affairs/article/sasthamkotta-lake-be-made-tourist-destination

LSG connects with a number of institutions for implementation work of Local Development Plans such as the Rural Development Commissionerate, Panchayat Directorate, Urban Affairs Directorate, Town and Country Planning Department, Kerala Institute of Local Administration (KILA), Information Kerala Mission, Kudumbashree, The Kerala Rural Employment and Welfare Society (KREWS) and State institute of Rural Development. Planning for the Panchayat located within Sasthamkotta Basin are placed within the ambit of the Local Self Government Department.

Suchitwa Mission, a government society, under the Local Self Government Department responsible for evolving implementation strategy, providing policy in the sectors of sanitation and various solid and liquid waste management issues, providing technical inputs for sanitation and waste management projects and has been functioning as the nodal agency for assisting Cities, Municipalities and Panchayats in sanitation and waste management aspects. Under its various sanitation schemes, sewage treatment plant at Government Taluk Hospital, Sasthamkotta (eco-restoration of Sasthamkotta) is under construction. 322 latrines have been provided to BPL families at Sasthamkotta Lake catchment area. Six girl friendly toilets and nine biogas plants have been constructed as part of school sanitation. As a part of public place sanitation, two sanitary complexes and biogas plant have been constructed at the Sasthamkotta lake catchment area.

Mining and industries

Sand and laterite mining are major issues in the lake catchments. Department of Mining and Geology is the statutory body for mineral exploration, prospecting, and administration in Kerala. The Department carries out short-term investigations/studies and being a scientific organization, also undertakes geosciences projects sponsored by agencies like Kerala State Council for Science, Technology and Environment.

Laterite, sand and clay fall under the category of minor minerals. In exercise of the powers conferred by sub-section (1) of section 15 of the Mines and Minerals (Development and Regulation) Act, 1957), the Government of Kerala has made the Kerala Minor Mineral Concession Rules, 2015 that replaces similar rules of 1967 to regulate the extraction of minor minerals in the state. Quarrying, is not permitted within a distance of 50 metres from any reservoir, tanks, canals, rivers, forest lands or village roads among others except with the previous permission of the authorities concerned or the Government or the competent authority. As per the provisions of the Kerala Protection of River Banks and Regulation of Removal of Sand Act (2001) sand mining is guided by the recommendations of a District Committee. Notably, the State Government has banned all sand mining in River Kallada.

Research and development

Research and development needs for wetland management are met through the Kerala State Council for Science, Technology and Environment, and a number of autonomous research and development centres as Centre for Water Resources Development and Management (CWRDM), Centre for Earth Sciences Studies (CESS), and number of academic institutions.

Engagement of civil society

Kerala has a strong tradition of proactive civil society organizations engaging of matters related to environment, which is well reflected in Sasthamkotta. Sasthamkotta Lake Protection Action Council and Paristhiti Samrakshana Ekopana Samithi are the major civil society organizations voicing issues related to wetland management with the government. The former was formed in 2002 to address sanitation issues in communities living around the lake, and is today a major community force triggering action for wetland conservation. In March 2010, the action council launched a hunger strike to move the government into taking positive actions for wetland restoration, thus triggering revision of the management plan. Within the state, The Kerala Sastra Sahitya Parishad (KSSP), founded in 1962 as a people's science movement has been vocal in raising issues related to environmental degradation of wetlands.

Key issues

The institutional and governance architecture for management of Sasthamkotta is well developed. At the same time, continued degradation of the lake is an indicator of ineffectiveness of current arrangements, Some of the key issues that limiting integrated management are:

- Absence of any mechanism for ensuring sectoral coordination: While a number of sectoral programmes are being implemented in the region around Sasthamkotta, there is no mechanism available to ensure cross-sectoral coordination at the level of lake's drainage basin to prevent any adverse change. The SWAK has been constituted only recently and the terms of reference are yet to be articulated completely.
- Limited participation of Panchayat: Communities living around Sasthamkotta have limited engagement in affairs of the lake, despite being the first to be affected by wetland degradation.
- Weak enforcement of regulations: While there are ample regulatory mechanisms in place, their enforcement continues to be a challenge. Field investigations indicated rampant violation of Kerala Pollution Control Board notification of 2010. The provisions of Wetlands (Conservation and Management) Rules, 2010 are not fully complied with. The zone of influence as required to be specified under the rules has not been designated, nor a listing of regulated activities done.
- Lack of capacity: Much of the available specialization within government agencies is sectoral in nature. There is limited capacity to ensure integrated wetland management, through a truly multi-disciplinary team.
- Financing: Financing of various activities is patchy, and not sufficient to comprehensively address the driver of change.
- Monitoring and evaluation: There is no system in place to comprehensively assess the status of wetland, and the impact of various interventions. On similar lines, effectiveness assessment of current management is also required to be able to enhance existing management arrangements.

3.3 Proposed institutional framework for managing Sasthamkotta

SWAK, if effective, will provide an institutional arrangement for achieving required level of coordinated action and enforcement of regulatory arrangements for conservation and wise use of wetlands of the state. However, it is important to ensure that various sectoral programmes being taken up within the catchment of Sasthamkotta are coordinated, with due consideration of the impact of such programmes on the Ramsar Site. It is therefore proposed to constitute a Sasthamkotta Wetland Authority (SWA), under the aegis of the SWAK, as the nodal agency for integrated management of Sasthamkotta.

The SWA is proposed to have the following functions:

- Coordinate implementation of the integrated wetland management plan through respective line departments
- Periodically review the wetland monitoring outcomes, and recommend necessary course correction measures to the respective departments
- Monitor enforcement of regulatory regimes related to wetlands (such as Wetlands (Conservation and Management) Rules, 2010; Kerala Conservation of Paddy Land and Wetland Act, 2008; The Kerala Protection of River Banks and Regulation of Removal of Sand Act (2001), notification on Sasthamkotta of the Kerala Pollution Control Board) and report any omissions to the respective enforcement agencies
- Commission specific studies to address knowledge gaps
- Promote awareness and outreach on biodiversity and ecosystem services values of Sasthamkotta
- Promote stakeholder led integrated management of Sasthamkotta

SWA is proposed to have a three-tiered governance structure. The Governing Body at the

apex under Chairmanship of the Hon'ble Minister (Environment), also the Chair of SWAK.

The Governing Body of SWA would include the following:

- Principal Secretary, Environment
- Principal Secretary, Water Resources
- Principal Secretary, Science and Technology
- Director, Kerala Water Authority
- Commissioner, Commissionerate of Land Revenue
- Chairman, Kerala State Pollution Control Board
- Principal Secretary, Local Self Government Department
- Principal Secretary , Fisheries
- Director, Centre for Water Resource Development and Management
- Subject matter Experts
- Civil Society representatives
- Representatives of the three Panchayats.

The SWA would have an Executive Committee to approve specific projects. The Committee is proposed to be headed by Principal Secretary, Environment and would have Principal Secretary, Local Self Government Department, and Director, Centre for Water Resource Development and Management as members.

The Authority would appoint a Chief Executive (on deputation from the Department of Environment) to implement the decisions of Governing Body and Executive Committee. The Authority would have, on its role, scientists from following disciplines:

a) Water management

b) Catchment conservation

c) Water chemistry

d) Community mobilization

4. Ecological Character Description and Evaluation

Wetland management planning is aimed at outlining a strategy for wise use, described in Ramsar Convention text as 'maintenance of ecological character, achieved through implementation of ecosystem approaches, within the context of sustainable development'. Ecological character is 'the combination of ecosystem components[1], processes[2] and services[3] that characterize the wetland at any given point in time.'

Changes to ecological character of wetlands outside natural variation may signal that uses of the site are unsustainable, and may lead to the breakdown of its ecological, biological and hydrological functioning (Ramsar Convention Secretariat, 1996). Assessing and responding to risks of human induced adverse changes in ecological character is therefore fundamental to achieving wise use of a wetland.

For wetland managers to be able to implement management that ensures maintenance of ecological character, it is important to identify and retain the site's essential ecological functions which underpin the wetland's ecosystem services and biodiversity values. Implicit within this recommendation is the need to identify key elements of ecological character maintaining which, would constitute the site's wise use. The extent to which ecological character is maintained and adverse human-induced changes prevented is reflected in these key features. Furthermore, a social-ecological systems perspective for defining and assessing ecological character, enables consideration of the interactions social actors and institutions have with biophysical components of wetlands.

The Ramsar Convention's guidelines for ecological character description are contained in Ramsar Resolution X.15. These elements have also been formally and systematically included in the 2015 revision of the Ramsar Information Sheet (RIS) Format, which needs to be updated every six years.

This chapter of management plan presents an evaluation of Sasthamkotta's ecological character, based on assessment of wetland features

[1] The living (biotic) and non-living (abiotic) constituents of wetland ecosystem. These include: Geomorphic setting (landscape, catchment, river basin); Climate (precipitation, wind, temperature, evaporation, humidity); Physical setting (area, boundaries, topography, shape, bathymetry, habitat type and connectivity); Water regime (inflow, outflow, balance, surface – groundwater interactions, inundation regime, tidal regime, quality); Wetland Soil (texture, chemical and biological properties); and Biota (Plant and animal communities)

[2] Processes that occur between organisms and within and between populations and communities, including interactions with non-living environment, that result in existing ecosystem state and bring about changes in ecosystems over time. These include: Physical processes (water stratification, mixing, sedimentation, erosion); Energy – nutrient dynamics (primary production, nutrient cycling, carbon cycling, decomposition, oxidation – reduction); Processes that maintain animal and plant population (recruitment, migration); and Species interaction (Competition, predation, succession, herbivory)

[3] Benefits obtained by humans from ecosystems, categorized as: Provisioning (fisheries, use of aquatic vegetation for economic propose, wetland agriculture, biochemical products); Regulating (maintenance of hydrological regimes) and Cultural (recreation and tourism, spiritual, scientific and educational value). Supporting services have been included in definition of ecosystem processes.

presented in the previous chapter. A description of ecological character is provided herein highlighting key elements, maintenance of which may be the focus of management. Status and trends in the key elements are discussed next, followed by an analysis of threats and risks of adverse change in ecological character. The chapter concludes with a listing of knowledge gaps.

4.1 Ecological Character Description

Sasthamkotta is a freshwater lake. Spanning an area of 373 ha, this inverted L-shaped lake has maximum depth of 13 m, is well oxygenated, has low nutrient concentrations and is neutral to weakly alkaline. During a normal monsoon year, the inundation peaks upto 16 m amsl post south-west monsoon, and gradually depletes by about 3 m by the end of April, wherein large parts of the shoreline transform into marshes. At its peak inundation level of 16 m amsl, the lake holds upto 15.6 Mm^3 of water. Well drained clayey soils on gently sloping laterites predominantly constitute the lake bed, which cap a sand layer upto 6 m deep, intervened by comparatively thin silt and clay dominated sediments. Recorded biodiversity includes 37 species of phytoplankton, 18 species of macrophytes, 158 species of terrestrial vegetation, 26 species of fish and 35 species of waterbirds. The overall biodiversity is lower due to hydrological isolation, low nutrients status and relatively higher depth.

Sasthamkotta forms a part of extensive floodplain wetland formation of River Kallada. The present form and shape of the lake are believed to have been acquired about 4,000 years ago, when extensive sedimentation, heavy load of siltation from the rivers along with meandering and migration cut-off isolated lakes and marshes. Sasthamkotta is surrounded by narrowly elevated ridges rising upto 35 m amsl on all sides except the south-west wherein, a 20 m amsl high embankment separates the waterbody from the floodplains of River Kallada. The direct drainage basin thus formed extends 629 ha, about 70 percent of which is under coconut based homestead agroforestry system, inter-linked with tree. The drainage basin is inhabited by 13,400 households who have livelihoods in the form of wage labour, migrant employment, small business and fishing. Presently, upto half of the water inflows into the lake are received from ground water, with the rest from rainfall and run-off from the catchment. Velanthra embankment on the southern margin isolates any surface water connectivity with the River Kallada.

The lake and its drainage basin are situated in a warm humid tropical climate. The average annual rainfall is 2251.57 mm, majorly received in two spells of south-west and north-east monsoon. Rainfall during the south-west monsoon is the predominant component accounting for 48% of the total rainfall. Temperature ranges between 22-33°C. The evaporation rate is highest (207 mm) during January and minimum in July (89 mm). Relative humidity ranges from 63% in January to 87% in June - July. Wind speed ranges from 1.3 - 2.1 km/hour.

Waters from Sasthamkotta are withdrawn to provide drinking water to 0.7 million inhabitants of Kollam City and settlements adjoining the lake. Sastha Temple, located on the shoreline of the lake, is a prominent religious place. The stunning beauty of placid waters with lush green hills, have earned Sasthamkotta the distinction of being the 'Queen of lakes' of Kerala State.

The following ecological character elements underpin the ecosystem and biodiversity values status of Sasthamkotta:

- A variable inundation regime that keeps territorialisation processes in check.
- High depth and water holding capacity that enable water storage and subsequent use for human purposes.
- A mix of water inflow sources (rainfall, surface run-off and ground water) that render stability to inundation regime.
- Low nutrient and metal concentrations and relatively high level of oxygen content, making the water fit for human consumption as well as preventing excessive growth of macrophytes.

- Presence of diverse flora and fauna, especially species of high conservation significance (present records indicate one fish species as globally Vulnerable and two fish and bird species each being Near Threatened)
- High aesthetic appeal in the form of open expanse with vegetated hills forming the background.
- A rich cultural heritage which makes Sasthamkotta an important natural asset.

Maintaining the aforementioned ecological character elements requires the following conditions:

- Maintaining surface and sub-surface hydrological connectivity with catchment run-off and river floodplains.
- Aligning water abstraction with natural variability of inundation regime of the lake.
- Maintaining a vegetated catchment and natural shoreline to prevent excessive siltation.
- Preventing anthropogenic enrichment of lake waters with nutrients, metals and other pollutants.
- Maintaining species habitats.
- Maintaining scenic beauty and naturality of the landscape.

4.2 Status and Trends

In order to detect any adverse change in ecological character, particularly human induced that requires management, it is pertinent to specify a baseline or a reference regime. In several circumstances, the description provided at the time of designation of wetland as a Ramsar Site serves as a baseline and periodic updation of the Ramsar Information Sheet every six years provides an opportunity to assess the trends. However, this approach becomes problematic if the wetland is heavily degraded at the time of designation, wherein maintenance of such a degraded state cannot be a suitable management objective.

The Ramsar Information Sheet prepared for Sasthamkotta at the time designation in 2001, contains a limited set of observations, much of which indicate that the lake was in a much healthier state than at present. Since no RIS update has been done since designation, this section presents the status information describing the ecological character elements using the data for 2011-15. The trend analysis pertains to the period since designation. The information is collated from primary records obtained during the management planning process, review of published literature, reports and community consultations.

The most significant trends relate to hydrological regimes of Sasthamkotta. There is a shrinkage in inundation regimes as well as a progression of the shoreline towards marsh dominated stage. Water balance assessments also indicate that the lake inflows are highly dependent on monsoon with sub-surface connectivity with River Kallada floodplains significantly impeded. Progressive shift of water quality towards pockets with high biological oxygen demand, elevated organic carbon and high levels of faecal coliform are indicative of pollution stresses. Species habitats, particularly of fish are also under stress. Construction of embankment on the southern margins of Sasthamkotta has already cut-off the influence of River Kallada flood pulses highly relevant for fish species. Worryingly, declining trends in south-west rainfall which contributes nearly half of the total rainfall are also evident.

The dependence on Sasthamkotta as a source of water supply has increased in the last two decades, requiring careful management so as to ensure that ecological integrity of the wetland is not compromised. The lake continues to be an important recreational and cultural asset, however, pollution loading into waters may compromise such values. The livelihood choices of communities living in and around the wetland have seen a gradual shift towards services sector driven economy, yet sustenance of water regimes remains a fundamental prerequisite.

A summary of the status and trends of the ecological character elements of Sasthamkotta Lake is presented in Table 4.1

Table 4.1 | Status and trends in components, processes and services of Sasthamkotta Lake

Ecological character element	Status	Data source	Trends	Data source
Ecosystem Components				
1. Area, boundary and dimensions				
1.1 Area	Wetland regime extends to 377.10 ha.	2015: LANDSAT 8 OLI Satellite Data	While the wetland area has been delineated on ground by the Revenue Department and Kerala Water Authority, parts of lake bed along Velanthara embankment and adjoining Rajagiri have been converted for agriculture and plantation.	2015: Field Survey
1.2 Depth	Available bathymetric information is of 2003 which indicates a maximum depth of 13 m. 75% of the lake area is less than 10 m deep, 23% has a depth between 10-11 m and the rest with depth higher than 11 m.	2003: Bathymetry survey by CESS (Centre of Earth Sciences Studies)	Assessments to discern trends not available. However, there is a high likelihood of reduced depth along shorelines on account of siltation due to road construction and other infrastructure development.	
1.3 Shape	The wetland is of an inverted L-shape.	2015: LANDSAT 8 OLI Satellite Data	No discernible trends.	
2. Occurrence of wetland types within the site	During a normal monsoon year, the open water area extends up to 306 ha with the rest under marshes and exposed lake bed.	2015: LANDSAT 8 OLI Satellite Data	Since 2010, there has been a considerable reduction in minimum inundation area and a commensurate increase in marshes and exposed lake bed area. There is a high likelihood of lake evolving towards a marsh dominated state.	1997-2015: Kerala Water Authority (KWA); 2015: LANDSAT 8 OLI Satellite Data
3. Habitat connectivity	Connectivity with adjoining marshes and floodplains of River Kallada is fragmented.	2015: Field Survey	With construction of Velanthara embankment, the flood pulses of Kallada River reaching into Sasthamkotta have been completely eliminated. More recently, extensive mining of sand from the floodplains has also impacted the sub-surface connectivity between Sasthamkotta and Kallada River floodplains.	2014: Sreekumari et al., 2015
4. Biological components				

Ecological character element	Status	Data source	Trends	Data source
4.1 Plant species	At least 37 phytoplankton, 18 macrophytes and 158 terrestrial vegetation species have been recorded from the lake.	2004-2005: Girijakumari, 2007; Nayar et al., 2011; 2015: Field Survey	The native vegetation along the shorelines was replaced by *Acacia* plantation done under a social forestry programme of the Department of Forest. With increased exposure of lake bed since 2011, the plantations have been mostly removed and being replaced with native species.	2015: Field Survey
4.1.1 Invasive alien plant species	Mats of *Salvinia, Eichhornia crassipes* and *Pistia stratiotes* have been recorded in post-monsoon seasons along the shorelines.	Nayar et al., 2011	The spread of invasive species has been on an increase and is gradually covering the entire shoreline.	2015: Field Survey
4.2 Animal species	Available records indicate the presence of six genera of zooplankton, 23 insect species (butterflies), 36 fish and 35 waterbird species.	2004-2005: Girijakumari, 2007; Nayar et al., 2011; 2008: CWRDM, 2010; AWC Records, 2012 and,	No temporal assessments available to discern trends.	
5. Physical components				
5.1 Climate	The lake and its drainage basin are situated in a warm humid tropical climate. The average annual rainfall is 2251.57 mm, majorly received in two spells of south-west and north-east monsoon. Rainfall during the south-west monsoon is the predominant component accounting for 48% of the total rainfall. Temperature ranges between 22-33°C. The evaporation rate is highest (207 mm) during January and minimum in July (89 mm). Relative humidity ranges from 63% in January to 87% in June-July. The wind speed ranges from 1.3 to 2.1 km/hour. The wind speed is high during March - June and less during the months of September to December.	1905-2015: IMD; 2009-2010: CWRDM, 2010; 2013: CGWB, 2013	An analysis of 100-year rainfall for IMD's Kollam Station indicates a decline in rainfall during south-west monsoon. This trend also underlies a decline in total rainfall. These are similar to state-wide trends.	1905-2015: IMD
5.2 Geomorphic setting	Sasthamkotta is isolated by marginally elevated ridges rising sharply from average lake level from 13.5 m amsl to nearly 35 m amsl on the	2014: Sreekumari et al., 2015; 2004-2005: Girijakumari, 2007;	Mining of sand and laterite have led to significant changes within floodplains of River Kallada and alteration in natural	Kuriakose, 2013

Ecological character element	Status	Data source	Trends	Data source
	northern, western and southern flanks, isolating a direct drainage basin of 1002 ha (including the lake area). Studies conducted on lithological characteristics of bore hole cores indicate the presence of an upper sand dominated layer intervened by comparatively thin silt and clay dominated sediments.	2015: LANDSAT 8 OLI Satellite Data	hydrological regimes of Sasthamkotta. In 2013, instances of land subsidence and earth fissure was noted along Velanthara bund, which has been attributed to mining of ground water aquifers.	
5.3 Soil	The drainage basin of Sasthamkotta consists of mostly very deep, well drained clayey soil on gently sloping coastal laterite. The clay does not allow much surface infiltration.	National Bureau of Soil Survey and Land Use Planning, 1996	No discernible trends.	
5.4 Water regime				
5.4.1 Water sources	Sasthamkotta Lake depends on inflows through rainfall, basin run-off and groundwater. As per water balance studies conducted for 2014-15, rainfall and run-off account for 52% of the inflows while the rest 48% flows in through ground water aquifers.	1905-2015: IMD; 1997-2015: Kerala Water Authority (KWA)	Mining of sand in River Kallada floodplains and relative lowering of river bed with respect to the lake has disrupted hydrological connectivity Sasthamkotta lake with the floodplains. Hydrological regimes of Sasthamkotta are largely monsoon driven at present, making it susceptible to climate variability.	2014: Sreekumari et al., 2015
5.4.2 Water permanence	During a normal rainfall year, the entire lake bed is inundated by November after two spells of south-west and north-east monsoon, covering an area of 373 ha. The lake levels at this juncture reaches upto 15.7 m amsl. Post monsoon, the inundation shrinks reaching its minimum of 210 ha by April, wherein levels dip to around 13 m amsl.	1997-2015: Kerala Water Authority (KWA)	Post 2010, there has been a conspicuous reduction in inundation regimes. In May 2013, the peak water levels have not been sufficient to ensure 80% inundation of the lake bed.	1997-2015: Kerala Water Authority (KWA)
5.4.3 Connectivity of surface water and ground water	The lake levels in Sasthamkotta are maintained by direct precipitation over the lake, run-off from direct drainage basin and ground water inflow. An isotope study on ground water movement indicated that some wells on the south-western margins of	Warrier, 2007	Mining of sand in River Kallada floodplains and relative lowering of river bed with respect to the lake has disrupted sub-surface hydrological connectivity Sasthamkotta lake with the floodplains.	2014: Sreekumari et al., 2015

Ecological character element	Status	Data source	Trends	Data source
	the lake were getting recharged by Sasthamkotta, whereas, the rest of the wells contributed water into the lake.			
5.5 Sediment regime	No recent studies of lake sedimentation are available. Hydrological investigation within the drainage basin indicate the recent sedimentation in the lake to range between 0.30 – 1.80 cm/year with higher values very close to Velanthara bund.	Warrier, 2007	The assessment of land use and land cover changes within the drainage basin indicates conversion of natural vegetation into plantation as well as expansion of settlement. There has also been extensive infrastructure development. All these changes are likely to enhance soil erosion. However, since the late 90s, intensive soil conservation measures have been taken up which is likely to slow down sedimentation rate.	2015: LANDSAT 8 OLI Satellite Data; 2015: Field Survey
5.6 Water turbidity and colour	Lake water is clear with turbidity ranging between 0.8-2.5 NTU. The stretch between Sasthamkotta and Bharanikavu Town has relatively lower turbidity than others.	2011-14: KSPCB	Turbidity levels for 2001-05 for all parts of the lake were marginally higher. However, it is difficult to discern trends owing to differences in sampling stations and methods.	2004-05: Girijakumari, 2007; 2008: CWRDM, 2010; 2011-14: KSPCB
5.7 Water temperature	Recent assessments not available. Surface water temperature were recorded to be 27.63 - 31.5 °C during 2001-05.	2004-05: Girijakumari, 2007	There is low likelihood of any appreciable change in water temperature in the last two decades.	2004-05: Girijakumari, 2007
5.8 Water pH	The lake waters are neutral to weakly alkaline ranging between 5.3 – 8.1.	2011-14: KSPCB	No discernible changes in the pH of the lake water. pH values during 2001-05 ranged between 6.45-7.36 showing similar trend of slight acidic to slight alkaline character.	2004-05: Girijakumari, 2007; 2006: George and Koshy, 2008; 2008: CWRDM, 2010 2011-14: KSPCB
5.9 Water salinity	Lake is freshwater with salinity ranging between 2.78 – 3.13 ppt.		There is low likelihood of any appreciable change in water salinity in the last two decades.	
5.10 Dissolved gases in water	The lake is well oxygenated with DO level in most parts of the lake ranging between 5.3 – 8.7 mg/l. However, values lower than 3 mg/l have been recorded from the areas	2011-14: KSPCB	Assessments of 2001-05 indicated high DO levels all throughout the lake (5.72-8.06 mg/l). Notably, the region around Velanthara bund has a relatively higher	2004-05: Girijakumari, 2007; 2006: George and Koshy, 2008; 2008: CWRDM,

Ecological character element	Status	Data source	Trends	Data source
	adjoining Velanthara bund.		rate of inundation shrinkage and marsh formation.	2010; 2011-14: KSPCB
5.11 Dissolved or suspended nutrients in water	Nitrate concentrations in the lake range between 0.01-9.9 mg/l. No recent assessments are available for phosphate and potassium. Phosphate levels during 2001-05 in the lake were recorded in the range of 0.0012-0.0559 mg/l.	2004-05: Girijakumari, 2007; 2008: CWRDM, 2010; 2011-14: KSPCB	Gradual increase in nitrate concentrations have been recorded within the lake. A study conducted in 1998 indicates high level of PO_4-P in deeper parts of the lake, trapped within organic clastic deposits, therefore, reducing available phosphates.	Prakasam and Joseph, 1991 Sreejith, 1998 2004-05: Girijakumari, 2007; 2008: CWRDM, 2010; 2011-14: KSPCB;
5.12 Faecal coliforms	Total coliform count ranges between 60 – 5200 MPN / 100 ml. Faecal contamination of the lake water is prominent throughout all stretches.	2011-14: KSPCB	High values of faecal coliform were recorded throughout all stretches with values ranging between 39.8-1400.3 MPN /100ml during 2001-05.	2004-05: Girijakumari et al., 2006; 2008: CWRDM, 2010; 2011-14: KSPCB
5.13 Features of surrounding area	As per land use land cover analysis for 2015, 68% of the direct drainage basin is under plantation, 20% under agriculture, 7% under settlements and the rest under marshes.	2015: LANDSAT 8 OLI Satellite Data	There has been a gradual intensification of land use within the direct drainage basin. There has also been an increase in plantation area and settlements with decline in area under plantation and marshes.	2015: LANDSAT 8 OLI Satellite Data
6. Ecological processes				
6.1 Primary production	Recent assessments not available. Primary productivity was recorded to be low in Sasthamkotta Lake, ranging between 0.072-4.5 mg / C /m^3 / day, showing peak during post-monsoon.	2004-05: Girijakumari, 2007	No assessments.	
6.2 Nutrient cycling	The lake is nutrient poor. However, no specific assessments have been carried out.		No assessments.	
7. Ecosystem services				
7.1 Provision of freshwater	Sasthamkotta Lake caters largely to the District of Kollam as a source of drinking water. 10.9 Mm^3 is withdrawn from the lake to support half a million people of the City of Kollam. Withdrawal of another 12.2 Mm^3 also supports the surrounding 7 Panchayats.	Kerala Water Authority (KWA), 2013	The water abstraction has increased over a period of time. New water supply projects implemented in 2013 have doubled the extraction. The total water withdrawal at present forms 2.48 times of the inflows received from rainfall and run-off net of evaporation.	Kerala Water Authority (KWA), 2013
7.2 Fisheries	The lake supports marginal fisheries with current annual	2015: Field Survey	There has been a significant decline in fish landings,	Prakasam and Joseph, 1991 as

Ecological character element	Status	Data source	Trends	Data source
	landing being less than 1 MT. Non-viable fisheries have also led to the redundancy of the two fisher cooperatives.		reported to be nearly 10 MT/ year in 1991. The fisher communities have gradually shifted to riverine and estuarine fisheries.	cited in Nayar et al., 2011; 2015: Field Survey
7.3 Inland navigation	A ferry service operating within the lake provides navigation between Sasthamkotta and West Kallada.	2015: Field Survey	No assessments.	
7.4Maintenance of water regimes	The portion of Sasthamkotta direct catchment located on the south-east is recharged by Sasthamkotta. The lake also has significant influence on the overall availability of water in the direct drainage basin	Warrier, 2007	Hydrological fragmentation has adversely affected the capability of Sasthamkotta to moderate hydrological regimes. However, detailed assessments are required to establish the degree of impact.	2014: Sreekumari et al., 2015
7.5 Cultural values	Several important sacred sites, including the Sastha Temple, are located on the banks of the lake and around it. The lake has high religious value and is visited by thousands of pilgrims every year for taking holy dip on its banks.	2015: Field Survey	No assessments.	
7.6 Recreational values	Sasthamkotta is distinct for its placid waters surrounded by lush green hills. Therefore, it provides scenic beauty to tourists and locals. Sasthamkotta also holds the title 'Queen of lakes' of Kerala State, which attracts tourists from around the region.	2015: Field Survey	No assessments. However, increase in invasives within the lake might hinder the aesthetic value of the lake.	
7.7 Important knowledge systems, and importance for research	Recent assessments on the lake's ecological character are meagre. As Sasthamkotta stands within the network of wetlands of international importance, it is pertinent that research, monitoring and inventory-making becomes a continuous task within lake management.		Studies on Sasthamkotta Lake have been sporadic.	

4.3 THREATS AND RISK OF ADVERSE CHANGE

An evaluation of wetland features and status and trends in ecological character, indicate the major threats to be sand and laterite mining within the drainage basin and floodplains; high rates of water abstraction; conversion of natural shoreline; siltation resulting from land use intensification in drainage basin; pollution and, increasing pressure on species habitats. An assessment of risk of adverse change resulting from these trends is discussed on Table 4.2

4.4 KNOWLEDGE GAPS

The following knowledge gaps need to be assessed to be able to track changes in ecological character and refine management of Sasthamkotta:

- Trends in bathymetry and water holding capacity.
- Surface-ground water interactions and relationship with lake levels.
- Nutrient cycles and implication for water quality and expansion of macrophytes.
- Role of ecological communities especially microbial in regulating water quality.
- Status of breeding and spawning grounds of fish.
- Utilization pattern of Sasthamkotta and adjoining marshes as waterbird habitats.

Table 4.2| Analysis of risks of change in ecological character of Sasthamkotta Lake

Major threats to ecological character	Likely impact on key ecological character elements	Degree of risk of adverse change in ecological character	Effectiveness of current management arrangements in preventing adverse change
Sand and laterite mining within drainage basin and floodplains Kallada River floodplains have been extensively mined for sand, which had provided hydrological connectivity between the River Kallada channel and the lake. The direct catchments have also been mined for laterite.	Mining has adversely impacted the hydrological connectivity of the lake with its drainage basin and river floodplains. As a result, water regimes have shifted from multiple inflow sources to being governed largely by monsoon. With increasing intensification of water use, both in terms of direct abstraction from Sasthamkotta and ground water use within the basin, the propensity of reduction in inundation regime is high. In medium term, this is likely to shift progression of lake towards marsh dominated state which may not provide a similar level of water storage function as in the former state.	Medium. Much of the shorelines particularly towards the southern part, exhibit marsh like conditions. The impact of mining on floodplain connectivity is a long-term one.	Regulatory measures to control mining have been put in place but are weakly enforced.
High water abstraction rate Despite variability in hydrological regimes (reduced south-west monsoon, cut-off of sub-surface flows from river floodplains) water abstraction from Sasthamkotta has been	In conjunction with declining rainfall and changing sources of water inflows, unsustainable water abstraction is likely to accentuate shrinkage in inundation regimes.	High	Planning is underway to reduce water supply burden from Sasthamkotta and provide alternate water source to Kollam City.

on an increase. Current water abstraction is 2.48 times the net surface water inflow into the lake.			
Pollution Areas around Velanthara embankment, Bharanikavu Town and Sasthamkotta Town, exhibit deteriorating water quality. The lake in general has high levels of faecal coliform.	Pollution within the lake would modify the low nutrient, low salt status of water quality to an elevated one. A direct implication would be on macrophyte growth and spread of invasive species. The overall aesthetic value of the lake is also likely to decline.	High	While measures have been taken to improve sanitation around the lake, the quality remains questionable. Sasthamkotta and Bharanikavu do not have an adequate waste management infrastructure.
Conversion of natural shoreline The natural shoreline has been rapidly transformed with removal of native vegetation and introduction of exotics. Parts of lake bed have also been reclaimed for plantation and agriculture.	Alteration of shorelines increases siltation rate and ultimately the water holding capacity.	Medium	Recently, the Department of Forest has intervened to remove Acacia plantation and reintroduce native species.
Increased pressure on species habitats The biodiversity of the lake, owing to hydrological isolation, high depth and low nutrient conditions is low. Therefore, various factors as unsustainable fisheries, degradation of fish life-cycle process supporting sites, and fragmentation of wetland habitat have emerged as a serious concern for continued habitat support from the lake.	Increased pressure may lead to reduction in species richness, some of which are related with international significance of the site.	Medium	No measures currently in place.
Land use intensification in drainage basin Within the direct drainage basin, there has been an increase in plantation area and settlements with decline in area under plantation and marshes. The adjoining River Kallada floodplains have been converted for plantations and agriculture.	Much of the land use changes are soil erosion intensifying, thus enhancing siltation and nutrient enrichment. In conjunction with shrinkage in inundation regimes, such changes are only likely to intensify progression towards marshy conditions.	Medium	Catchment conservation programmes have been undertaken in the direct drainage basin but require intensification.
Increased variability in rainfall A decline in the south-west monsoon (which is the predominant system of monsoon for Kerala) has been observed.	Decline in rainfall will reduce stability of inundation regimes.	High	No measures currently in place.

5. Monitoring Plan

Wise use of Sasthamkotta entails ensuring its wise use, and thereby maintenance of ecological character. Inherent within this management objective is the need for retaining those critical ecosystem components and hydrological processes that underpin Sasthamkotta's ability to provide wide ranging ecosystem services, as well it resiliency. Thus, having a system to describe, monitor and detect changes in ecological character is critical to support decision making for wise use of the Sasthamkotta Lake. Equally important is establishing a system to assess effectiveness of management that is put in place for the wetland, so that complementing institutional arrangements are also ensured.

There is no coherent mechanism for monitoring Sasthamkotta at present. Only a few aspects of wetland features have been monitored under State Government department/agencies' programmes, with sporadic assessments being conducted by research agencies and academic institutions. The KWA keeps a record of the lake levels through its manual gauge at pump house. Select water quality parameters are recorded at monthly frequency by the Kerala State Pollution Control Board, whereas the Groundwater Department maintains the status of borewells around the region, as a part of the larger pan-India groundwater monitoring network. Information on changes in status of catchments and pressures as mining and pollution are largely derived from assessments done by agencies as CESS. As most of these studies do not form part of a systematic monitoring framework design, there is a high risk of adverse trends being undetected for long periods of time, and not leading to any management intervention.

Assessment of management effectiveness is also limited to independent monitoring of sectoral programmes by the concerned departments, largely based on physical and financial targets, and rarely linked with specific result. There are no mechanisms in place to assess the cumulative impacts of sectoral programmes on the status of the lake or various ecosystem components and processes.

This section of management plan outlines a monitoring framework for Sasthamkotta to support integrated management, and is built around Ramsar Framework for Integrated Wetland Inventory, Assessment and Monitoring (Ramsar

Settlements around Sasthamkotta Lake

Convention Secretariat, 2010c). Monitoring purpose and strategy and associated resource requirement are detailed herein. The cost implications of the monitoring plan are factored in Chapter 6 (Management Plan) and Chapter 7 (Budget and Financing).

5.1 Monitoring Objectives

Developing a monitoring plan for Sasthamkotta requires addressing the following inter-related requirements of wetland inventory and wetland assessment:

- Establishing the ecological character baseline (inventory).
- Establish status, trends and threats to wetland using inventory information (assessment).
- Assess changes in status and trends, including reduction in existing threats or appearance of new threats, or even changes in management effectiveness (monitoring).

Monitoring is expected to be hypothesis driven (for example, deterioration in water quality due to a specific pollution source), and applied for management. Non-hypothesis driven collection of information is termed as surveillance, and plays an equally important role in management by helping discern underlying trends or risks of adverse change in ecological character.

It is imperative therefore to put in place an integrated wetland inventory, assessment and monitoring system (WIAMS) to address the overall information needs for wetland management, and to provide a robust decision support system for the same. The ambit of monitoring is also envisaged to include assessment of management effectiveness.

The follow are the specific objectives for establishing WIAMS:

- Developing up-to-date and scientifically valid information on status and trends of wetland features and influencing factors.
- Establishing a baseline for measuring change in ecosystem components, processes and services.
- Informing decision makers and stakeholders on the status and trends in biodiversity, ecological functioning and ecosystem services of the wetland.
- Supporting compliance to national and state legal requirements and regulatory regimes.
- Determining impacts of developmental projects on ecosystem components, processes and services.
- Identifying risks to ecological character and support development of response strategies.
- Assessing effectiveness of wetland management.

5.2 Monitoring Strategy

The state of Sasthamkotta is linked with status and trends of its direct drainage basin, as well as the indirect river basin. Information requirements can therefore be organized along three spatial scales:

- Sasthamkotta Lake site
- Sasthamkotta Drainage Basin (which is also the zone of direct influence)
- Kallada River Basin

A hierarchical classification of inventory, assessment and monitoring needs for Sasthamkotta is presented in Table 5.1. The information needs for inventory are derived from the core datasets needed to establish a baseline on ecological character[1] for Sasthamkotta, and contain all the essential ecosystem components, processes and services, as well as management related parameters that characterize the site. At the basin scale, the information requirement is related to geo-morphological and climatological setup, as well as basin wide management

[1] Derived from the core inventory fields required for ecological character description as per Ramsar Convention Resolution X.15: Describing the ecological character of wetlands, and data needs and formats for core inventory: harmonized scientific and technical guidance. These fields have been further integrated into guidance related to information requirement for describing Ramsar site at the time of designation and subsequent updates (Ramsar Convention Resolution XI.8 and XI.8)

arrangements, particularly those related to land and water resources. As the drainage basin is the zone of direct influence on the lake, information needs to include land and water management practices which have direct influence on the wetland status of the lake; including assessing the habitat connectivity and water, sediment, energy and nutrient flux which influence its ecological character. Finally, at the site scale, the information requirements pertain to important ecosystem component, processes and services, which are applicable to the site condition. At all levels, information on institutional arrangements and management practices is included so as to enable creation of a baseline on sectoral programmes, and the linked stakeholders, which are likely or have an impact on the wetland state.

Information needs related to assessment are aimed at deriving the status, trends and existing or likely threats to wetland. At the site scale, the focus is on deriving ecological character change and ecosystem services valuations and trade-offs. At the drainage basin scale, the focus is on deriving the land use change and implications for water, sediment and nutrient flux. At the Kallada River basin scale, the assessments are aimed at determining the climate induced risks to ecological character, ultimately aimed at developing a suitable response strategy for risk reduction and management. While not explicitly mentioned, strategic environmental assessments can be commissioned for any developmental project that has or likely to have negative impact on the wetlands.

Information needs for monitoring Sasthamkotta Lake have been derived from assessment of ecological character carried out for development of the management plan. Four cluster of needs have been identified: a) land use and land cover change, to assess the dynamics of land use within the drainage basin; b) hydrological regimes, to assess the flux of water, sediments and nutrients; c) ecological components and processes, to assess the biodiversity, habitat quality and resource productivity; and d) socio-economics and livelihoods, to assess the trends in ecosystem services – livelihoods interlinkages.

These monitoring information, adequately address the needs of Wetland (Conservation and Management) Rules, 2010 and the subsequent 2016 Draft. Being a Ramsar Site, the provisions of the said rules are automatically applicable. A list of wetland features, indicators and corresponding methodology and data collection frequency is provided as Table 5.2.

The monitoring and assessment needs are envisaged to be addressed by a dedicated monitoring programme and specific research and assessment projects. Inventory, being based on collated information on identified wetland features and management practices, will be developed based on the monitoring and assessment information, as well as secondary sources.

Inventory, assessment and monitoring form an integral part of wetland management, and thereby need to be placed as a core activity of the nodal agency entrusted with the task of ensuring conservation and wise use of Sasthamkotta Lake. The management plan proposes establishment of a Sasthamkotta Wetland Authority under the aegis of the Kerala State Wetland Authority. Monitoring functions can be delivered by the Center for Water Resources Development and Management (CWRDM), which has existing human and technical resources and expertise to manage such a function.

Linkages also need to be developed so that data from the existing monitoring networks of different agencies (for example, river flow and flood extent information from Central Water Commission and Department of Water Resources; groundwater quality and quantity from Central Ground Water Board; select surface water quality parameters from Kerala State Pollution Control Board) can be accessed and shared. Provision for participation of NGOs and civil society in monitoring programme should also be built, especially for socio-economics and livelihoods aspects and, biodiversity monitoring (for example, waterbird census being implemented by NGOs under the aegis of Asian Waterbird Census and Important Bird Area Programmes).

Table 5.1| Inventory, assessment and monitoring needs for managing Sasthamkotta Lake

	Information Purpose		
Information Scale	Inventory	Assessment	Monitoring
Sasthamkotta Lake	**Physical setting** (area, boundary, topography, shape, bathymetry, habitat type and connectivity) **Climate** (precipitation, wind, temperature, humidity) **Water regime** (inflow, outflow, balance, surface-groundwater interactions, inundation regimes, quality) **Sediment regime** (inflow, outflow, balance, distribution and transport) **Wetland soils** (texture, chemical and biological properties) **Biota** (plant and animal communities, conservation status) **Energy and nutrient dynamics** (primary productivity, nutrient cycling,) **Species interaction** (invasion, competition, succession) **Processes that maintain animal and plant population** (recruitment, migration) **Ecosystem services, stakeholders and trade-offs** (Provisioning – water abstraction for various uses, fisheries, inland navigation; Regulating – flood moderation; Cultural – tourism and recreational values) **Institutional arrangements** (governance, formal and informal rights and ownership, application of acts and regulations)	**Ecological character change** (change in ecosystem components, processes and services – can also be derived based on assessment of indicators related to ecosystems, habitat, species and / or management) **Land use land cover change in lake fringes**	**Impacts of land use land cover change in lake fringes** on water quality **Changes in inundation patterns** and impacts on vegetation
Sasthamkotta Drainage Basin	**Climate** (Precipitation, temperature, wind, humidity, evaporation) **Land use, land cover and management practices** **Physical setting** (area, boundary, connectivity) **Water regime** (riverine flows, surface-groundwater interactions, inundation regimes, quality, regulation, abstraction) **Sediment regime** (inflow, outflow, balance, distribution and transport) **Sectoral programmes and institutional arrangements** for management of land and water resources and biodiversity conservation	**Ecological character risk and vulnerability** (limits of acceptable change for critical ecosystem components, processes and services; sensitivity and adaptive capacity of critical components; risks of adverse change in ecological character)	**Land use and land cover change and impacts on lake hydrodynamics** (water availability and allocation for various human uses) **Impact of mining** on stability of inundation regimes.
Kallada River Basin	**Geology and Geomorphology** (Soils, elevation, slope, drainage pattern) **Climate** (Precipitation, Temperature) **Land use and land cover** **Water regimes** (river flows, upstream abstraction)	**Climate risk and vulnerability** (changes in river flows, vegetation changes and implications for the lake)	**River basin management planning** (water regulating structures and water allocation/discharge plans along the river basin)

Table 5.2 Monitoring and assessment parameters and indicators

Parameter	Indicator	Priority	Monitoring Method	Monitoring Frequency
Land Use and Land Cover				
Land use and land cover change within Sasthamkotta drainage	% area under various land use and cover classes (agriculture, forest cover, settlements, wetlands)	High	GIS and Remote Sensing Radar sensed data	Once in 5 years
Hydrological regime				
Water and sediment flux	Water inflow	High	Monitoring at gauging stations	Daily
	Water outflow	High		Daily
	Sediment inflow	High		Daily
	Sediment outflow	High		Daily
Water holding capacity	Bathymetry	High	Bathymetric surveys	Once in 5 years
Inundation Regime	Seasonal fluctuation in waterspread area	High	Remote sensing	Once in 5 years
Surface Water quality	Temperature	Medium	Standard procedures of APHA	Once in 15 days
	pH	High		Once in 15 days
	Dissolved Oxygen	High		Once in 15 days
	Specific Conductance	High		Once in 15 days
	Nutrients and Nutrient Cycling (Nitrate, Phosphate, Silicate)	High		Once in 15 days
	Cations and Anions (Calcium, Magnesium, Sulphate, Chloride, Fluoride, Sulphite)	High		Once in 15 days
	Chemical Oxygen Demand	Low		Once in 15 days
	Transparency	Medium		Once in 15 days
	Heavy metals (Arsenic, Mercury)	Low		Once in 15 days
	Biological oxygen demand	Medium	Standard procedures of APHA	Once in 15 days
	Total coliform	Medium		Once in 15 days
	Faecal coliform	Medium		Once in 15 days
Sediment quality	Texture	Low	Standard procedures of APHA	Once in a month
	pH	High		Once in a month
	Organic carbon	High		Once in a month
	Available nitrogen	High		Once in a month
	Available phosphorus	High		Once in a

				month
	Available calcium carbonate	Medium		Once in a month
Ground water quality	Water level	High	Methodology approved by Groundwater Estimation Committee (1997)	Monthly
	Conductivity	Medium		Monthly
	Total hardness	Medium		Monthly
	Chloride	Medium		Monthly
	Fluoride	High		Monthly
	Arsenic	Medium		Monthly
	Iron	High		Monthly
Ecosystem Processes and Biodiversity				
Flora	Phytoplankton (diversity and abundance)	Medium	Taxonomic studies, Standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10	Pre-monsoon, monsoon and post monsoon
	Periphyton	Medium		Pre-monsoon, monsoon and post monsoon
	Macrophytes (diversity and abundance)	High		Pre-monsoon, monsoon and post monsoon
	Species invasion	High	Habitat Sampling and Remote sensing (using high resolution data)	Pre-monsoon, monsoon and post monsoon
	Primary production	High	Standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10	Seasonal
Fauna	Zooplankton (diversity and abundance)	Medium	Taxonomic studies, standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10	Pre-monsoon, monsoon and post monsoon
	Aquatic macro-invertebrates	Medium	Taxonomic studies, standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10	Once in 5 years
	Aquatic Insects	Medium	Taxonomic studies, standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10	Once in 5 years
	Fish diversity	Medium	Taxonomic studies	Once in 5 years
	Amphibians	Medium	Taxonomic studies	Once in 5 years
	Reptiles	Medium	Taxonomic studies	Once in 5 years
	Fish breeding, spawning and migration pattern	High	Specific assessments and tagging experiments	Once in 5 years
	Waterbird population and diversity	High	Census and Taxonomic studies	Annual

	Waterbird migration pattern	High	Species specific ringing and banding studies	Once in 5 years
	Avian disease	Medium	Surveillance	Annual
	Habitat quality of bird congregation sites: - Number of nests or egg - Type of vegetation - Water level - Abundance of macro benthos	Medium	Assessment of bird habitat quality and standard procedures in Central Inland Fisheries Research Institute Bulletin No. 10 (for macro benthos)	Annual
Socio-economics and livelihoods				
Community dependence on wetland ecosystem services	Number of households benefitting from water withdrawn from lake; number of tourists visiting wetland and direct and indirect spending; number of communities	High	Socio-economic survey	Once every 5 years
Livelihood status of wetland dependent communities	Physical capital, financial capital, social capital, human capital indicators of livelihood systems	Medium		
	Number of reported instances of conflicts	Medium		

5.3 Assessing management effectiveness

In order to ensure wise use of Ramsar Sites, site managers must be able to anticipate risks, including new risks and respond to these effectively and timely. This requires conducting regular and open management effectiveness assessments and learn from successes and failures. It is with this backdrop that the Contracting Parties to the Ramsar Convention, in their 12th meeting Conference, adopted a specific resolution on evaluating and ensuring the effective management of Ramsar Sites (Ramsar Convention Secretariat, 2015).

Simply stated, management effectiveness assessment is a tool for knowing how well a conservation area is being managed. Periodic assessments of management effectiveness for Sasthamkotta Lake, and incorporation of its results, would improve planning management of the wetland. It would as well, pave way for adaptive management, and promote accountability and transparency.

The assessment should ideally cover the following management stages:

- the **context** of managing the area (status)
- the **planning** strategies undertaken to achieve the management goals (appropriateness)
- the **inputs** required to support the plan (resources)
- the **processes** through which the management plan has been implemented (efficiency, appropriateness)
- the **outputs** generated as a result of the implementation (effectiveness); and
- the **outcomes** achieved with respect to the intended objectives (efficiency, appropriateness)

Table 5.3 Parameters for assessing management effectiveness

Management element	Variables
Context	• Clarity on site's ecosystem services and biodiversity values • Clarity on threats and relationship with wetland ecosystem services and biodiversity • Clarity of management purpose and desired ecological condition of wetland
Planning	• Clarity in management objectives • Extent of stakeholder engagement in wetland management • Development of clear and timebound annual action plans based on management plan • Clear demarcation of wetland boundaries and drainage basin • Degree of convergence planning
Input	• Proportion of funds requirement made available for implementation of management plan • Designation of a nodal agency for coordinating wetland management • Implementation of capacity development programme for wetland managers • Implementation of communication and outreach programme for stakeholders, particularly local communities • Creation of infrastructure for integrated wetland inventory, assessment and monitoring • Putting in place a system for periodic management effectiveness review • Funding new research for assessing existing and emerging threats and remedial pathways
Processes	• Opportunities for stakeholders, particularly local communities to participate in wetland management • Coordinated development of workplans within the ambit of management plan • Degree to which integrated wetland inventory, assessment and monitoring implemented • Degree to which reduction in stakeholder conflicts is ensured • Extent to which intersectoral convergence is ensured • Extent to which compliance to existing regulatory regimes takes place
Output	Extent to which various activities within the management plan are implemented
Outcome	Status and trends in major threats • Extent of mining prevented • Extent of catchment revegetated • Control of pollution at source • Extent to which key ecosystem component, processes and services are maintained • Reduction in frequency of lowering of inundation and exposure of lake beds • Reduction in rate of conversion of lakebed into marshy condition • Maintenance of natural shorelines • Reestablishment of riverine connectivity

The process of assessment should be participatory, be based on scientific and social evidences and not have biased results. Most importantly, threats and opportunities that affect or may potentially affect the management should be recognized within the framework of assessment.

It is desirable that the management effectiveness assessment is carried out every two years, through an external agency and reported to the Sasthamkotta Wetland Authority for their information and action.

5.4 Infrastructure and Human Resource Requirements

Implementing the monitoring strategy as outlined in the previous sections requires the following physical and human infrastructure support:

- Remote Sensing and GIS unit with advanced capabilities of remote sensing image processing, preparation of maps and maintenance of spatial datasets.
- Ecological monitoring laboratory with capabilities for analysis of chemical, physical and biological properties of water and soil.
- Database system for storing and retrieving monitoring and assessment data. The monitoring data would be stored along with metadata, as per the quality control procedures suggested in the following sections.
- Network of hydro-meteorological and water quality stations for hydro-biological monitoring (locations indicated in Map 5.1).

Deployment of the aforementioned resources can be done in a cost-effective manner by availing the existing infrastructure of the CWRDM and Devaswom Board College, Sasthamkotta. The Science Department of the college has the necessary infrastructure and experience to conduct ecological monitoring. It is therefore recommended that a sub-centre for coordinating ecological monitoring may be created at the campus of the college.

Need based training programmes should be conducted to upgrade skills of the concerned college departments.

5.5 Reporting

Reporting constitutes an important element of wetland monitoring programme. The intended user group, format, style and peer review requirement need to be set in the initial phases of set up of the monitoring programme.

Periodic reports, for example as a part of the annual report of the Sasthamkotta Wetland Authority should aim to provide a summary overview of the outcomes of monitoring.

Outcomes of the lake monitoring can also be published in the form of an ecosystem health report card. It should be developed such that it is easily understood by most importantly, the local lake community and general public. Visual representation of aspects of ecological health of the lake and utilization of graphics to represent the collected data from monitoring activities, can help reach wider spectrum of population. Reporting priority should be given to the characteristics that are the most degraded and/or threatened by a potential change. It is recommended that the Sasthamkotta Wetland Authority publish the ecosystem health report card annually.

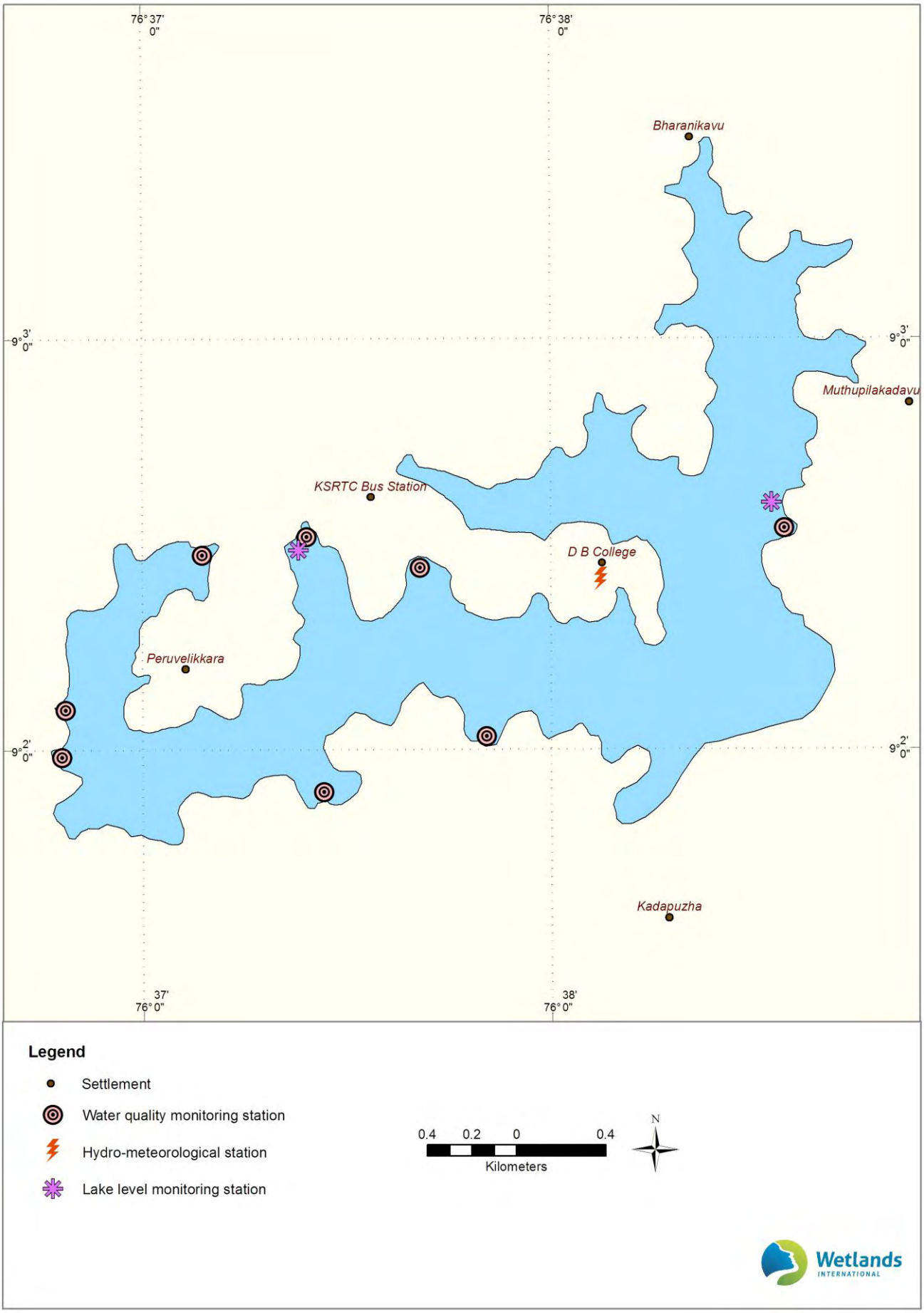
Outcomes of specific assessments, for example ecological character status and trends, economic valuation, environmental flows etc. could be made available in the form of technical report series, with an extended summary for general readership. As the monitoring programs get sophisticated over a period of time, real time monitoring options through use of satellite based data communication techniques can be explored.

5.6 Review and Adaptation

Quality control in monitoring systems is required to ensure the scientific validity of sampling, laboratory analysis, data analysis and reporting. They also play a critical role in preventing introduction of random and systematic errors in data collection, analysis and reporting.

It is recommended that a Quality Management and Assurance Plan is developed for the monitoring programme. The plan should determine, *inter alia*:

- **Specification of objectives** for sampling programme.
- **Data quality objectives**: maximum amount of uncertainty that can be tolerated to ensure that the data is fit for intended use.
- **Sampling programme design**: Statistical robustness of sampling frame; means to ensure that samples are representative of environment; sample recording; procedures for minimizing environmental impact.



Map 5.1 | Hydro-meteorological and water quality stations proposed at Sasthamkotta Lake

- **Documentation** Procedures for field sample record keeping and methods documentation.
- **Sample processing validity** (especially for water quality and biological components).
- **Data quality control methods**: processes for quality control samples, duplicates and replicates.
- **Performance audit procedures** (including data and systems audit).

A periodic review of the monitoring programme is required to determine the extent to which the objectives, particularly support to management is achieved, and monitoring system remains relevant for the wetland state (particularly in the light of new and emerging threats). The review process should also aim at increasing the sophistication of the monitoring system to be able to assess complex landscape scale processes affecting the ecological character of wetland and related management.

Review process should include documentation on the way wetland inventory, assessment and monitoring information is being used to support management planning and policy goals. Review should also include identification of appropriate mechanisms to ensure that wetland monitoring is continued in the event of a funding shortfall.

6. Management Plan

6.1 Goal and Purpose

Integrated management of Sasthamkotta requires strategies that can ensure provisioning of societal benefits while ensuring maintenance of its natural functioning and biodiversity. Given the role of hydrological processes in governing the ecological character of Sasthamkotta, there is a need to mainstream its full range of ecosystem services and biodiversity values in management of River Kallada Basin management, in order to achieve wise use outcomes.

The goal of integrated management of Sasthamkotta is to secure ecological integrity of the wetland ecosystem while providing ecological, economic and cultural benefits to the society on a sustainable basis.

The purpose is to put in place effective institutional and governance arrangements with stakeholder-led management of Sasthamkotta at river basin scale.

6.2 Strategy

Creating an institutional setup for integrated management

Integrating management of Sasthamkotta requires a dedicated institution for coordinating implementation of sectoral action plans, maintaining an overview of wetland status and trends, promoting stakeholder engagement and representing concern related to the wetland in sectoral planning. It is envisaged to constitute a Sasthamkotta Wetland Authority under the aegis of Department of Environment and functioning under the purview of Kerala State Wetlands Authority for integrated management of Sasthamkotta. An important task of the authority will be to ensure mainstreaming of the full range of ecosystem services and biodiversity values of Sasthamkotta within the sectoral planning for agriculture, fisheries, rural development, tourism, forestry and wildlife and others.

Stakeholder-led management

In line with the wise use philosophy, implementation of the management plan is envisaged to be stakeholder-led. Proactive measures would be taken to seek community consent and endorsement for specific actions, involve communities in implementation and post intervention monitoring. The local self-governments would be the key institutions driving wetland management.

Integrated wetland monitoring and assessment system to guide management

As a dynamic ecosystem, Sasthamkotta is prone to changes in response to a number of anthropogenic as well as natural drivers. Having a system to detect such changes, in particular, human-induced adverse change in ecological character, is critical for the success of management. Equally important is the need to periodically assess the effectiveness of management in terms of ability to achieve wise use with broad stakeholder participation. An integrated wetland inventory assessment and monitoring system is therefore proposed to be put in place to address the diverse information needs for managing Sasthamkotta and undertake mid-course correction if any. A research strategy to address the gaps in existing knowledge base and assess future risks will form an integral part of the system. It is proposed that CWRDM is mandated to manage the monitoring system with systematic reporting to Sasthamkotta Wetland Authority.

Harmonising water abstraction with ecological condition

Hydrological assessments underline the need to link any water abstraction with the ecological condition of the Sasthamkotta, particularly, the stability of its hydrological regimes. It is therefore proposed to link water abstraction from Sasthamkotta to the quantum of rainfall received. The management plan also includes a proposal for alternate water supply to Kollam City, as a reduction in water off-take in Sasthamkotta will result in reduced water availability to the city.

Enforcing regulation

The Wetlands (Conservation and Management) Rules, 2010 provide the necessary regulatory framework for management of Sasthamkotta as it is designated as a Ramsar Site. The Rules require clear demarcation of wetland boundary and its zone of influence and prohibiting a number of detrimental activities including reclamation, discharge of untreated wastes and effluents, solid waste dumping, construction of permanent nature and any activity likely to have an adverse impact on the ecosystem. The 2010 Notification of Kerala Sate Pollution Control Board, prohibit a range of polluting activities within 500 m periphery of the lake and agriculture activities within 100 m periphery of the lake. Mining of sand from alluvial plains of Kallada River has also been banned by the State Government. The management plan envisages enforcement of the aforementioned regulations with the identified agencies, in order to maintain and improve the ecological health of Sasthamkotta. Notably, controlling pollution is urgently required to slow down transition of Sasthamkotta towards a marsh dominated stage.

Integrating Sasthamkotta in Kallada River Basin management

The ecosystem services of Sasthamkotta have a critical role functioning of River Kallada. Conversely, land and water-related human activities within River Kallada Basin can have a significant influence on the ecological character of Sasthamkotta and associated wetlands. It is of utmost importance to recognise the value of Sasthamkotta within the management of river basin and integrate these into water sector planning.

6.3 MANAGEMENT COMPONENTS AND OBJECTIVES

Management planning for Sasthamkotta is proposed to be structured around following five components: a) Institutions and Governance, b) Catchment Conservation; c) Water Management, and d) Biodiversity Conservation and e)Sustainable Livelihoods. Specific objectives for each of these management components is as follows:

Component 1: Institutions and Governance

- An effective arrangement for cross-sectoral coordination and multi-stakeholder engagement in wetland management established and operationalized
- Systematic wetland inventory, assessment and monitoring system established to support decision making and management
- Capacity of concerned state government departments and agencies, civil society organisations and local communities for integrated wetland management enhanced
- Regulatory framework are effective and implemented for improvement of wetland ecosystem health
- Stakeholders, particularly local communities are aware of status and trends in Sasthamkotta, management strategies and actions

Component 2: Catchment Conservation

- Reduce soil erosion from degraded catchments
- Improve soil moisture retention within catchments

Component 3: Water Management

- Restore inundation regimes to near natural conditions to slow down formation of marshy conditions
- Optimise water abstraction in line with requirements for maintenance of ecosystem health
- Maintain water quality in low nutrient, low salt, low bacterial contamination and high oxygenated conditions

Component 4: Biodiversity Conservation

- Enhance habitat conditions for maintaining fish diversity
- Enhance habitat conditions for waterbird diversity
- Manage invasion of macrophytes

Component 5: Sustainable Livelihoods

- Provide incentives to communities for adopting measures preventing adverse change in ecological character of Sasthamcotta
- Ensure community participation in all aspects of management plan implementation

6.4 Action Plan

Component 1: Institutions and governance

1.1 Establishment of Sasthamkotta Wetland Authority

Sasthamkotta Wetland Authority is proposed to be established as a nodal agency mandated for coordinating the integrated management of Sasthamkotta and adjoining wetlands. The Authority may be registered as a non-profit organisation to enable flexibility in raising financial resources from public and private sources.

As per the provisions of the Societies Registration Act, a Memorandum of Association defining the jurisdiction, aims and objectives and governance structure will need to be submitted to the Registrar of Authorities. Rules and Regulations detailing the membership, powers and functions of governing and executive bodies, accounting and audit procedures, and management of property of the authority will also need to be formulated and submitted to the Registrar. A three-tier governance structure is proposed with the Governing Body at the apex, an Executive Committee responsible for approval of implementation plans and projects, and an office of the Chief Executive to implement the programmes. Activities to be undertaken include:

- Finalization of Memorandum of Association and governance structure
- Notification of SMA
- Registration under Societies Registration Act
- Staffing and work allocation as per the structure suggested in Section 3.
- Conducting business as per the Terms of Reference outlined in Section 3.3

1.2 Integrated wetland inventory, assessment and monitoring system

An integrated wetland inventory, assessment and monitoring system is proposed to be set up to address the overall information needs of wetland management and to provide a robust decision support system for the same. Specific objectives and a detailed framework have been outlined in Chapter 5 of the management plan. The following activities are proposed:

Establishment of wetland monitoring and research centre

A state of the art wetland monitoring and centre is proposed to be established at D. B. College premises for monitoring the ecological, hydrological and socio-economic features of Sasthamkotta. The centre would function under the aegis of CWRDM which would coordinate all inventory and assessment programmes. A list of

necessary equipment to be procured for the centre is in Annex 12

Development of database management system

A database system for storing, retrieving and analysing the WIAMS is proposed to be set up in a GIS environment. This will include: a) development of data quality management and assurance plan including specification of data collection objectives, data quality objectives, sampling programme design, data and metadata documentation procedure, data quality control methods and performance audit procedures; and b) development of GIS-based database management system

Wetland monitoring and evaluation

Wetland monitoring and inventory protocols for land use and land cover, hydrological regimes, ecosystem processes and biodiversity and socio-economics and livelihoods as proposed in Section 5.2 will be implemented.

Ecosystem Health Report Card

It is proposed to develop an Ecosystem Health Report Card to assess and communicate wetland monitoring information to decision-makers and stakeholders. The health report card summarises indicators along major indices (water quality, catchment status, biodiversity status) which represent various ecosystem features of the lake, that are reported against respective thresholds set in line with management goals. Such a report card is being biennially published for Lake Chilika and has been found to be highly effective in communicating complex ecological, hydrological and socio-economic information in simple terms to decision-makers and stakeholders.

Research studies

Following specific research studies are proposed to be commissioned to address the knowledge gaps in assessing status and trends in ecological character:

- Trends in bathymetry – to assess the degree and source of siltation and implication for water holding capacity.
- Surface and groundwater interactions and relationship with lake levels.
- Nutrient cycles and implications for lake water quality and macrophytes spread.
- The role of ecological communities, especially microbial communities in regulating water quality.
- Status of breeding and spawning ground for fish, with specific reference to Etroplus suratensis.
- Utilisation pattern of Sasthamkotta and adjoining marshes as bird habitats, with specific reference to endemic and migratory waterbirds.
- Climate risk and vulnerability to assess perception of climate risks based on sensitivity and adaptive capacity of critical ecological character elements; climate scenarios with respect to the ecological character; and risk management options.

1.3 Capacity development

Capacity building of Sasthamkotta Wetland Authority, concerned State Government departments, agencies and local communities is proposed to be undertaken through professional training in integrated wetland management, water management, biodiversity conservation, wetland inventory and assessment and sustainable livelihoods.

Implementation of this component would be guided by a detailed capacity assessment of all management plan implementing agencies and departments to be conducted during the first year of implementation. At the initial stage, tow training programmes for all concerned institutions on integrated wetland management and wetland risk assessment are proposed. In addition, provision for exposure visits to Lake Chilika and other sites wherein management has been relatively successful has also been made.

1.4 Monitoring compliance with existing laws and regulations

Compliance with the provision of following rules and laws will be comprehensively monitored, and violations reported to the concerned authority for ensuring remedial action:

- Provisions of Wetlands (Conservation and Management) Rules, 2010 – prohibiting the conversion of wetlands into non-wetland usages, discharge of untreated sewage, soil waste dumping and activities likely to adversely affect wetland ecosystem health.
- Notification of zone of influence as per the requirements of Wetlands (Conservation and Management) Rules, 2010. It is recommended that the boundary of the direct drainage basin is demarcated and notified as the zone of influence.
- Provisions of the Kerala Conservation of Paddy Land and Wetland Act, 2008 barring reclamation of wetlands.
- Provisions of The Kerala Protection of River Banks and Regulation of Removal of Sand Act (2001) under which mining is banned in Kallada River.
- Notification of The Kerala State Pollution Control Board barring a range of polluting activities around the lake and its adjoining areas. The actions prescribed herein may be considered as prohibited and restricted activities within the zone of influence.

1.5 Communication and outreach

Stakeholder engagement in wetland management will be promoted through creating awareness on values and functions of Sasthamkotta, management strategies adopted and opportunities for participation. Specific activities to be undertaken include:

Signage

Signage indicating Sasthamkotta as a Ramsar Site is proposed to be placed at all three major entry points of the lake, namely Ambalakadavu, Mutthupilakadavu and Rajagiri. Recommended wording for signs is provided in the decision of the 19th meeting of Ramsar Site (Annex 12). It is also proposed to place a signage at the entrance of Sastha temple, as it is frequented by a large number of people.

Webpage

It is proposed to create a dedicated webpage for Sasthamkotta, as an electronic interface for stakeholders to connect with wetland managers. The page may be linked to the webpage of Department of Environment, and include information on various aspects of the lake, management plan implementation, research and development, news and career opportunities. The page will also host resources for wetland managers.

Resource material

Brochures, fact sheets and awareness material on Sasthamkotta are proposed to be published in English and Malayalam for public distribution. A photo album is also proposed to be published for serious nature lovers.

Newsletter

A newsletter highlighting progress made and key emerging issues related to Sasthamkotta is proposed to be published annually in English and Malayalam, and disseminated to all stakeholders.

Workshops and public events

Public events are proposed to be organised on the eve of World Wetlands Day (Feb 2), World Environment Day (June 5) and International Day for Biological Diversity (May 22) as a means of reaching out to public on the issues of wetland conservation and wise use. Public events on specific issues, as pollution control or water management, are also proposed to be organised as a means of engaging with stakeholders.

Sasthamkotta Rangers' Camp

Camps, at least once a year, are proposed to be organised for school and college students to make them aware of the significance of the lake. Students can be given an honorary Sasthamkotta Rangers' badge on completion of the camp.

1.6 Management plan review

A mid-term and end-term review of management plan implementation is proposed to assess the extent to which stipulated objectives have been achieved with a high degree of resource efficiency and in participation with stakeholders. These assessments would be conducted by engaging external agencies, which would report to the Sasthamkotta Wetland Authority as well as to funding agencies.

Component 2: Catchment conservation

Work under catchment conservation component of the management plan is aimed at improved management of agricultural land and homesteads, strengthening drainage lines, enhancing groundwater recharge and overall soil moisture regime, enhance overall vegetative cover. This section of the action plan integrates the project proposal prepared by the Department of Soil Survey and Soil Conservation for Eco-restoration of Sasthamkotta Lake and its Catchments, submitted to the Environment Department in 2014 as a part of JICA loan assistance. Locations of specific interventions indicated in Map 6.1.

2.1 Microplanning

Interventions within the direct catchment include a set of vegetative and small scale engineering measures. For the purpose of implementation of these interventions, the entire direct catchment has been delineated into 14 parts. It is proposed to prepare detailed microplans for each of these parts through participatory appraisals involving Panchayat members. The microplanning will also serve as an awareness building exercise for the catchment communities on the interlinkages of upstream land use actions on the downstream wetland, and the overall implication for water,

food and climate security. Besides outlining a plan of action, the microplanning will also involve capacity development needs assessment of the communities, which will be integrated into the implementation of the management plan. Following are the specific actions:

Constitution of Catchment Conservation Committees

In line with guidelines for convergence of various programmes with IWMP (DOLR, 2015), Catchment Conservation Committees (comprising representatives of Panchayat, civil Society, community members and a representative of the Department of Soil Conservation) shall be constituted for each of these parts. These committees shall assist the Department of Soil Survey and Soil Conservation in:

- Preparing detailed microplans for each of the parts with specific locations of interventions.
- Promoting awareness of values and functions of Sasthamkotta within catchment communities, and the need for catchment scale management.
- Assessing community views, rights and capacities for integrated management, and linking them with management plan implementation.
- Assessment of capacity development needs for implementation of management plan interventions.
- Periodic monitoring and evaluation of implementation, and reporting progress to the department officials.

Preparation of catchment management plans

For each part, the Catchment Committees will facilitate the development of a detailed plan, with clear specification of intervention type, location, modality and local resource requirement. The plans will also include yearwise phasing and modalities for ensuring sustainability after completion of management plan implementation.

Capacity development

Training and outreach workshops are proposed to be conducted for each of the parts to address the capacity development needs identified in each of the catchment management plans. A generic listing of workshops is as follows:

- Integrated watershed management
- Vegetative measures for catchment management

- Small scale engineering measures for catchment management
- Agroforestry techniques

The training workshops would be imparted by engaging with Krishi Vigyan Kendra, Kollam; Kerala Agricultural University and Kerala Forestry Research Institute.

2.2 Vegetative measures

Afforestation using native species

Lake catchments previously under *Acacia* plantation are proposed to be planted with 5000 seedlings of tree species as Teak (*Tectona grandis*), Mahogany *(Swietenia mahogani),* Anjili *(Artocarpus hirsutus);* fruit trees like Mango *(Mangifera indica),* Jackfruit *(Artocarpus heterophyllus),* and Guava *(Psidium guajava).* Planting would be done in the narrow hedge with weeding and pruning operations. Controlled grazing, border row plantation, bund plantations would be promoted. In addition, 1000 saplings of medicinal plants as Neem *(Azadirachta indica*), Asoka *(Saraca asoca),* Amla *(Emblica* sp.*)* are also proposed to be planted.

Along stream banks and gully mouths, species of bamboo, *Pandanus*, *Vetiver* and other seeding species is proposed as soil binders. Such plantation would be taken up in 14 ha.

Pasture development

Slopes and berms of bunds are proposed to be planted with suitable grass species of fodder value. The fibrous root system of grass will offer better protection of the top soil and filter run-off, thus trapping sediments. Conservation based management through techniques such as balancing numbers with grazing capacity of the grasslands, controlled grazing by fencing, area closure, cut and carry will help to preserve soil and vegetation and improve grassland productivity. The introduction of better forage species can be done by seeding, using seeds of native species or by a plantation of sods. Such plantation is estimated to be done in 12,000 Rm.

Development of village woodlots

Though fuelwood dependency for villagers was observed to be low, village commons as Panchayat lands are ideal for raising woodlots to meet the energy requirements of the village. Small timber, fuel wood and fodder species could be raised for the bonafide uses of the beneficiaries. Identification of land and beneficiaries for the programme is proposed to be carried out by the village Panchayats, which will stipulate clear cut rules for the management of these lands and sharing of the usufruct. 20 ha has been proposed to be developed as village woodlots.

Coir – Geotextiles and Green belt

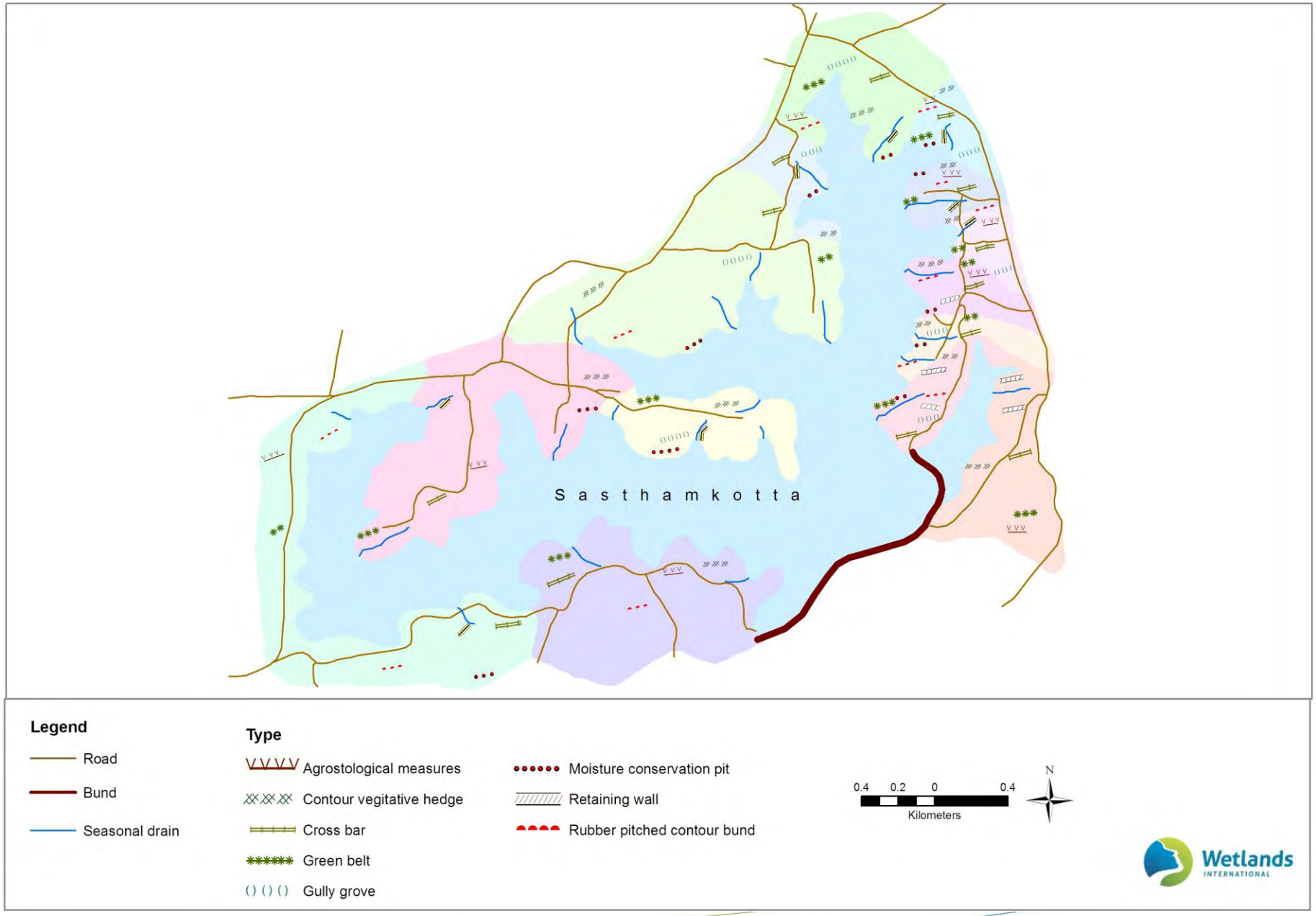
It is proposed to cover 2.2 km of very steep lake banks with geotextiles, wherein establishment of native vegetation is prevented due to physical limitation.

Coir-geotextiles have a demonstrated capacity for moisture retention and soil erosion control while supporting development of a dense network of root system, and the establishment of vegetative cover with the required degree of growth.

Blanks (areas devoid of vegetation) beyond 50 m of maximum inundation level are proposed to be planted with native *Vetiver zizanoides* and *Pandanus.* However, no existing vegetation is to be removed for the plantation of these grass strips. Illegal harvest of these aromatics is also to be controlled such that the soil near lake bed is not disturbed.

Promotion of agroforestry

Much of the Sasthamkotta catchment is under coconut based plantation systems, with limited canopy. Within farmlands, it is proposed to undertake agroforestry measures in 10 ha integrating tree and suitable horticultural crops (as mango, jackfruit, guava, cashew, pomegranate and others) in various temporal / spatial combinations such as bund plantations. In-situ moisture conservation techniques such as mulching would be followed by laying V-shaped ditches along the contour with the planting of fruit trees on the hillsides.



Map 6.1 | Sasthamkotta catchment conservation intervention sites

Gully groves

It is proposed to establish 1,000 plant clusters at the mouths of gullies debauching directly or indirectly into the lake. The groves would constitute suitable species of *Pandanus*, Pineapple, Bamboo and other native vegetation, and would serve to restrict the flow of silt and into the lake. *Pandanus* is also known to provide sheltering grounds for Pearlspot, and would thereby contribute to enhancing habitat for this species.

2.3 Small-scale engineering measures

Following interventions are proposed to be undertaken for enhancing retention of flow within drainages, and reducing soil erosion:

Check dams and Crossbars

Several rill channels and gullies have been formed in the upper catchments of Sasthamkotta as a result of constant erosion and concentrated monsoonal flows. Many of these channels serve as pathways or footpaths. It is proposed to construct 300 loose boulder and logwood check dams with vegetative support, at sites having scope for vegetation establishment. In places where logwood is proposed to be used, only locally available material shall be used. In addition, 1000 crossbars, with up to 0.5 m height are proposed to be constructed to reduce the bed slope of gullies thus allowing deposition of sediments. Specific locations wherein check dams and crossbars are to be constructed would be guided by detailed microplans.

Retaining walls

Retaining walls are proposed to be constructed in parts of lake boundary with steep slopes, devoid of vegetation and unstable terrace. The wall length would vary depending on its location, and lower side sunk into the ground by an amount equal to soil depth and rise above the ground surface by, an amount equal to the depth of deposition expected. The walls would be of a considerable thickness to withstand the pressure exerted by the retained soil and with adequate provision for draining accumulated water. It is proposed to cover approximately 11 km of the lake boundary by retaining walls. Wherever boulders are available, gabion structures would be used for the construction of retaining wall.

Rubble pitched contour bunds and stabilisation structures

It is proposed to construct 4,000m^2 of rubble pitched contour bunds as embankments along the contours with an elevation between 20 m – 35 m amsl, having slope up to 20%. These bunds would serve to break the slope, thus reducing the erosive capacity of run-off. Where slopes exceed 20%, stabilisation structures are proposed. The length of stabilisation structures requires within Sasthamkotta catchment has been estimated to be 2300 Rm.

Moisture conservation pits

6,000 moisture conservation pits are proposed to collect rain water. The dimensions of the pits will depend up on slope and soil conditions. These pits would serve to improve soil moisture condition by storing runoff.

Component 3: Water management

3.1 Alternate water supply for Kollam City

The present levels of water abstraction for providing drinking water to the Kollam City are adversely impacting the stability of inundation regimes of Sasthamkotta. The management plan, therefore, envisages providing an alternate source of drinking water to the city, such that the current levels of abstraction from the lake may be reduced. This component of the management plan has been worked out by the Kerala Water Authority in the form of a separate proposal entitled 'Improvement of Water Supply System to Kollam Corporation with Njankadavu in Kallada River as Source' (KWA, 2013).

The proposal is designed to meet water requirement of 60 MLD in 2045 as compared with the present supply of 18 MLD, by tapping water from Kallada River. As the river has salinity intrusion in the areas adjoining Kollam City, the intake point is proposed to be near Njankadavu Bridge, about 20 km upstream. The pumped

water is to be stored in an intermediate balancing reservoir located near Cheerankavu, 10 km downstream from the inlet. Water would subsequently flow under gravity to the treatment plant at Vadakkevila in Kollam Corporation. Post treatment, the water would be fed to the existing ground level sump of Quilon Water Supply Scheme located at Anandavalleeswaram.

Kallada River is the source of several water supply schemes being operated by Kerala Water Authority. Presently, installed capacity of these schemes is 100 MLD. Implementation of the current proposal would enhance the withdrawal to 160 MLD, requiring a minimum flow of 3.7 m^3/s within the river to ensure adequate downstream flow. Assessment of available information on flows regimes indicates that the river discharge may fall below this threshold in summer months. To maintain flow conditions, it is estimated that an additional 300 MLD of water would need to be released from the dam, to ensure that water supply schemes have sufficient availability.

The Department of Local Self Government has included Kollam City within the 2015-16 State Annual Action Plan for Atal Mission for Rejuvenation and Urban Transformation (URBAN), a flagship scheme of the Ministry of Urban Development aimed at improving the basic amenities (particularly water supply, sewerage, drainage, public transport and open spaces). A provision of Rs. 26.87 Cr for implementing the alternate water scheme, in addition to improvement of the existing system and rainwater harvesting.

3.2 Optimisation of water abstraction

Water balance assessment conducted as a part of management planning process indicated high levels of susceptibility of inundation regime shrinkage in response to the decline in rainfall. It is thereby proposed to implement a dynamic system of water abstraction optimisation, such that the ecological integrity of the lake is not adversely impacted. Such a decision-making process is proposed to be built on the outcomes of a technical study commissioned by the SWA, for consideration of the SWAK.

The Terms of Reference of the technical study are proposed to be as follows:

- Determine threshold inundation regime, below which there is a high risk of adverse change in ecological character.
- Assess long-term trends in rainfall and the likelihood of a decline in various monsoon and non-monsoon components.
- Conduct a detailed water-balance assessment, establishing the influence of various water inflow and outflow components on inundation regime.
- Determine the impact of monsoon and non-monsoon rainfall on inundation regime, and concomitant ecological response.
- Conduct stakeholder consultations on acceptance levels for various scenarios of water off-take reduction.
- Prescribe an optimal water withdrawal level which would ensure maintenance of the ecological integrity of Sasthamkotta.

3.3 Improve waste treatment infrastructure for direct drainage basin

In order to improve waste treatment in the direct drainage basin of Sasthamkotta, a Sewage Treatment Plant of 8 MLD capacity is proposed to be constructed in Sasthamkotta Town. A tentative location has been identified by the CWRDM team and needs to be firmed up. This treatment capacity is sufficient to cater to the needs of 60,000 people. The population of Sasthamkotta Town, as per 2011 census, is 33, 285, which is projected to increase to 53,300 by 2050 (using a 1.94% decadal growth as per census). A Sequential Batch Reactor based technology is proposed, considering a low land requirement. The management of the plant would be vested in the Local Self Government.

3.4 Sanitation and hygiene

Despite a near complete sanitation coverage, the water of Sasthamkotta still has very high levels of faecal coliform, indicating a significant leaching for the toilets. Socio-economic surveys conducted during the part of management planning indicated that 96% of the houses have

single pits. Panchayat members indicated that only 8% of the houses have safe sanitation, with rest without adequate seals to prevent contamination of groundwater.

As a part of measures for improving overall sanitation, the following interventions are proposed:

- Support to Panchayat for improving toilets (from single pit to double pit with an adequate water seal to prevent leaching) on the immediate periphery of the lake.
- Construction of a bathing unit at Sasthamkotta Temple and West Kallada, with the wastewater diverted to the treatment plant.
- Construction of public toilet complexes at Sasthamkotta and Bharanikavu (land to be made available by the Panchayat).
- Rejuvenation and disinfection of 100 open wells.

Component 4: Biodiversity conservation

Freshwater fish habitat assessment

The Ramsar Site designation of Sasthamkotta is based on Criterion 2 and 7, related to the presence of diverse freshwater fish, including some of the high conservation significance within the lake. It is proposed to conduct a systematic assessment of current freshwater fish diversity, habitat preferences and condition thereof (with a specific focus on *Etroplus* sp. and other endemic species). Such information would form the basis of a habitat conservation plan for securing freshwater fish diversity in the lake. The assistance of Kerala University of Fisheries and Oceanus Studies will be taken to undertake this assessment.

Annual waterbird census

Sasthamkotta forms an important component of a network of sites which are used by wetland-dependent waterbirds. Waterbird census conducted within the framework of Asian Waterbird Census provide a useful information base for assessing their regional and global populations. Sasthamkotta is yet to be covered within the framework, with only one census conducted thus far. It is proposed to conduct comprehensive mid – winter counts each year, in Sasthamkotta and adjoining wetlands in coordination with the BMC, and as per protocols recommended under AWC. Census programmes will include training of prospective census participants and local waterbird enthusiasts. The Asian Waterbird Census Coordinator for Kerala is proposed to be involved in study implementation.

Breeding waterbirds investigation

An assessment of distribution and breeding concentrations of all waterbird species (reed bed, marsh and tree nesting) in Sasthamkotta and adjoining wetlands (Karali marshes, Chittumala, Veliyapadam marshes and Chellurpola kayal) is proposed to be undertaken to determine the current baseline population of breeding birds. Studies of the habitat preferences, precise requirements, the ecology of key waterbird species and determination of current threats are proposed to enable planning and execution of measures to manage and improve existing habitats, to identify potential breeding areas and restore degraded areas to increase breeding habitats and address increased prey requirements. The services of Bombay Natural History Society or Salim Ali Center for Ornithology will be sought for implementing this study.

Animal disease surveillance

Knowledge of health of resident and migratory waterbird species is critical for assessing the risk and potential threat of avifaunal diseases. Knowledge of the health of these species that inhabit the wetland is critical to understand the risk and potential threat of transmission of avifauna diseases. It is proposed to train the Sasthamkotta Wetland Authority is the general identification of traits of common diseases as well as avian influenza. The authority will also be networked with surveillance teams of State Animal Husbandry Department to enable a timely response.

Periodic updation of Biodiversity Registers

A Biodiversity Register for Sasthamkotta has been compiled through the BMCs of the three villages around the lake. It is proposed to support periodic updation of the register, to assess any changes in species and habitat preferences.

Regulating proliferation of aquatic macrophytes

Dense beds of *Salvinia* associated with *Eicchornia* were observed in areas near Rajagiri, Velanthra Embankment, Sasthamkotta Town and Muthupilakadavu. A long-term check on the spread of these macrophytes is the restoration of inundation regime and control of pollution. However, as an immediate check, it is proposed to physically remove these vegetation mats, and use as mulch in croplands and composting.

Component 5: Sustainable livelihoods

The component would aim to create community incentives for adopting sustainable land use practices within Sasthmcotta catchment. Following activities are envisaged:

Upgradation of Rajagiri fish hatchery

A fish hatchery for *Etroplus suratensis* and Macrobrachum sp was established in 1998 at Rajagiri through the support of Department of Fisheries to fisher cooperatives. The hatchery, however, was rendered dysfunctional within two years as the part of the lake used for stocking fingerlings could retain the required level. The cooperative members also lacked the technical capacity for hatchery operations.

The Rajagiri Fish Hatchery is proposed to be rejuvenated. The management plan would provide support to the formation of a cooperative committee, training on hatchery management and providing seed capital for operations. Arrangements would be made with the cooperative to release atleast one-fourth of seeds thus produced in the lake to boost dwindling stock.

Ecotourism master plan

A community managed ecotourism master plan for Sasthamkotta would be drawn up by engaging experts. The plan would establish the tourism potential by:

a) assessing and determining pristine areas which need to be protected and therefore need to have minimal tourist impact

b) identifying areas of tourism potential

c) current status and comprehensive analysis of physical infrastructure requirements

d) Analysis of regulatory environment in the context of ecotourism

e) Institutional development needs

f) Strength, Weakness, Opportunities and Threat Analysis for ecotourism development

g) Development of Regional Ecotourism Plan

Additional livelihoods

Following additional income opportunities are proposed for communities to engage in sustainable lane use practices:

a) Food processing units for 3 groups based on horticultural crops grown in the catchment. Possible products are jackfruit jam, pickles, mango bar and others.

b) Bamboo and Pandanus based cottage industry for 3 self-help groups with support of Kerala State Bamboo Corporation

c) Vermi composting for 50 groups, using household waste. Arrangements would be made with Panchayat for sale of compost at fixed rates through Kudumbasree units.

6.5 Implementation arrangements

Implementation of the management plan would be the overall responsibility of the Department of Environment, under the strategic direction of State Wetland Authority. The Department would constitute Sasthamkotta Wetland Authority as the nodal agency for coordinating management plan implementation and maintaining an overview of ecosystem health. Activities would be implemented departmentally, as following:

- Wetland Monitoring: CWRDM reporting to Sasthamkotta Wetland Authority
- Coordination of Research Projects: CWRDM and expert agencies reporting to Sasthamkotta Wetland Authority
- Communication and Outreach: Sasthamkotta Wetland Authority
- Catchment Conservation: Department of Soil Survey and Soil Conservation
- Water Management: Kerala Water Authority and Suchitwa Mission
- Biodiversity Conservation: Kerala Biodiversity Board with support of expert agencies

6.6 Prioritisation and phasing

During the first year, implementation modalities would be firmed up, and Sasthamkotta Wetland Authority notified. Microplans for catchment treatment would be drawn up. Studies for optimisation of water abstraction would also be initiated. During the second, third and fourth year, all physical implementation would be completed. A phasing out strategy would also be drawn up at the end of the second year. During the final year, the outcomes of management plan implementation would be consolidated, and the phasing out strategy implemented.

6.7 Review and adaptation

Results based monitoring system would be adopted for review of the management plan. Performance indicators and benchmarks would be established at the beginning of management plan implementation. A mid-term review would be carried out at the end of 2.5 years, by engaging an external agency. The review would include the degree of change in adverse trends on ecological character, as well as management effectiveness achieved. The outcomes would be used to revise management, as appropriate, in consultation with the State Wetland Authority. An end term review would be done at the end of five years, the outcomes of which would be used to assess the degree to which the intended outcomes have been achieved.

7. Budget

7.1 COMPONENT-WISE BUDGET

Implementation of the management action plan as outlined in Chapter 6 entails a budget of Rs. 98.63 crore over a period of 5 years. Of the total funds, 69% are earmarked for water management and 19% for catchment conservation. The component on institutional development has been allocated 10% of the overall budget. Components on livelihoods and biodiversity conservation will benefit from all the aforementioned components, and have been separately allocated 2% and 1% of the funds respectively. Component-wise funds requirement is presented in Table 7.1. Detailed activity-wise budget is presented in Table 7.2.

Table 7.1 Component-wise budget required for implementation of management plan (in Rs. Lakh)

	Component	Total	Year 1	Year 2	Year 3	Year 4	Year 5
1	Institutional Development	959.25	304.25	328.75	209.75	71.75	44.75
2	Catchment Conservation	1,828.70	35.00	474.80	481.05	473.05	364.80
3	Water Management	6,774.60	3,193.00	2,941.00	221.20	209.20	210.20
4	Biodiversity Conservation	128.00	31.00	43.00	28.00	17.00	9.00
5	Sustainable Livelihoods	172.50	15.00	66.50	72.00	16.00	3.00
	Grand Total	**9,863.05**	**3,578.25**	**3,854.05**	**1,012.00**	**787.00**	**631.75**

Table 7.2 | Activity wise budget

Components and Activities	Rate (Rs..)	Unit	Targets		Year 1		Year 2		Year 3		Year 4		Year 5	
			Physical (2017 - 21)	Financial (2017 - 21) (Rs.. Lakhs)	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial
1 Institutional Development				**959.25**		**304.25**		**328.75**		**209.75**		**71.75**		**44.75**
1.1 Establishment of Sasthamkotta Management Authority				**10.00**		**10.00**								
1.2 Integrated wetland inventory, assessment & monitoring system				**783.00**		**270.00**		**306.50**		**155.00**		**41.50**		**10.00**
1.2.1 Establishment of wetland monitoring and research centre				500.00		200.00		200.00		100.00				
1.2.2 Development of database management system				50.00		25.00		25						
1.2.3 Wetland monitoring and evaluation	7,50,000	per year		50.00		10.00		10		10.00		10		10.00
1.2.4 Ecosystem health Report Card				-										
a) Analysis				5.00				2.50				2.50		
b) Publication				3.00				1.50				1.50		
c) Stakeholder workshop				5.00				2.50				2.50		
1.2.5 Research studies														
a) Trends in Bathymetry	40,00,000	per study		40.00		25.00		15.00						
b) Surface and ground water interaction with lake le	35,00,000	per study		35.00		10.00		20.00		5.00				
c) Nutrient cycle & implication for lake water quality	25,00,000	per study		25.00				10.00		10.00		5.00		
d) Role of ecological committee in water quality	25,00,000	per study		25.00				10.00		10.00		5.00		
e) Breeding & spawning ground of fish	25,00,000	per study		25.00				10.00		10.00		5.00		
f) Climate risk & vulnerability on ecological charact	25,00,000	per study		20.00						10.00		10.00		
1.3 Capacity development				**39.00**		**8.00**		**7.50**		**8.00**		**15.50**		**-**
a) Training on Integrated Wetland Management	8,00,000	per training	2	16.00	1	8.00					1	8.00		
b) Training on Wetland Risk Assessment	8,00,000	per training	1	8.00					1	8.00				
c) Exposure visit	7,50,000	per visit	2	15.00			1	7.50			1	7.50		
1.4 Monitoring compliance with existing laws & regulation				**10.00**		**2.00**		**2.00**		**2.00**		**2.00**		**2.00**
a) Surveys	Lump sum			7.50		1.50		1.50		1.50		1.50		1.50
b) Reporting	Lump sum			2.50		0.50		0.50		0.50		0.50		0.50
1.5 Communication & outreach				**82.25**		**14.25**		**12.75**		**29.75**		**12.75**		**12.75**
1.5.1 Signage	1,25,000	per sign	2	2.50	2	2.50								
1.5.2 Webpage				-										
a) Creation				2.00		2.00								
b) Maintenance				2.00				0.50		0.50		0.50		0.50
1.5.3 Resource material				25.00		5.00		5.00		5.00		5.00		5.00
a) Brochure and Pamphlet	2,00,000	per set	2	4.00	1	2.00			1	2.00				
b) Coffee table book	8,00,000	per publication	1	8.00					1	8.00				
c) Popular reading book	5,00,000	per publication	1	5.00					1	5.00				
1.5.4 Newsletter	75,000	per annum	5	3.75		0.75		0.75		0.75		0.75		0.75
1.5.5 Workshops & public event	2,00,000	per event	10	20.00	1	2.00	2	4.00	3	6.00	2	4.00	2	4.00
1.5.6 Sasthamkotta Rangers camp	2,50,000	per camp	4	10.00			1	2.50	1	2.50	1	2.50	1	2.50
1.6 Management Plan Review				**35.00**		**-**		**-**		**15.00**		**-**		**20.00**
1.6.1 Mid-term review				15.00						15.00				
1.6.2 Final Review				20.00										20.00
2 Catchment Conservation				**1,828.70**		**35.00**		**474.80**		**481.05**		**473.05**		**364.80**
2.1 Micro-planning				**35.00**		**35.00**								**-**
2.1.1 Establishment of Catchment Conservation Committe	50,000	per Committee	14.00	7.00	14	7.00								
2..1.2 Preparation of Catchment Management Plans	1,00,000	per Committee	14.00	14.00	14	14.00								
2.1.3 Capacity development	1,00,000	per Committee	-	14.00		14.00								
2.2 Vegetative measures				**49.20**		**-**		**15.80**		**17.05**		**11.55**		**4.80**
2.2.1 Afforestation using native species				-		-								
a) Plantation	25,000	per Ha	14.00	3.50			5.00	1.25	5.00	1.25	4.00	1.00		
b) Maintenance (First Year)	10,000	per Ha	14.00	1.40					5.00	0.50	5.00	0.50	4.00	0.40

Components and Activities	Rate (Rs..)	Unit	Targets		Year 1		Year 2		Year 3		Year 4		Year 5	
			Physical (2017 - 21)	Financial (2017 - 21) (Rs.. Lakhs)	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial
c) Maintenance (Second Year)	8,000	per Ha	10.00	0.80							5.00	0.40	5.00	0.40
2.2.2 Pasture development	25	per Rm	12,000.00	3.00		-	4,000.00	1.00	4,000.00	1.00	4,000.00	1.00		
2.2.3 Development of village woodlots	15,000	per ha	20.00	3.00			7.00	1.05	7.00	1.05	6.00	0.90		
2.2.4 Coir-Geo textiles and Green belts	500	per m2	2,200.00	11.00			1,100.00	5.50	1,100.00	5.50				
2.2.5 Promotion of agro-forestry	15,000	per ha	10.00	1.50		-			5.00	0.75	5.00	0.75		
2.2.6 Gully Groves	2,000	per cluster	1,000.00	25.00			700.00	7.00	700.00	7.00	700.00	7.00	400.00	4.00
2.3 Small scale engineering measures				**1,744.50**		**-**		**459.00**		**464.00**		**461.50**		**360.00**
2.3.1 Check dams & Cross bars														
Gully check (3m wide)	10,000	per structure	300	30.00		-	50.00	5.00	100.00	10.00	100.00	10.00	50.00	5.00
Cross bar	2,500	per structure	1000	25.00		-	300.00	7.50	300.00	7.50	200.00	5.00	200.00	5.00
2.3.3 Retaining walls														
2 m height	4,200	per Rm	3000	126.00		-	1,000.00	42.00	1,000.00	42.00	1,000.00	42.00		
1.5 m height	3,100	per Rm	4500	139.50		-	1,500.00	46.50	1,500.00	46.50	1,500.00	46.50		
2.3.4 Rubble Pitched contour bund & Stabilization structure														
Rubble Pitched contour bund	35,000	per 100m^2	2000	1,400.00		-	1,000.00	350.00	1,000.00	350.00	1,000.00	350.00	1,000.00	350.00
2.3.5 Moisture Conservation pit	400	per unit	6000	24.00		-	2,000.00	8.00	2,000.00	8.00	2,000.00	8.00		
3 Water Management				**6,764.60**		**3,193.00**		**2,936.00**		**216.20**		**209.20**		**210.20**
3.1 Alternate water supply for Kollam city				**5,273.60**		**2,374.00**		**2,374.00**		**175.20**		**175.20**		**175.20**
3.1.1 Infrastructure				4,748.00		2,374.00		2,374.00						
3.1.2 Operation and Maintenance				525.60						175.20		175.20		175.20
3.2 Optimization Water abstraction				**27.00**		**12.00**		**7.00**		**7.00**		**-**		**1.00**
3.2.1 Assessment				20.00		10.00		5.00		5.00				
3.2.2 Stakeholder consultations				6.00		2.00		2.00		2.00				
3.2.3 Implementation				-										
3.2.4 Review and adaptation				1.00										1.00
3.3 Improved waste water treatment infrastructure for direct drainage basin				**1,216.00**		**672.00**		**448.00**		**32.00**		**32.00**		**32.00**
3.3.1 Infrastructure														
Civil works	84,00,000	per MLD	8	672.00	8.00	672.00								
Engineering and Manufacturing works	56,00,000	per MLD	8	448.00			8.00	448.00						
3.3.2 Operation and Maintenance	4,00,000	per MLD		96.00					8.00	32.00	8.00	32.00	8.00	32.00
3.4 Sanitation and hygiene				**248.00**		**135.00**		**107.00**		**2.00**		**2.00**		**2.00**
3.4.1 Improvement of toilets to double pit	12,000	per toilet	1000	120.00	500.00	60.00	500.00	60.00						
3.4.2 Bathing unit at Sastha temple & West Kallada	40,00,000	per unit	2	80.00	1.00	40.00	1.00	40.00						
3.4.3 Public toilet complex in Sasthamkotta & Bharanikkavu														
Construction cost	15,00,000	per complex	2	30.00	2.00	30.00								
O&M cost	1,00,000	per complex		8.00			2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
3.4.4 Rejuvenation of open wells	10,000	per well	100	10.00	50.00	5.00	50.00	5.00						
4 Biodiversity Conservation				**128.00**		**31.00**		**43.00**		**28.00**		**17.00**		**9.00**
4.1 Freshwater fish habitat assessment				**50.00**		**25.00**		**20.00**		**5.00**		**-**		**-**
4.1.1 Assessment				45.00		25.00		20.00						
4.1.2 Dissemination workshop				2.00						2.00				
4.1.3 Publication				3.00						3.00				
4.2 Annual waterbirds census				**20.00**		**4.00**		**4.00**		**4.00**		**4.00**		**4.00**
4.2.1 Pre-census workshops				2.50		0.50		0.50		0.50		0.50		0.50
4.2.2 Census				12.50		2.50		2.50		2.50		2.50		2.50
4.2.3 Results synthesis and publication				5.00		1.00		1.00		1.00		1.00		1.00

Components and Activities	Rate (Rs..)	Unit	Targets		Year 1		Year 2		Year 3		Year 4		Year 5	
			Physical (2017 - 21)	Financial (2017 - 21) (Rs.. Lakhs)	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial	Physical	Financial
4.3 Breeding waterbirds investigation				25.00		-		10.00		10.00		5.00		-
4.1.1 Assessment				20.00				10.00		10.00				
4.1.2 Dissemination workshop				2.00								2.00		
4.1.3 Publication				3.00								3.00		
4.4 Animal disease surveillance				10.00		2.00		2.00		2.00		2.00		2.00
4.4.1 Surveillance				10.00		**2.00**		**2.00**		**2.00**		**2.00**		**2.00**
4.4.2 Reporting				-										
4.5 Periodic updation of biodiversity registers				9.00		-		-		-		6.00		3.00
4.5.1 Assessments				6.00								6.00		
4.5.2 Publication				3.00										3.00
4.6 Regulating proliferation of aquatic macrophytes				14.00				7.00		7.00				
4.6.1 Removal				10.00				**5.00**		**5.00**				
4.6.2 Economic Utilization				4.00				**2.00**		**2.00**				
5 Sustainable Livelihoods				172.50		15.00		66.50		72.00		16.00		3.00
5.1 Rejuvenation of Rajagiri fish hatchery				38.00		-		21.00		17.00		-		-
5.1.1 Registration of PFCS				1.00				1.00						
5.1.2 Refurbishment of infrastructure				20.00				20.00						
5.1.3 Seed capital support				10.00						10.00				
5.1.4 Training				2.00						2.00				
5.1.4 Hatchery operations				5.00						5.00				
5.2 Eco-Tourism master plan				40.00		-		-		35.00		5.00		-
5.2.1 Development of master plan				35.00						**35.00**				
5.2.2 Stakeholder consultation				2.00								**2.00**		
5.2.3 Publication				3.00								**3.00**		
5.3 Additional Livelihoods				94.50		15.00		45.50		20.00		11.00		3.00
5.3.1 Food Processing	9,00,000.00	per group	3.00											
a) SHG Formation				1.00		1.00								
b) Training				4.00		4.00								
c) Financing support				15.00				15.00						
d) Marketing linkages				5.00						5.00				
e) Evaluation				2.00								1.00		1.00
5.3.2 Bamboo / Pandanus Based Enterprise	7,50,000.00	per group	5.00											
a) SHG Formation				1.00		1.00								
b) Training				4.00		4.00								
c) Financing support				25.50				25.50						
d) Marketing linkages				5.00						5.00				
e) Evaluation				2.00								1.00		1.00
5.3.3 Vermicomposting	60,000.00	per group	50.00											
a) SHG Formation				5.00		5.00								
b) Training				5.00				5.00						
c) Equipment support				19.00						10.00		9.00		
d) Evaluation				1.00										1.00
Grand Total				9,853.05		3,578.25		3,849.05		1,007.00		787.00		631.75

7.2 CONVERGENCE FINANCING OPPORTUNITIES

The management plan has been budgeted on the principle of convergence, by analyzing developmental schemes which can support specific activities. An analysis of such schemes (Table 7.3) indicates that nearly 74% of funds can be leveraged from various developmental schemes of the central and state government. The rest of the resources may be placed for consideration of the National Plan for Conservation of Aquatic Ecosystems (NPCA) of the MoEFCC.

Table 7.3 | Convergence financing opportunities for management of Sasthamkotta Lake

Management Plan Components		Budget	Convergence Scheme	Concerned Department/ Agency/Organization	Convergence Budget
1	**Institutional Development**	**959.25**			
1.1	Establishment of Sasthamkotta Management Authority	10.00			
1.2	Integrated wetland inventory, assessment & monitoring system	783.00			
1.3	Capacity development	39.00			
1.4	Monitoring compliance with existing laws & regulation	10.00			
1.5	Communication & outreach	82.25			
1.6	Management Plan Review	35.00			
2	**Catchment Conservation**	**1,828.70**	Integrated Watershed Development Programme	Local Self Government Department, Government of Kerala	**1,828.70**
2.1	Micro-planning	35.00			
2.2	Vegetative measures	49.20			
2.3	Small scale engineering measures	1,744.50			
3	**Water Management**	**6,774.60**			
3.1	Alternate water supply for Kollam city	5,273.60	Atal Mission for Rejuvenation and Urban Transformation	Local Self Government Department, Government of Kerala	5,273.60
3.2	Optimization Water abstraction	37.00			
3.3	Improved waste water treatment infrastructure for direct drainage basin	1,216.00			
3.4	Sanitation and hygiene	248.00	Suchitwa Mission	Local Self Government Department, Government of Kerala	120.00

4	**Biodiversity Conservation**		**128.00**		
	4.1	Freshwater fish habitat assessment	50.00		
	4.2	Annual waterbirds census	20.00		
	4.3	Breeding waterbirds investigation	25.00		
	4.4	Animal disease surveillance	10.00	Department of Animal Husbandry	
	4.5	Periodic updation of biodiversity registers	9.00		
	4.6	Regulating proliferation of aquatic macrophytes	14.00		
5	**Sustainable Livelihoods**		**172.50**		
	5.1	Rejuvenation of Rajagiri fish hatchery	38.00	National Fisheries Development Board	38.00
	5.2	Eco-Tourism master plan	40.00		
	5.3	Additional Livelihoods	94.50	National Mission on Bamboo Applications	25.00
			9,863.05		7,285.30

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Annexes

Annex 1

WATER BALANCE

It is an equation used to describe the flow of water in and out of the system. It is basically a statement of law of conservation of matter as applied to hydrological cycle. It states that all water entering in a specified area must be there in the storage or withdrawn from there only. The general water balance equation is

$$I - O = \pm \Delta S$$

Where I = Total Inflow, O = Total Outflow, ΔS = Change in Storage

Here the total inflow is combination of Rainfall, Runoff, city inflow and ground water interchange. The outflow is the combination of evaporation throughout and the withdrawal for city water supply.

$$I = P + Rf + GWi + Wi$$

Where I = Total Inflow, P = Precipitation/ Rainfall, R_f = Runoff, GWi = Ground Water Interaction, Wi = Water inflow

$$O = E + Wo$$

Where O = Total Outflow, E = Evaporation of lake water, Wo = Water Withdrawal Outflow

From the above equation, the water balance can be re-written as: -

$$(P + Rf + GWi + Wi) - (E + Wo) = \pm \Delta S$$

Knowing the inflow and the outflow data like rainfall, waste inflow, evaporation, water withdrawal& the lake level from various sources like the Indian Metrological Department (IMD) & Kerala Water Authority (KWA), the ground water interchange was calculated with the help of water balance.

As rainfall is a major source of inflow, various scenarios (Table 1) are constructed by reducing the rainfall in certain monsoon period and comparing it with the condition with the situation of normal rainfall. This gives us an idea of how rainfall is effecting the lake inundation, based on which appropriate plans can be suggested for the conservation of the lake. For all the above cases the lake level is assumed to be 16m at the starting of December, when both the South-West and North-East monsoon are over so the lake level is at its higher limit for the year, when the lake bed is not exposed.

The various scenarios given below gives us an idea how reduction in rainfall is affecting the inundation pattern of the lake, thus stating the importance of rainfall in the system which is on a declining trend of the last few years.

Table 1: Various Scenarios

Scenario	% Reduction in Rainfall
Scenario 1	5% reduction in SW Monsoon
Scenario 2	10% reduction in SW Monsoon
Scenario 3	15% reduction in SW Monsoon
Scenario 4	5% reduction in NE Monsoon
Scenario 5	10% reduction in NE Monsoon
Scenario 6	15% reduction in NE Monsoon
Scenario 7	5% reduction in SW & NE Monsoon
Scenario 8	10% reduction in SW & NE Monsoon
Scenario 9	15% reduction in SW & NE Monsoon

Table 2: Estimation of Groundwater interchange

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level Closing
			Rainfall	Runoff	City inflow	Net GW interchange	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	13.75	9.33	1.52	1.67	0.02	-0.04	3.17	0.32	1.91	2.23	0.95	10.27	14.15
July	14.15	10.27	1.19	1.31	0.02	0.49	3.02	0.31	1.97	2.28	0.74	11.01	14.45
August	14.45	11.01	0.75	0.82	0.02	0.96	2.54	0.35	1.97	2.31	0.23	11.24	14.54
September	14.54	11.24	0.67	0.73	0.02	0.95	2.38	0.37	1.91	2.28	0.10	11.34	14.58
October	14.58	11.34	0.96	1.05	0.02	0.50	2.53	0.36	1.97	2.33	0.20	11.55	14.66
November	14.66	11.55	0.63	0.69	0.02	0.91	2.26	0.41	1.91	2.31	-0.05	11.49	14.64
December	14.64	11.49	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	10.76	14.35
January	14.35	10.76	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	9.99	14.03
February	14.03	9.99	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	9.51	13.83
March	13.83	9.51	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	8.94	13.58
April	13.58	8.94	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	9.33	13.75
May	13.75	9.33	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	9.33	13.75

Table 3: Water Balance Components of Lake for Normal Rainfall Condition

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.52	1.67	0.02	-0.04	3.17	0.32	1.91	2.23	0.95	13.87	15.53
July	15.53	13.87	1.19	1.31	0.02	0.49	3.02	0.31	1.97	2.28	0.74	14.61	15.78
August	15.78	14.61	0.75	0.82	0.02	0.96	2.54	0.35	1.97	2.31	0.23	14.84	15.86
September	15.86	14.84	0.67	0.73	0.02	0.95	2.38	0.37	1.91	2.28	0.10	14.94	15.90
October	15.90	14.94	0.96	1.05	0.02	0.50	2.53	0.36	1.97	2.33	0.20	15.15	15.97
November	15.97	15.15	0.63	0.69	0.02	0.91	2.26	0.41	1.91	2.31	-0.05	15.62	16.00
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**7.27**	**7.97**	**0.24**	**13.62**	**29.10**	**5.92**	**23.18**	**29.10**			

Table 4: Water Balance Components of Lake for 10% Deficit in South-West Monsoon Rainfall (Scenario 1)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.37	1.50	0.02	-0.04	2.85	0.32	1.91	2.23	0.63	13.55	15.41
July	15.41	13.55	1.08	1.18	0.02	0.49	2.77	0.31	1.97	2.28	0.49	14.04	15.59
August	15.59	14.04	0.67	0.74	0.02	0.96	2.38	0.35	1.97	2.31	0.07	14.11	15.61
September	15.61	14.11	0.67	0.73	0.02	0.95	2.38	0.37	1.91	2.28	0.10	14.21	15.65
October	15.65	14.21	0.96	1.05	0.02	0.50	2.53	0.36	1.97	2.33	0.20	14.42	15.72
November	15.72	14.42	0.63	0.69	0.02	0.91	2.26	0.41	1.91	2.31	-0.05	14.37	15.70
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.93**	**7.59**	**0.24**	**13.62**	**28.37**	**5.92**	**23.18**	**29.10**	**-0.73**		

Table 5: Water Balance Components of Lake for 20% Deficit in South-West Monsoon Rainfall (Scenario 2)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.22	1.33	0.02	-0.04	2.53	0.32	1.91	2.23	0.31	13.24	15.30
July	15.30	13.24	0.96	1.05	0.02	0.49	2.51	0.31	1.97	2.28	0.24	13.47	15.38
August	15.38	13.47	0.60	0.65	0.02	0.96	2.23	0.35	1.97	2.31	-0.09	13.39	15.35
September	15.35	13.39	0.67	0.73	0.02	0.95	2.38	0.37	1.91	2.28	0.10	13.49	15.39
October	15.39	13.49	0.96	1.05	0.02	0.50	2.53	0.36	1.97	2.33	0.20	13.69	15.46
November	15.46	13.69	0.63	0.69	0.02	0.91	2.26	0.41	1.91	2.31	-0.05	13.64	15.44
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.58**	**7.21**	**0.24**	**13.62**	**27.65**	**5.92**	**23.18**	**29.10**	**-1.45**		

Table 6: Water Balance Components of Lake for 30% Deficit in South-West Monsoon Rainfall (Scenario 3)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.07	1.17	0.02	-0.04	2.21	0.32	1.91	2.23	-0.01	12.92	15.18
July	15.18	12.92	0.84	0.92	0.02	0.49	2.26	0.31	1.97	2.28	-0.01	12.90	15.17
August	15.17	12.90	0.52	0.57	0.02	0.96	2.07	0.35	1.97	2.31	-0.24	12.66	15.08
September	15.08	12.66	0.67	0.73	0.02	0.95	2.38	0.37	1.91	2.28	0.10	12.76	15.12
October	15.12	12.76	0.96	1.05	0.02	0.50	2.53	0.36	1.97	2.33	0.20	12.97	15.20
November	15.20	12.97	0.63	0.69	0.02	0.91	2.26	0.41	1.91	2.31	-0.05	12.92	15.18
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.23**	**6.83**	**0.24**	**13.62**	**26.92**	**5.92**	**23.18**	**29.10**	**-2.18**		

Table 7: Water Balance Components of Lake for 10% Deficit in North-East Monsoon Rainfall (Scenario 4)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.52	1.67	0.02	-0.04	3.17	0.32	1.91	2.23	0.95	13.87	15.53
July	15.53	13.87	1.19	1.31	0.02	0.49	3.02	0.31	1.97	2.28	0.74	14.61	15.78
August	15.78	14.61	0.75	0.82	0.02	0.96	2.54	0.35	1.97	2.31	0.23	14.84	15.86
September	15.86	14.84	0.60	0.66	0.02	0.95	2.24	0.37	1.91	2.28	-0.04	14.80	15.85
October	15.85	14.80	0.86	0.94	0.02	0.50	2.33	0.36	1.97	2.33	0.00	14.80	15.85
November	15.85	14.80	0.57	0.63	0.02	0.91	2.13	0.41	1.91	2.31	-0.18	14.62	15.79
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**7.05**	**7.72**	**0.24**	**13.62**	**28.63**	**5.92**	**23.18**	**29.10**	**-0.47**		

Table 8: Water Balance Components of Lake for 20% Deficit in North-East Monsoon Rainfall (Scenario 5)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.52	1.67	0.02	-0.04	3.17	0.32	1.91	2.23	0.95	13.87	15.53
July	15.53	13.87	1.19	1.31	0.02	0.49	3.02	0.31	1.97	2.28	0.74	14.61	15.78
August	15.78	14.61	0.75	0.82	0.02	0.96	2.54	0.35	1.97	2.31	0.23	14.84	15.86
September	15.86	14.84	0.54	0.59	0.02	0.95	2.10	0.37	1.91	2.28	-0.18	14.66	15.80
October	15.80	14.66	0.77	0.84	0.02	0.50	2.13	0.36	1.97	2.33	-0.20	14.46	15.73
November	15.73	14.46	0.51	0.56	0.02	0.91	2.00	0.41	1.91	2.31	-0.32	14.15	15.62
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.82**	**7.47**	**0.24**	**13.62**	**28.15**	**5.92**	**23.18**	**29.10**	**-0.95**		

Table 9: Water Balance Components of Lake for 30% Deficit in North-East Monsoon Rainfall (Scenario 6)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.52	1.67	0.02	-0.04	3.17	0.32	1.91	2.23	0.95	13.87	15.53
July	15.53	13.87	1.19	1.31	0.02	0.49	3.02	0.31	1.97	2.28	0.74	14.61	15.78
August	15.78	14.61	0.75	0.82	0.02	0.96	2.54	0.35	1.97	2.31	0.23	14.84	15.86
September	15.86	14.84	0.47	0.51	0.02	0.95	1.96	0.37	1.91	2.28	-0.32	14.52	15.75
October	15.75	14.52	0.67	0.73	0.02	0.50	1.93	0.36	1.97	2.33	-0.40	14.12	15.61
November	15.61	14.12	0.44	0.49	0.02	0.91	1.86	0.41	1.91	2.31	-0.45	13.67	15.45
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.59**	**7.22**	**0.24**	**13.62**	**27.68**	**5.92**	**23.18**	**29.10**	**-1.42**		

Table 10: Water Balance Components of Lake for 10% Deficit in South-West and North-East Monsoon Rainfall (Scenario 7)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.37	1.50	0.02	-0.04	2.85	0.32	1.91	2.23	0.63	13.55	15.41
July	15.41	13.55	1.08	1.18	0.02	0.49	2.77	0.31	1.97	2.28	0.49	14.04	15.59
August	15.59	14.04	0.67	0.74	0.02	0.96	2.38	0.35	1.97	2.31	0.07	14.11	15.61
September	15.61	14.11	0.60	0.66	0.02	0.95	2.24	0.37	1.91	2.28	-0.04	14.07	15.60
October	15.60	14.07	0.86	0.94	0.02	0.50	2.33	0.36	1.97	2.33	0.00	14.08	15.60
November	15.60	14.08	0.57	0.63	0.02	0.91	2.13	0.41	1.91	2.31	-0.18	13.89	15.53
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.70**	**7.34**	**0.24**	**13.62**	**27.90**	**5.92**	**23.18**	**29.10**	**-1.20**		

Table 11: Water Balance Components of Lake for 20% Deficit in South-West and North-East Monsoon Rainfall (Scenario 8)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.22	1.33	0.02	-0.04	2.53	0.32	1.91	2.23	0.31	13.24	15.30
July	15.30	13.24	0.96	1.05	0.02	0.49	2.51	0.31	1.97	2.28	0.24	13.47	15.38
August	15.38	13.47	0.60	0.65	0.02	0.96	2.23	0.35	1.97	2.31	-0.09	13.39	15.35
September	15.35	13.39	0.54	0.59	0.02	0.95	2.10	0.37	1.91	2.28	-0.18	13.21	15.29
October	15.29	13.21	0.77	0.84	0.02	0.50	2.13	0.36	1.97	2.33	-0.20	13.01	15.21
November	15.21	13.01	0.51	0.56	0.02	0.91	2.00	0.41	1.91	2.31	-0.32	12.69	15.10
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**6.13**	**6.71**	**0.24**	**13.62**	**26.70**	**5.92**	**23.18**	**29.10**	**-2.40**		

Table 12: Water Balance Components of Lake for 30% Deficit in South-West and North-East Monsoon Rainfall (Scenario 9)

Month	Water Level	Opening Storage	Inflow					Outflow				Closing Storage	Water Level
			Rainfall	Runoff	City inflow	Net GW inflow	Total Inflow	Evaporation Loss	Direct withdrawal	Total Outflow	Net storage		
	m	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	Mm^3	m
June	15.18	12.93	1.07	1.17	0.02	-0.04	2.21	0.32	1.91	2.23	-0.01	12.92	15.18
July	15.18	12.92	0.84	0.92	0.02	0.49	2.26	0.31	1.97	2.28	-0.01	12.90	15.17
August	15.17	12.90	0.52	0.57	0.02	0.96	2.07	0.35	1.97	2.31	-0.24	12.66	15.08
September	15.08	12.66	0.47	0.51	0.02	0.95	1.96	0.37	1.91	2.28	-0.32	12.34	14.96
October	14.96	12.34	0.67	0.73	0.02	0.50	1.93	0.36	1.97	2.33	-0.40	11.94	14.81
November	14.81	11.94	0.44	0.49	0.02	0.91	1.86	0.41	1.91	2.31	-0.45	11.49	14.64
December	16.00	15.62	0.09	0.10	0.02	1.65	1.86	0.63	1.97	2.59	-0.73	14.36	15.70
January	15.70	14.36	0.01	0.01	0.02	1.87	1.91	0.72	1.97	2.68	-0.78	13.59	15.42
February	15.42	13.59	0.03	0.03	0.02	1.87	1.95	0.64	1.78	2.42	-0.47	13.11	15.25
March	15.25	13.11	0.13	0.14	0.02	1.82	2.10	0.71	1.97	2.68	-0.57	12.54	15.04
April	15.04	12.54	0.45	0.49	0.02	1.94	2.90	0.60	1.91	2.51	0.39	12.93	15.18
May	15.18	12.93	0.85	0.93	0.02	0.70	2.49	0.52	1.97	2.49	0.00	12.93	15.18
Total			**5.55**	**6.08**	**0.24**	**13.62**	**25.50**	**5.92**	**23.18**	**29.10**	**-3.60**		

PHYTOPLANKTON RECORDED IN SASTHAMKOTTA LAKE

(Source: Girijakumari, 2007)

Bacillariophyceae
- Bacillariaceae
  1. *Nitzschia acicularis*
  2. *Nitzschia major*
- Cocconeidaceae
  3. *Cocconeis pediculus*
  4. *Cocconeis* sp.
- Cymbellaceae
  5. *Cymbella ventricosa*
- Diploneidaceae
  6. *Diploneis puella*
- Eunotiaceae
  7. *Eunotia formica*
- Fragilariaceae
  8. *Fragilaria rumpens*
  9. *Synedra acus*
  10. *Synedra formosa*
- Grammatophoraceae
  11. *Grammatophora* sp.
- Mastogloiaceae
  12. *Mastogloia exilis*
- Naviculaceae
  13. *Navicula cuspidata*
  14. *Navicula radiosa*
  15. *Navicula rectangularis*
  16. *Navicula tenalla*
- Pinnulariaceae
  17. *Pinnularia biceps*
- Stauroneidaceae
  18. *Stauroneis acuta*
- Surirellaceae
  19. *Surirella* sp.
- Tabellariaceae
  20. *Asterionella formosa*

Chlorophyceae
- Hydrodictyaceae
  21. *Pediastrum simplex*
- Oedogoniaceae
  22. *Oedogonium* sp.
- Scenedesmaceae
  23. *Scenedesmus quadricauda*

Conjugatophyceae
- Closteriaceae
  24. *Closterium dianae*
  25. *Closterium aciculare*
- Desmidiaceae
  26. *Cosmarium orthostuchuno*
  27. *Staurastrum* sp.
  28. *Desmidium* sp.
- Zygnemataceae
  29. *Spirogyra* sp.

Coscinodiscophyceae
- Coscinodiscaceae
  30. *Coscinodiscus granii*
- Melosiraceae
  31. *Melosira granulata*

Cyanophyceae
- Microcystaceae
  32. *Microcystis* sp.
- Nostocaceae
  33. *Anabaena* sp.
- Oscillatoriaceae
  34. *Oscillatoria prolifica*

Dinophyceae
- Peridiniaceae
  35. *Peridinium* sp.

Mediophyceae
- Thalassiosiraceae
  36. *Thalassiosira* sp.

Ulvophyceae
- Ulotrichaceae
  37. *Ulothrix* sp.

MACROPHYTES RECORDED IN SASTHAMKOTTA LAKE

(Source: Nayar et al., 2011 and Field Assessment, 2015)

Acanthaceae

1. *Hygrophila auriculata* (Schumach.) Heine

Aponogetonaceae

2. *Aponogeton natans* (L.) Engl. & K.Krause

Araceae

3. *Colocasia esculenta* (L.) Schott
4. *Pistia* sp.

Convolvulaceae

5. *Ipomoea aquatica* Forssk.

Hydrocharitaceae

6. *Hydrilla verticillata* (L.f.) Royle
7. *Vallisneria spiralis* L.
8. *Blyxa octandra* (Roxb) Planch. ex Thwaites

Lentibulariaceae

9. *Utricularia reticulata* Sm.

Menyanthaceae

10. *Nymphoides indica* (L.) Kuntze

Nymphaeaceae

11. *Nymphaea stellata*

Poaceae

12. *Hygroryza aristata* (Retz.) Nees ex Wight & Arn.
13. *Paspalidium geminatum* (Forssk.) Stapf
14. *Oryza rufipogon* Griff.

Pontederiaceae

15. *Eichhornia crassipes* (Mart.) Solms
16. *Monochoria vaginalis* (Burm.f.) C.Presl

Salviniaceae

17. *Salvinia molesta* D. S. Mitch.

Scrophulariaceae

18. *Limnophila heterophylla* (Roxb.) Benth.

TERRESTRIAL VEGETATION RECORDED AROUND SASTHAMKOTTA LAKE

(Source: Nayar et al., 2011)

Acanthaceae
1. *Barleria prionitis*

Amaranthaceae
2. *Achyranthes aspera* L.
3. *Aerva lanata* (L.) Juss. ex Schult.
4. *Amaranthus spinosus* L.

Anacardiaceae
5. *Anacardium occidentale* L.
6. *Holigarna arnottiana* Wall. ex Hook. fil.
7. *Lannea coromandelica* (Houtt.) Merr.
8. *Mangifera indica* L.

Annonaceae
9. *Annona squamosa* L.

Apiaceae
10. *Centella asiatica* (L.) Urb.

Apocynaceae
11. *Allamanda cathartica* L.
12. *Alstonia scholaris* (L.) R.Br.
13. *Calotropis gigantea* (L.) W. T. Aiton
14. *Cerbera odollam* Gaertn.
15. *Hemidesmus indicus* (L.) R. Br.
16. *Plumeria alba* L.
17. *Tabernaemontana heyneana* Wall.
18. *Vinca rosea* L.

Araceae
19. *Alocasia indica* (Lour.) Spach
20. *Amorphophallus paeoniifolius* (Dennst.) Nicolson
21. *Amorphophallus* sp.
22. *Colocasia esculenta* (L.) Schott

Arecaceae
23. *Areca catechu* L.
24. *Borassus flabellifer* L.
25. *Calamus rotang* L.
26. *Caryota urens* L.
27. *Cocos* nucifera L.

Asparagaceae
28. *Agave americana* L.
29. *Asparagus* racemosus Willd.

Asteraceae
30. *Ageratum conyzoides subsp. houstonianum* (Mill.) M.Sharma
31. *Elephantopus scaber* auct. non L.
32. *Emilia sonchifolia* (L.) DC. ex Wight
33. *Eupatorium odoratum* Walter
34. *Spilanthes calva* DC.
35. *Vernonia* cinerea (L.) Less.

Balsaminaceae
36. *Impatiens balsamina* L.

Bignoniaceae
37. *Pajanelia longifolia* (Willd.) K.Schum.
38. *Spathodea campanulata* Beauv.

Bromeliaceae
39. *Ananas comosus* (L.) Merr.

Campanulaceae
40. *Lobelia trigona* Roxb.

Caricaceae
41. *Carica papaya* L.

Casuarinaceae
42. *Casuarina equisetifolia* L.

Clusiaceae
43. *Calophyllum inophyllum* L.
44. *Garcinia gummi-gutta* (L.) N. Robson

Colchicaceae
45. *Gloriosa superba* L.

Combretaceae
46. *Terminalia catappa* L.
47. *Terminalia paniculata* Roth

Convolvulaceae
48. *Ipomoea carnea*
49. *Ipomoea repens* (L.) Lam.
50. *Merremia tridentata* (L.) Hall. fil.

Cucurbitaceae
51. *Cucurbita pepo* L.
52. *Cucurbita* sp.
53. *Luffa acutangula* (L.) Roxb.
54. *Momordica charantia*
55. *Trichosanthes dioica* Roxb.

Cyperaceae
56. *Cyperus rotundus* L.

Dennstaedtiaceae
57. *Pteridium* sp.

Dipterocarpaceae
58. *Hopea parviflora* Bedd.

Droseraceae
59. *Drosera burmanni* Vahl

Euphorbiaceae
60. *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg.
61. *Jatropha curcas* L.
62. *Jatropha glandulifera* Roxb.
63. *Macaranga peltata* (Roxb.) Müll.Arg.
64. *Manihot esculenta* Crantz
65. *Ricinus communis* L.

Fabaceae
66. *Acacia auriculiformis* Benth.
67. *Acacia mangium* Willd.
68. *Albizia chinensis* (Osbeck) Merr.
69. *Bauhinia purpurea* L.
70. *Butea monosperma* (Lam.)Taub.

71. *Caesalpinia pulcherrima* (L.)Sw.
72. *Cassia fistula* L.
73. *Cassia leschenaultii* Wall.
74. *Cassia occidentalis* (L.)Rose
75. *Cassia tora* sensu auct.
76. *Clitoria ternatea* L.
77. *Delonix regia* (Hook.) Raf.
78. *Desmodium* sp.
79. *Entada rheedii* Spreng.
80. *Mimosa pudica* L.
81. *Mucuna pruriens* (L.)DC.
82. *Peltophorum pterocarpum* (DC.) K.Heyne
83. *Sesbania grandiflora* (L.)Pers.
84. *Tamarindus indica* L.

Flacourtiaceae

85. *Hydnocarpus pentandrus* (Buch.-Ham.) Oken

Lamiaceae

86. *Anisomeles* sp.
87. *Clerodendrum viscosum* Vent., nom. superfl.
88. *Leucas aspera* (Willd.) Link
89. *Ocimum sanctum* L.
90. *Tectona grandis* L.f.
91. *Vitex negundo* L.

Lauraceae

92. *Cinnamomum malabathrum* Miq.
93. *Cinnamomum zeylanicum* Nees

Lecythidaceae

94. *Barringtonia racemosa* Spreng.

Loganiaceae

95. *Strychnos nux-vomica* L.

Lomariopsidaceae

96. *Nephrolepis* sp.

Lythraceae

97. *Lagerstroemia reginae* Roxb.
98. *Lawsonia inermis* L.

Malvaceae

99. *Abutilon* sp.
100. *Ceiba pentandra* (L.) Gaertn.
101. *Grewia nervosa* (Lour.) G. Panigrahi
102. *Hibiscus rosa-sinensis* L.
103. *Sida cordifolia* L.
104. *Thespesia populnea* (L.) Soland. ex Correa

Melastomataceae

105. *Osbeckia virgata* D. Don ex Wight & Arn.

Meliaceae

106. *Aphanamixis polystachya* (Wall.) R.N. Parker
107. *Azadirachta indica* A. Juss.
108. *Naregamia alata* Wight & Arn.

Menispermaceae

109. *Cyclea peltata* Hook. fil. & Thoms.

Moraceae

110. *Artocarpus communis* J. R. & G. Forst.
111. *Artocarpus heterophyllus* Lam.
112. *Artocarpus hirsutus* Lam.
113. *Artocarpus incisus* (Thunb.) L. fil.
114. *Ficus benghalensis* L.
115. *Ficus racemosa* L.
116. *Ficus religiosa* L.

Moringaceae

117. *Moringa pterygosperma* Gaertn.

Musaceae

118. *Musa paradisiaca* L.

Myristicaceae

119. *Myristica fragrans* Houtt.

Myrtaceae

120. *Eucalyptus globulus* Labill.
121. *Psidium guajava* L.
122. *Syzygium cumini* (L.) Skeels
123. *Syzygium zeylanicum* (L.) DC.

Nyctaginaceae

124. *Boerhavia diffusa* L.

Oxalidaceae

125. *Averrhoa bilimbi* L.
126. *Biophytum sensitivum* (L.) DC.
127. *Oxalis corniculata* L.

Pandanaceae

128. *Pandanus odoratissimus* L.f.

Pedaliaceae

129. *Sesamum* sp.

Phyllanthaceae

130. *Emblica officinalis* Gaertn.
131. *Phyllanthus amarus* Schumach. & Thonn.
132. *Phyllanthus emblica* L.

Piperaceae

133. *Piper nigrum* L.

Plantaginaceae

134. *Scoparia dulcis* L.

Poaceae

135. *Bambusa arundinacea* Willd.
136. *Cymbopogon flexuosus* (Nees ex Steud.) W.Watson
137. *Cynodon dactylon* (L.) Pers.
138. *Oryza rufipogon* Griff.
139. *Pennisetum polystachion* (L.) Schult.

Rhamnaceae

140. *Ziziphus oenopolia* (L.) Mill.

Rubiaceae

141. *Ixora coccinea* L.
142. *Morinda tinctoria* Noronha, nom. inval.
143. *Mussaenda frondosa* L.
144. *Plectronia parviflora* Harv. & Sond.

Rutaceae

145. *Citrus maxima* (Burm. fil.) Osbeck
146. *Glycosmis pentaphylla* (Retz.) Correa

147. *Murraya koenigii* (L.) Spreng.

Sapindaceae

148. *Cardiospermum halicacabum* L.

Sapotaceae

149. *Manilkara zapota* (L.) P.Royen

Scrophulariaceae

150. *Bacopa monnieri* (L.) Wettst.

Simaroubaceae

151. *Ailanthus triphysa* (Dennst.) Alston

Verbenaceae

152. *Citharexylum spinosum* L.
153. *Lantana camara* L.
154. *Stachytarpheta indica* (L.) Vahl

Violaceae

155. *Hybanthus enneaspermus* (L.) F. Müll.

Xanthorrhoeaceae

156. *Aloe vera* (L.) Burm.f.

Zingiberaceae

157. *Curcuma longa* L.
158. *Zingiber officinale* Roscoe

INSECTS (BUTTERFLIES) RECORDED IN SASTHAMKOTTA LAKE

(Source: Nayar et al., 2011)

Lycaenidae

1. *Freyeria trochylus* (Freyer, 1845)
2. *Lampides boeticus* (Linnaeus, 1767)
3. *Rathinda amor* (Fabricius, 1775)

Nymphalidae

4. *Danaus chrysippus* Linnaeus, 1758
5. *Danaus genutia* Cramer, 1779
6. *Euploea core* Cramer, 1780
7. *Junonia atlites* Linnaeus, 1763
8. *Junonia hierta* (Fabricius, 1798)
9. *Mycalesis perseus* Fabricius, 1775
10. *Neptis hylas* Linnaeus, 1758
11. *Orsotriaena medus* Fabricius, 1775
12. *Tirumala limniace* Cramer, 1775
13. *Ypthima baldus* Fabricius, 1775
14. *Ypthima huebneri* Kirby, 1871

Papilinoidae

15. *Graphium agamemnon* (Linnaeus, 1758)
16. *Graphium sarpedon* (Linnaeus, 1758)
17. *Pachliopta aristolochiae* (Fabricius, 1775)
18. *Papilio demoleus* Linnaeus, 1758
19. *Papilio clytia lanata* Fruhstorfer, 1907

Pieridae

20. *Catopsilia pomona* (Fabricius, 1775)
21. *Delias eucharis* (Drury, 1773)
22. *Eurema hecabe* (Linnaeus, 1758)
23. *Leptosia nina* (Fabricius, 1793)

Fish Species recorded in Sasthamkotta Lake

(Source: Girijakumari, 2007 and Nayar et al., 2011)

Ambassidae

1. *Parambassis dayi* (Bleeker, 1874)
2. *Chanda nama* Hamilton, 1822

Anguillidae

3. *Anguilla bicolor* McClelland, 1844

Aplocheilidae

4. *Aplocheilus blockii* Arnold, 1911
5. *Aplocheilus lineatus* (Valenciennes, 1846)
6. *Aplocheilus panchax* (Hamilton, 1822)

Bagridae

7. *Horabagrus brachysoma* (Günther, 1864)
8. *Mystus bleekeri* (Day, 1877)
9. *Mystus oculatus* (Valenciennes, 1840)
10. *Mystus vittatus* (Bloch, 1794)
11. *Mystus* sp.

Belonidae

12. *Xenentodon cancila* (Hamilton, 1822)

Channidae

13. *Channa marulius* (Hamilton, 1822)
14. *Channa micropeltes* (Cuvier, 1831)

Cichlidae

15. *Etroplus maculatus* (Bloch, 1795)
16. *Etroplus suratensis* (Bloch, 1790)

Clupeidae

17. *Dayella malabarica* (Day, 1873)

Cyprinidae

18. *Puntius amphibius* (Valenciennes, 1842)
19. *Puntius dorsalis* (Jerdon, 1849)
20. *Puntius filamentosus* (Valenciennes, 1844)
21. *Puntius sarana* (Hamilton, 1822)
22. *Puntius ticto* (Hamilton, 1822)
23. *Puntius vittatus* Day, 1865

Gobiidae

24. *Glossogobius giuris* (Hamilton, 1822)

Hemiramphidae

25. *Hemirhamphus* sp.
26. *Hyporhamphus limbatus* (Valenciennes, 1847)

Heteropneustidae

27. *Heteropneustes fossilis* (Bloch, 1794)

Mastacembelidae

28. *Macrognathus guentheri* (Day, 1865)

Megalopidae

29. *Megalops cyprinoides* (Broussonet, 1782)

Moringuidae

30. *Moringua raitaborua* (Hamilton, 1822)

Osphronemidae

31. *Pseudosphromenus cupanus* (Cuvier, 1831)

Poeciliidae

32. *Gambusia affinis* (Baird & Girard, 1853)

Siluridae

33. *Ompok bimaculatus* (Bloch, 1794)
34. *Ompok malabaricus* (Valenciennes, 1840)
35. *Wallago attu* (Bloch & Schneider, 1801)

Tetraodontidae

36. *Tetraodon cutcutia* (Hamilton, 1822)

WATERBIRDS RECORDED AT SASTHAMKOTTA LAKE

(Source: CWRDM, 2010; Nayar et al., 2011; AWC Records, 2012 and Field Assessment, 2015)

Sl. No.	Scientific Name	Common Name	Family	IUCN Status
1.	*Actitis hypoleucos* Linnaeus, 1758	Common Sandpiper	Scolopacidae	LC
2.	*Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Waterhen	Rallidae	LC
3.	*Anas acuta* Linnaeus, 1758	Northern Pintail	Anatidae	LC
4.	*Anas poecilorhyncha* Forster, 1781	Indian Spot-billed Duck	Anatidae	LC
5.	*Anas querquedula* Linnaeus, 1758	Garganey	Anatidae	LC
6.	*Anastomus oscitans* (Boddaert, 1783)	Asian Openbill	Ciconiidae	LC
7.	*Anhinga melanogaster* Pennant, 1769	Oriental Darter	Anhingidae	NT
8.	*Ardea intermedia* Wagler, 1829	Intermediate Egret	Ardeidae	LC
9.	*Ardea purpurea* Linnaeus, 1766	Purple Heron	Ardeidae	LC
10.	*Ardeola grayii* (Sykes, 1832)	Indian Pond-heron	Ardeidae	LC
11.	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret	Ardeidae	LC
12.	*Butorides striata* (Linnaeus, 1758)	Striated Heron	Ardeidae	LC
13.	*Casmerodius albus* (Linnaeus, 1758)	Great Egret	Ardeidae	LC
14.	*Chlidonias hybrida* (Pallas, 1811)	Whiskered Tern	Laridae	LC
15.	*Dendrocygna javanica* (Horsfield, 1821)	Lesser Whistling-duck	Anatidae	LC
16.	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	Ardeidae	LC
17.	*Fulica atra* Linnaeus, 1758	Common Coot	Rallidae	LC
18.	*Gallinula chloropus* (Linnaeus, 1758)	Common Moorhen	Rallidae	LC
19.	*Himantopus himantopus* (Linnaeus, 1758)	Black-winged Stilt	Recurvirostridae	LC
20.	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	Jacanidae	LC
21.	*Ixobrychus flavicollis* (Latham, 1790)	Black Bittern	Ardeidae	LC
22.	*Ixobrychus sinensis* (Gmelin, 1789)	Yellow Bittern	Ardeidae	LC
23.	*Metopidius indicus* (Latham, 1790)	Bronze-winged Jacana	Jacanidae	LC
24.	*Nettapus coromandelianus* (Gmelin, 1789)	Cotton Pygmy-goose	Anatidae	LC
25.	*Phalacrocorax carbo* (Linnaeus, 1758)	Great Cormorant	Phalacrocoracidae	LC
26.	*Phalacrocorax fuscicollis* Stephens, 1826	Indian Cormorant	Phalacrocoracidae	LC
27.	*Phalacrocorax niger* (Vieillot, 1817)	Little Cormorant	Phalacrocoracidae	LC
28.	*Porphyrio porphyrio* (Linnaeus, 1758)	Purple Swamphen	Rallidae	LC
29.	*Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe	Podicipedidae	LC
30.	*Threskiornis melanocephalus* (Latham, 1790)	Black-headed Ibis	Threskiornithidae	NT
31.	*Tringa glareola* Linnaeus, 1758	Wood Sandpiper	Scolopacidae	LC
32.	*Tringa nebularia* (Gunnerus, 1767)	Common Greenshank	Scolopacidae	LC
33.	*Tringa ochropus* Linnaeus, 1758	Green Sandpiper	Scolopacidae	LC
34.	*Vanellus indicus* (Boddaert, 1783)	Red-wattled Lapwing	Charadriidae	LC
35.	*Vanellus malabaricus* (Boddaert, 1783)	Yellow-wattled Lapwing	Charadriidae	LC

PANCHAYAT WARD CONNECTED WITH SASTHAMKOTTA LAKE

(Source: Census of India, 2011)

	Sasthamkotta		West Kallada		Mayangapalli		Total	
Ward Number	HH	Population	HH	Population	HH	Population	HH	Population
1.	-	-	-	-	-	-	-	-
2.	-	-	-	-	-	-	-	-
3.			482	1960	-	-	482	1960
4.	535	2133	348	1404	-	-	883	3537
5.	-	-	551	2078	-	-	551	2078
6.	527	1930	334	1397	-	-	861	3327
7.	-	-	-	-	-	-	-	-
8.	516	1981	-	-	327	1372	843	3353
9.	522	2022	-	-	501	2082	1023	4104
10.	479	1768	-	-	-	-	479	1768
11.	495	1888	-	-	-	-	495	1888
12.	367	1398	-	-	-	-	367	1398
13.	-	-	-	-	-	-	-	-
14.	-	-	-	-	-	-	-	-
15.	-	-	-	-	-	-	-	-
16.	-	-	-	-	-	-	-	-
17.	-	-	-	-	-	-	-	-
18.	547	2189	-	-			547	2189
Total	3988	15309	1715	6839	828	3454	6531	25602

NOTIFICATION OF KERALA STATE POLLUTION CONTROL BOARD

☎: General: 0471- 2312910, 2318153, 2318154, 2318155 Chairman: 2318150 Member Secretary: 2318151
E-mail: keralapcb@asianetindia.com FAX: 2318152 web: www.keralapcb.org

KERALA STATE POLLUTION CONTROL BOARD
കേരള സംസ്ഥാന മലിനീകരണ നിയന്ത്രണ ബോർഡ്
Pattom P.O., Thiruvananthapuram – 695 004
പട്ടം പി.ഒ., തിരുവനന്തപുരം - 695 004

PCB/GEN/01/2010 Date: 09.06.2010

NOTIFICATION

WHEREAS Sasthamcotta Lake in Kunnathoor Taluk of Kollam district is the largest fresh water lake of Kerala, source of water supply to Kollam Municipal Corporation and suburbs and is a Ramsar site deserving to be protected from pollution, sedimentation and encroachment;

WHEREAS the lake is subjected to pollution of anthropogenic origin;

WHEREAS urgent preventive and mitigative measures are required to restore and protect the wholesomeness of the lake;

WHEREAS Section 24 of the Water (Prevention & Control of Pollution) Act 1974 prohibits direct or indirect discharge of any poisonous, noxious or polluting matters into any water body;

WHEREAS Section 33 A of the said Act empowers the State Pollution Control Board to issue directions for prevention and control of water pollution and maintaining or restoring of wholesomeness of water;

AND WHEREAS Section 5 of the Environment (Protection) Act 1986 read with notification no. SO 327 (E) dated 10.04.2001 empowers the undersigned to issue directions for protection of environment,

1

NOW THEREFORE, in exercise of the aforesaid powers, the following activities which, by themselves or in conjunction with other activities, are causing or are likely to cause pollution of Sasthamcotta Lake and aggravation of the pollution are expressly prohibited with effect from the date of publication of this notification in the official website of the Board. The prohibition shall be applicable within the following survey numbers in the catchment area and more particularly within the distances mentioned.

1) Bathing and washing clothes, animals and vehicles in the lake.

2) Discharge of waste water from hotels, commercial establishments, industries, health care establishments etc. into drains or pathways leading to the lake.

3) Discharge of sewage into the lake or into drains or pathways leading to the lake.

4) Mining of sand, granite, laterite, clay or soil from within 500 m from the lake periphery.

5) Storage of materials, polluted leachate from which is likely to flow towards the lake, within 500 m of the periphery of the lake.

6) Agricultural activities within 100 m of the periphery of the lake.

7) Catching of fish from the lake by explosives.

8) Construction of any sewage disposal facility (such as pit latrines) inferior to the minimum requirement of septic tank of IS 2470 Part-1 1985 design within 500 m of the periphery of the lake.

9) Disposal of overflow from septic tank into land other than through soak pit with concreted bottom, perforated ring or honeycomb

brick work sidewall and 45 cm thick sand envelope around within 500 m distance of the periphery of the lake.

(The concerned Local Self Government Bodies shall take action within one year to get inferior sewage disposal facilities converted to meet the minimum requirement stated in 8 and 9 above).

Sasthamcotta Village

Block No – 13

Re Sy No - 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76 77 78 81 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 119, 126, 127, 138, 141, 142, 150, 151, 152, 153, 154 ,155, 156, 157, 158, 159, 160

Block No – 14

Re Sy No - 207, 208, 209, 210, 211, 212, 213, 214, 215, 216,217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 229(Road), 230, 231, 232, 233, 234(Road), 235, 239, 241, 242(Road), 243(Road), 244

Block No – 15

Re Sy No - 152/1, 2, 3, 4, 8, 9, 12, 15, 16, 17, 18, 20, 22, 23
(Subdivisions)

West Kallada Village

Block No – 12

Re Sy No - 95, 97, 98, 99, 100, 101, 102, 103, 104, 106, 107, 108, 109, 110, 111, 119, 129, 130, 131, 132, 134, 240, 246, 247, 248, 249, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274,275, 276, 277, 278, 279, 282, 283, 284, 365, 368, 385, 386, 387, 391, 392, 393(Bund Road), 394, 395(Bund Road), 397(Bund Road), 398, 402, 405(Bund Road), 406, 407, 408, 410, 411, 416, 417

Mynagappally Village

Block No – 10

Re Sy No - 167, 168, 170, 173, 174, 175, 176, 178, 579, 580, 582, 584, 586, 587, 589, 590, 602, 604, 606, 607

Take notice that non-compliance with the aforesaid requirements and directions is liable to incur punishment of imprisonment for a term upto 6 years and fine.

Dated this the 9th day of June 2010.

FOR AND ON BEHALF OF THE
KERALA STATE POLLUTION CONTROL BOARD

JEYAPRASAD S.D.
CHAIRMAN

(Republished in the Government Gazette for public information)

NOTIFICATION FOR CONSTITUTION OF STATE WETLAND AUTHORITY KERALA

Kerala Gazette No. 49 dated 15th December 2015.
PART I

GOVERNMENT OF KERALA

Abstract

ENVIRONMENT DEPARTMENT—INTEGRATED MANAGEMENT OF WETLANDS IN KERALA—THE WETLAND (CONSERVATION & MANAGEMENT) RULES, 2010—STATE WETLAND AUTHORITY KERALA (SWAK) CONSTITUTED—ORDERS ISSUED

ENVIRONMENT (A) DEPARTMENT

G. O. (P) No. 157/2015/Envt. Dated, Thiruvananthapuram, 13th November 2015.

Read:—(1) D. O. No. J-22012/68/2003-CS(W)-Pt.V dated 23-12-2013, 14-3-2014 and 19-9-2014 from the Additional Secretary, Ministry of Environment and Forests, Government of India.

(2) D. O. No. J-22012/31/2013-C(W)-dated 10-1-2014 from the Additional Secretary, Ministry of Environment and Forests, Government of India.

(3) G. O. (Ms.) No. 08/2015/Envt. dated 25-5-2015.

ORDER

In exercise of the powers conferred by sub-sections (3) of section 3 of the Environment Protection Act, 1986 and in pursuance of the Rule 8(2) of the Wetlands (Conservation and Management) Rules, 2010 published as the notification of the Government of India in the Ministry of Environment and Forest, No. G. S. R. 951 (E) dated 4th December 2010, the Government of Kerala hereby constitute the State Wetland Authority Kerala (SWAK) comprising of the following members, namely:—

(i)	Hon'ble Minister (Environment)	— Chairman (Ex-officio)
(ii)	Principal Secretary (Environment)	— Convener (Ex-officio)
(iii)	Principal Secretary (Water Resources)	— Member (Ex-officio)
(iv)	Principal Secretary (Science and Technology)	— Member (Ex-officio)
(v)	Principal Secretary (LSGD)	— Member (Ex-officio)
(vi)	Secretary (Agriculture)	— Member (Ex-officio)
(vii)	Smt. B. G. Sreedevi, Director, National Transportation Planning and Research Centre, Thiruvananthapuram (NATPAC)	— Expert Member (Pollution Control)
(viii)	Dr. Beena, K., Head of the Department, Department of Zoology, Devaswam Board College, Sasthamkotta.	— Expert Member (Limnology)
(ix)	Shri S. Jain Mithra, Scientist, State Remote Sensing and Environment Centre, Thiruvananthapuram	— Expert Member (Hydrology)
(x)	Dr. Rajesh, R., Regional Director, Kerala Social Security Mission	— Expert Member (Ecology)

(2) The State Authority shall be the regulatory authority designated for the identified activities for management and wise use of Wetlands situated as described under Rule 7 and as defined as Rule 2 (g) of the Central Rules.

(3) The non-official member of the State Authority shall hold office for a term of 3 years from the date of issue of this order.

(4) An expert member in Biodiversity shall be nominated later.

(5) In pursuance of the G. O. (Ms.) No. 08/2015/Envt. dated 25-5-2015 the State Authority shall be registered as a Government owned society under the Travancore-Cochin Literary, Scientific and Charitable Societies Act, 1955.

By order of the Governor,

P. MARA PANDIYAN,
Principal Secretary to Government.

To

The Secretary, Ministry of Environment and Forests, Government of India (with C/L)
All Members of the State Wetland Authority, Kerala
Dr. Chidambara Iyer., J, Under Secretary, Environment Department
Director of Environment and Climate Change, Thiruvananthapuram
Finance Department
Law Department (vide Ref. No. 2824/Leg.F2/2015/Law)
The Principal Accountant General (A&E/Audit) Kerala, Thiruvananthapuram
Environment (B) Department
Information and Public Relations Department (Web and New Media)
Stock File/Office Copy.

Annex 11

Sectoral investment schemes and programmes relevant for management of Sasthamkotta Lake

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
Watershed Management	Land cover , Water sources, Erosion	Sedimentation		Integrated Watershed Management Programme		Department of Land Resources, Ministry of Rural Development, GoI (with support of the National Rainfed Area Authority (NRAA), Ministry of Agriculture , GoI)	State Level Nodal Agency (SLNA), Commissionerate of Rural Development	IWMP provides a platform for implementing watershed conservation in Sasthamkotta.	There is need for better inter-sectoral coordination to create synergies through convergence of sectoral programmes particularly through more active involvement of forest department and state biodiversity board
					Mahatma Gandhi National Rural Employment Generation Scheme				

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
					Protection of Catchments of Reservoirs of Water Supply Schemes (PCRWSS)		Department of Soil Survey and Soil Conservation	Watershed physical infrastructure can be implement in Sastahamkotta direct drainage basin	
				Prime Minister KrishiSinchayeeYojna		Department of Land Resources, Ministry of Rural Development, GoI (with support of the National Rainfed Area Authority (NRAA), Ministry of Agriculture , GoI)		This new government scheme can be used to augment watershed conservation practices	
					Sand Auditing of Kallada River		Department of Revenue and Disaster management	Ban on sand mining in Sastahamkotta direct drainage basin and associated marshes in Kallada River floodplain	Enforcement of government order, rules and acts for better implementation and monitoring
Water Resources Management					Jalanidhi Scheme (Kerala Rural Water Supply and Sanitation Project)		Kerala Rural Water Supply and Sanitation Agency	Repair and maintenance of rural water infrastructures to reduce wastage of water and optimise water use from Sasthamkotta Lake.	Excess water withdrawal without consideration of ecological needs and

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
					Quilon Water Supply Scheme		Kerala Water Authority	Optimum water withdrawal from lake and explore alternate water supply source from Kallada River for Kollam City	meteorological information
Wetland Management				National Wetland Conservation Programme			,	Catchment conservation, augmentation of biodiversity and prevention of pollution	
				Eco-restoration of Sasthamkotta Wetland			Suchitwa Mission Local Self Government Department	Control pollution load from the catchments to the Sasthamkotta Lake through implementation of appropriately designed site specific sanitation measures	
Environment Conservation					Ecosystem conservation through joint Biodiversity Management Committee		Kerala State Biodiversity Board (KSBB) , Forest Department and Local Self Government	Afforestation of bamboo and other trees all along the fringes and catchment of the lake . Coordination with the panchayat to cut down Acacia tree around the lake and deweeding of invasive macrophytes. Update and maintain People's Biodiversity Register (PBR) of Sasthamkotta Lake	

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
					Monitoring water quality of Sasthamkotta Lake		Kerala Pollution Control Board	Water quality of Sasthamkotta Lake is being monitored every month by collecting samples from various parts of the lake from 2011	
Fishery Development					Ornamental fishery development programme		Department of Fisheries	Breeding and rearing of ornamental fishes for women SHGs. Financial Assistance for setting up of backyard rearing cum breeding ground unit and technical support .	Fisheries infrastructure need to be maintain and developed
					MatsyaSamruddhiYojana		Department of Fisheries	Extension and training programme of fisher for sustainable fishing practice. Promote fresh water fisheries	
Tourism Development					District tourism promotion council (DTPC) Project		Tourism Department , Kerala	Important tourist infrastructure such as tourist interpretation centre, signages, etc. can promote for tourist guidance	Tourism feasibility need to be analysed for large scale tourism programme
Agriculture Development				RashtriyaKrishiVikasYojana				Awareness and training to the farmer abut sustainable agriculture practices and new eco friendly technologies	

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
Rural Development and Livelihoods					Kudumbshress		Local Self Government	Panchayat plan focus livelihood promotion provides financial and technical support to women led SHGs	
				Pradhan MantriAwassYojana - Gramin (Indira AwaasYojana)		Department of Rural Development		Housing support for SC/ST, minorities and physically disabled	Limited Coverage
				Swacch Bharat Abhiyan		Department of Drinking Water and Sanitation		The programme provides safe sanitation coverage through its individual components and improved solid /liquid waste management	Limited Coverage
				Mahatma Gandhi National Rural Employment Guarantee Scheme		Department of Rural Development	Ministry of Rural development, Government of India	The programme can provide assured employment to communities in Sasthamkotta Lake catchment and promote sustainable resource management practices to bring improved social and natural capital	
				DeenDayalAntyodayaYojana (Aajeevika)		Department of Rural Development		Livelihood promotion scheme providing capital support to individual and SHGs projects	

Sector	Key ecological character element that is (likely to be) influenced by sector policy environment			Schemes/Programmes in operation having relevance for management of Sasthamkotta		Nodal implementing agencies		Opportunities for sectoral programing providing support for Integrated Management of Sasthamkotta	Gaps within sectoral programmes that need to be addressed for integrated management of Sasthamkotta
	Component	Processes	Services	National (CSS)	State	National	State		
				RashtriyaSwasthBimaYojana				Scheme provide health insurance coverage to Below Poverty Line (BPL) families	
				Pradhan Mantri Jan-DhanYojana		Department of Financial Services, Ministry of Finance		Ensure financial access, namely Banking/Savings, Remittance, Credit, Insurance and Pension in an affordable manner.	
				Pradhan Mantri Suraksha BimaYojana		Department of Financial Services, Ministry of Finance		Accidental coverage (sum-insured) under the scheme is Rs. 2 Lakh	
				Pradhan Mantri Jeevan JyotiBimaYojana		Department of Financial Services, Ministry of Finance		Provides death coverage (sum-insured) under the scheme is Rs. 2 Lakh	
				Integrated Child Development Services		Department of Women and Child Welfare		Services available under the scheme: Supplementary Nutrition, Immunization, Health Check-up, Referral Services and Pre-School Education	

LIST OF EQUIPMENT FOR WETLAND MONITORING

Hydrological Equipment and Material

- Automatic Weather Station
- Sunshine recorder
- Automatic water level recorder
- AA Current meters
- Stream gauge
- Piezometer
- Staff gauge on permanent piers
- Wireless Station
- Thermo-hydrograph
- Digital depth- temperature analysers
- Ecosounders
- Fibreglass boat with outboard motor
- Poles fixed for float observations
- Wading rods and cable and drum (cranes) for lowering current meters

Fisheries Equipment

- Fishing gears
- Plankton nets
- Buoys
- GPS
- Fisheries Assessment Softwares (ELEFAN, CEDA, etc)
- Fish base Application – Fish identification
- Fibreglass boat with outboard motor

Research Equipment

- DR 4000 Spectrophotometer
- UV spectrophotometer
- Digital pH and conductivity meters
- Multiparameter Water quality meter
- Water quality multi parameter probes
- Paqua Lab with bacteriological assembly
- Colorimeter
- Distillation unit
- Kjeldahl assembly
- Incubators
- Autoclave
- COD digester
- BOD Incubator
- Burette
- Automatic pippettes
- Digital Flame photometers
- Electronic Balance
- Centrifuge machines
- Cold centrifuge machine
- Grinders
- Automatic sieves
- Hot air oven
- Magnetic stirrers
- Burners & heaters
- Ekmans Grab and potable dredgers
- Plankton samplers
- Glassware and Chemicals

GIS Equipment

- GIS softwares (Erdas, ArcGis, QGis, etc)
- GIS workstation
- Plotters
- A0 size scanner
- GPS

Computing and Networking Equipment

- Desktop (I 7)
- Laptop
- Laser printer Colour A3
- Online UPS 2KVA
- Broadband Internet connection
- MS Office software and other software

Documentation and Display equipment

- Photocopier
- LED Projector
- LED Panel
- DSLR Camera with tripod
- Binoculars

Facilities

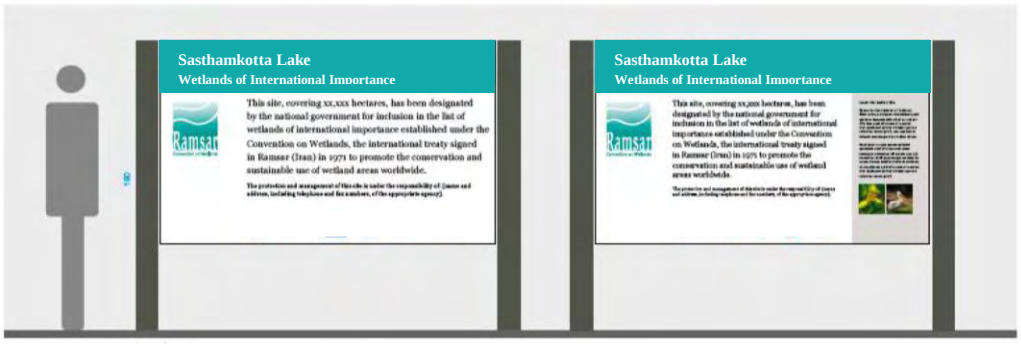
- Furnishing and accessories
- Vehicle
- Silent Generator 15 KVA

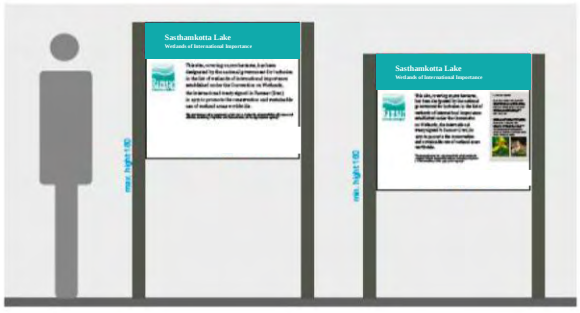
GUIDANCE ON SIGNS FOR RAMSAR SITES

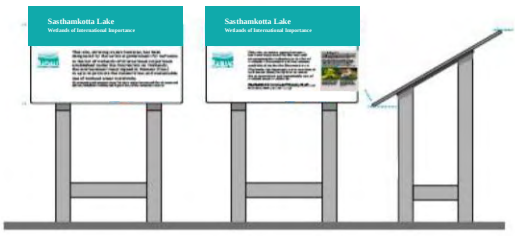
Guidance on signs for Ramsar Sites

11 January 1997

At the 19th meeting of the Ramsar Standing Committee, 29 October-1 November 1996, the members adopted a decision that defines recommended wording for signs at all Ramsar Sites, when translated into the local languages of the sites.







The decision reads as follows:

Decision 19.18: The Contracting Parties should endeavor to place descriptive signs at all Ramsar Sites, and these signs should include the Ramsar logo, as well as the following suggested text as amended to meet particular circumstances:

THIS SITE, COVERING 373 HECTARES, HAS BEEN DESIGNATED BY THE NATIONAL GOVERNMENT FOR INCLUSION IN THE LIST OF WETLANDS OF INTERNATIONAL IMPORTANCE ESTABLISHED UNDER THE CONVENTION ON WETLANDS, THE INTERNATIONAL TREATY SIGNED IN RAMSAR (IRAN) IN 1971 TO PROMOTE THE CONSERVATION AND SUSTAINABLE USE OF WETLAND AREAS WORLDWIDE.

The protection and management of this site is under the responsibility of: [name and address, including telephone and fax numbers, of the appropriate agency].

Variation for countries with a federal system:

ON THE PROPOSAL OF [NAME OF THE STATE/PROVINCIAL GOVERNMENT], THIS SITE, COVERING [xxx] HECTARES, HAS BEEN DESIGNATED BY THE NATIONAL GOVERNMENT .... [continues as above]

Sasthamkotta Lake
Wetlands of International Importance

Ramsar
Convention on Wetlands

This site, covering 373 hectares, has been designated by the national government for inclusion in the list of wetlands of international importance established under the Convention on Wetlands, the international treaty signed in Ramsar (Iran) in 1971 to promote the conservation and sustainable use of wetland areas worldwide.

The protection and management of this site is under the responsibility of:
Department of Environment, Government of Kerala

Stay in touch

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