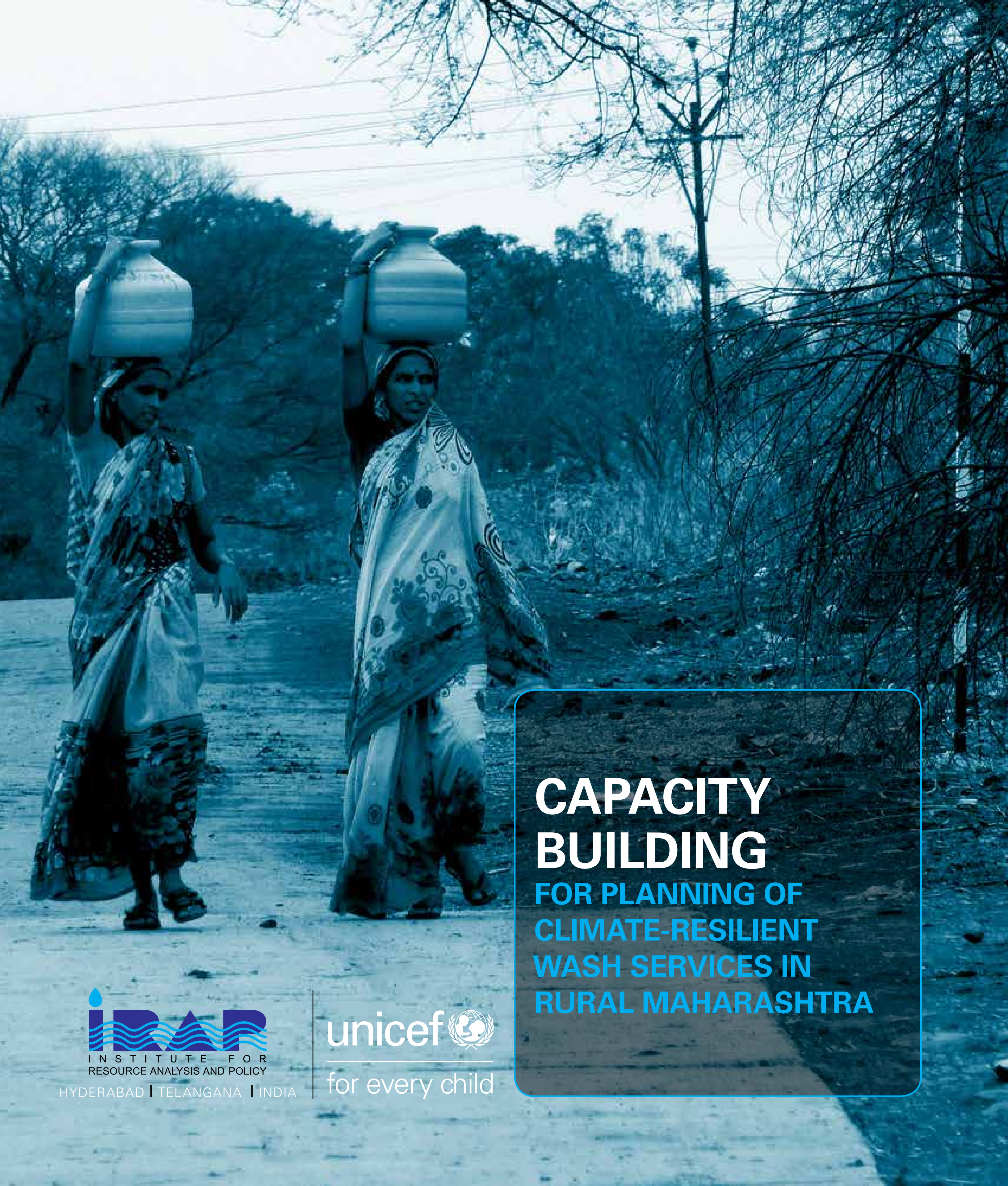

CAPACITY BUILDING

FOR PLANNING OF CLIMATE-RESILIENT WASH SERVICES IN RURAL MAHARASHTRA

INSTITUTE FOR RESOURCE ANALYSIS AND POLICY
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Content

List of Abbreviations

CCVI	Climate Change Vulnerability Index
CDRI	Climate Disaster Resilience Index
CRI-LS	Coastal Risk Index for Local Scale
DDMA	District Disaster Management Authority
DMA	Disaster Management Act
DMU	Disaster Management Unit
EOC	Emergency Operation Centre
FDRI	Flood Disaster Resilience Index
FVI	Flood Vulnerability Index
GoM	Government of Maharashtra
GR	Government Resolution
GSDA	Groundwater Surveys and Development Agency
GWP	Global Water Partnership
HH	Household
HR	Human Resource
HVI	Household Vulnerability Index
HWTS	Household water treatment and safe storage
ICE	Information, Communication and Education
IDRN	Indian Disaster Resource Network
IMD	Indian Meteorological Department
IRAP	Institute for Resource Analysis and Policy
Lpcd	Litre per capita per day
MDWS	Ministry of Drinking Water & Sanitation
MHA	Ministry of Home Affairs
MJP	Maharashtra Jeevan Pradhikaran
MoH&FW	Ministry of Health and Family Welfare
MSDMA	Maharashtra State Disaster Management Authority
MUWS	Multiple Use Water Systems
MWSSB	Maharashtra Water Supply and Sewerage Board Act
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NGOs	Non-Governmental Organizations
NVI	Net Volume Index
O&M	Operation and Maintenance
PHED	Public Health Engineering Department
RDMC	Regional Disaster Management Centres
RDPMU	Reform Support and Project Management Unit
RO	Reverse Osmosis
Rs	Rupees
SDMA	State Disaster Management Authorities
SDRF	State Disaster Response Force
SEC	State Executive Committee
SeVI	Socio-Economic Vulnerability Index
SPI	Standardized Precipitation Index
SVI	Social Vulnerability Index
ULB	Urban Local Body
UNICEF	United Nations Children's Funds
VOCs	Volatile Organic Compounds
WASH	Water, Sanitation and Hygiene
WEILAI	Water, Economy, Investment and Learning Assessment Indicator
WHO	World Health Organization
WMO	World Meteorological Organization
WSSD	Water Supply and Sanitation Department
WSSO	Water Supply and Sanitation Organization
WWRC	Watershed Water Resources Committee
ZP	Zilla Parishads

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Acknowledgement

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Executive Summary

Capacity Building for Planning of Risk Informed Climate-Resilient WASH Services in Rural Maharashtra was a project undertaken by Institute for Resource Analysis and Policy (IRAP) in technical and financial collaboration with the office of United Nations Children's Fund (UNICEF) in Mumbai, India. The project covered two divisions of Maharashtra State, viz., Marathwada and Vidarbha.

The project aimed at developing a composite index for assessing climate induced risk in Water, Sanitation and Hygiene; mapping the degree of risk in water and sanitation associated with climate hazards;identifying the technical and institutional innovations required to make WASH interventions of the Government resilient to climate-induced risks and their cost implications; and also,identifying the capacity building requirements of WASH sector line agencies to plan, design and execute climate resilient schemes for water supply and sanitation.

The methodology used for the study included the following: climate risk assessment mapping; mapping of WASH institutions and programmes, including a systematic review of international best practices in climate-resilient planning and design of WASH interventions, with particular reference to the natural, socio-economic and institutional contexts in which they work; costing of climate resilient WASH interventions; and identification of institutional capability building requirements.

The project used the following approaches: a)Review of national and international literature on a range of topics relating to climate-induced risk and resilience in WASH to understand the factors that determine the degree of climate hazards, the exposure of WASH systems to such hazards, and vulnerability of communities that are dependent on these exposed WASH systems to the hazards;b)Collection of secondary data from various official agencies on natural, physical, socio-economic and institutional factors which determine the hazards, exposure and vulnerability;c) Collection of details of various Government policies and programmes at the national and State level for disaster reduction and climate resilience, and d) Collection of primary data from sample villages/households.

The composite index developed for assessing climate risks in WASH has three sub-indices for assessing - the magnitude of hazard; the exposure of WASH systems to the hazard; and the vulnerability of communities to problems associated with WASH caused by climate hazard. The index uses a total of 28 different parameters, which pertain to nature, technology, socio-economic and institutional factors.The analysis based on this index indicatesthe highest climate-induced WASH risk in the districts of Parbhani (0.35), Osmanabad (0.31) and Nanded (0.31) in Marathwada. Akola and Washim districts of Vidarbha,with a score of 0.33 each, also fall in high risk bracket.

Analysis of the factors causing high climate risks showed that improving water infrastructure can play a significant role in reducing the hazard and exposure. Import of surface water from water-rich regions of Western Ghats, which has a rich endowment of river flows, would help reduce the hazard caused by meteorological droughts in Marathwada region. Dependable sources of water for irrigation as well as water supply would be required for improving food and nutritional security, consequently reducing malnutrition and infant mortality. Only this can reduce the region'svulnerability to impacts of drought.

Vidarbha region requires better drinking water supply and sanitation-infrastructure, despite better water endowment of the region with several perennial rivers. This could mean more number of large and medium surface reservoirs, and infrastructure for pumping and transporting this water to rural areas, and building distribution systems at the village level. If adequate and dependable source of good quality water is made available to the villagers, they may be motivated to go for individual HH level tap water connections, and also pay for the services.

Structural and non-structural disaster risk reduction plans and measures exist in Maharashtra. However, they are not specific to risks associated with poor water supply and sanitation. The current Government measures to reduce drought exposure comprising structural (such as construction of dams, and small water harvesting structures) and non-structural ones(-such as drought forecasting and warning) alone are unlikely to have any significant impact on reducing WASH related risks. On the contrary, they may increase the exposure of WASH systems to droughts. Similarly, the measures being proposed for reducing community's vulnerability to droughts through enhancing their awareness to drought-resistant crops and use of micro irrigation systems will not be effective in reducing WASH related risks.

Nevertheless, the non-structural measures such as strengthening the flood forecasting systems and creating additional infrastructure for flood warnings are very useful in reducing community vulnerability. Imparting training to the stakeholders involved in flood mitigation and management, organizing mock drills on flood rescue operations, etc., will be effective.

A major reform initiative of Government of Maharashtra is the decision to change water supply norm for rural areas to 140 lpcd, which is at par with urban areas. The unit cost (Rs/m3 of water) of future investments for drought-prone regions of Marathwada and Vidarbha will have to be much higher than the water-rich Konkan and Western Ghat regions for ensuring sustainable water supply.This is essential as the local water endowment is limited in drought prone areas and has to be imported from exogenous sources.

The current over-emphasis of the State Government on small-scale rainwater harvesting and watershed development as measures for drought proofing isa matter of concern.These measures will not be effective in chronically drought-prone Marathwadaregion, given the paucity of rainfall, its yearly variation, aridity, and high degree of water exploitation. On the contrary, as being observed in drought prone areas of Maharashtra, structures such as farm ponds can actually increase the exposure of WASH systems to droughts in rural areas. Farm ponds are observed to reduce the amount of water in the natural system that can be tapped by surface water and groundwater based supply schemes.

Capacity building Water Resources Department and the Water Supply and Sanitation Department for designing and executing projects that reduce climate-induced hazards and exposure is important. The first and the foremost step is to build the skills of technical officers of MJP to design reliable and dependable rural water supply systems in areas experiencing climatic extremes. The following are the important areas for skill building:

A. Hydrological modelling of river basins for climate change scenarios;

B. Designing surface reservoirs in flood prone areas for greater flood cushioning,

C. Designing reservoirs to increase multi annual storage of inflows from catchments in drought prone areas;

D. Importing water from water-rich regions to chronically drought-hit region of Marathwada;

E. Leakage detection and prevention in water distribution pipes of regional water supply systems;

F. Designing and operation of decentralized desalination systems;

G. Designing ecologicallysound sanitation infrastructure; and,

H. Designing, execution and operation of wastewater treatment systems

The report has provided a detailed capacity building training plan for agency professionals toundertake these measures, comprising topics to be covered, objectives, and target audience.

These measures should be complimented by strengthening financial capabilities to execute the related infrastructure projects. The type of infrastructure projects required to improve climate resilience of WASH systems include: i)large reservoirs having multi-annual storage capacity, in regions experiencing high inter-annual variability in rainfall and streamflows; ii)building infrastructure for transfer of water from water-rich regions of the State to chronically drought-prone areas; iii)building decentralized desalination systems in coastal areas affected by severe salinity and not served by piped water supply schemes; iv)building decentralized wastewater treatment systems for enabling reuse of water from domestic sector; v)rainwater harvesting in hilly andhigh rainfall hilly areas; vi) rehabilitation of dilapidated water distribution pipes in large water supply schemes; and, vii)raised hand-pumps, well-head protection walls, and raised latrines placed at a safe distance from water sources in flood prone areas.

I

Introduction

Maharashtra is in one of the most climate risk sensitive zones of India (Vedeld et al., 2014). The State displays high degree of spatial heterogeneity in climate, hydrology, geology, geo-hydrology, soils and topography resulting in significant regional variations in the availability of water resources. The State has pockets with cold and humid climate as also large areas under hot and arid climate. Rainfall varies drastically from over 3000mm in the Western Ghats, nearly 2500mm in the coastal areas to less than 500mm in Marathwada region. The topography varies from coastal plains to the hilly areas and high mountain regions of Deccan plateau (UNICEF/IRAP, 2013). With these unique natural conditions, compounded by inadequate water and sanitation infrastructure and presence of large populations living under poverty, vast areas of the State succumb to impacts of climate extremes.

Large parts of the State, especially the hot and arid areas of Marathwada and Vidharba, experience high annual and seasonal variation in weather conditions, particularly precipitation and temperature. Wells are the main water source for domestic supplies in rural areas in the hot and the arid regions. In these regions, water supply systems are threatened during drought years, as aquifers do not get adequately recharged. Drinking water shortage is felt even before the onset of summer, with agriculture claiming most of the underground water. In the high rainfall regions of Western Ghats, due to steep terrain and hard rock geology, very little water gets stored on the surface and in aquifers. In the summer months, with no major runoff and recharge inducing showers, wells dry up and there is acute shortage of drinking water. In such situations people tend to use contaminated water from non-conventional sources for washing, bathing etc., at the cost of personal hygiene. Though there is sufficient water available in large reservoirs located in high rainfall regions of the State, even during drought years, adequate infrastructure to transport this to water-deficit areas is absent. In the absence of adequate water to meet all needs, sanitation is a major casualty in all these areas. Even when households (HHs) have access to toilets they are abandoned due to acute water shortage.

A small geographical area of Maharashtra, estimated to be 0.23 m. ha, is prone to floods. Many parts of the State suffer from flash floods during monsoon, whose effects are compounded by poor drainage systems, especially in cities and towns. Floods also affect the plain areas of Konkan, which receive excessively high rainfall. Heavy rains and flash floods threaten rural HHs' access to water supply, as only 42.9% of the HHs have access to drinking water within the premises and a much smaller percentage (20.6) has access to treated tap water in their dwelling premises. Poor adoption of improved sanitation facilities in the rural areas (44.1%) (MoH& FW, 2016) and poorly-designed toilets, which do not take the natural and socio-economic factors into consideration in their design, increase the flood induced health risk. Unsafe open disposal of animal waste is another risk factor. Given the high prevalence of open defecation and disposal of animal waste in rural (44.2%) and open defecation in urban areas (51.9%) the flood waters with faecal matter also induce health risks in the form of water borne diseases by contaminating groundwater used for drinking purpose without treatment.

This project aimed at building institutional capacities to plan, design and develop climate-resilient water and sanitation systems in the rural WASH sector of Maharashtra. The efforts were to converge these capabilities with existing national and State flagship programmes on rural water, sanitation, and water resource management. The capabilities so devised were to subsume proper risk informed planning, based on climate risk assessment in two distinct regions of the State. The project was undertaken by Institute for Resource Analysis and Policy (IRAP) in technical collaboration with and financial support from UNICEF-Mumbai. It covered two distinct regions of Maharashtra with respect to natural, physical, socio-economic and cultural environments. The regions are: a) Marathwada - part of the Deccan plateau which is hot and semi-arid and drought prone, but agriculturally prosperous; and, 2) Vidarbha - hot and semi-arid, with hilly and undulating terrain, dominated by socially and economically backward, tribal communities. These communities mostly practice rain fed and subsistence farming, often resulting in high rate of migration from rural areas due to perennial water shortage for agriculture and other uses.

II

Objectives of the Project

The project had the following objectives:

1. Identify and map magnitude of various risks in water supply and sanitation in the context of climate variability and change;

2. Identify technical and institutional innovations required in the existing national as well as State Government water and sanitation programmes, to make water supply and sanitation interventions resilient to climate-induced risks

3. Assess cost implications of making various water supply and sanitation interventions climate resilient in the State

4. Identify capacity building requirements of various line agency personnel in water and sanitation sector to enable them plan, design and execute climate resilient schemes relating to water supply and sanitation

III

Conceptual and Analytical Frameworks for Assessing Climate Risks in WASH Sector

01. Climate Risk Assessment and Mapping

Climate risk is composite of hazard, exposure and vulnerability (WMO, 2014). The degree of risks in water supply and sanitation induced by climate variability and change depends on a variety of cultural, economic, environmental, institutional, natural, physical, and social factors. For development of climate-resilient WASH programmes in any locality there is a need to understand factors influencing climate risks and the local vulnerability to these factors are important (source: based on GWP & UNICEF, 2014; UNICEF, 2016).

The magnitude of climate induced hazards to WASH system is determined by a host of natural and physical factors. The hazards can be in the form of hydrological droughts, floods, cyclones, waterlogging of low lying areas, severe contamination of surface water bodies and shallow aquifers with biological matter and pathogens, groundwater depletion with resultant drying up of reservoirs, and the like. For instance, low to medium rainfall regions may experience high year to year rainfall variability, whereas there could be high dependability in high rainfall regions. In hard rock areas of Deccan plateau, which also coincide with low to medium rainfall region, monsoon failure results in groundwater droughts.

The degree of exposure of WASH systems to climate hazards is determined by a range of natural, physical, socio-economic and institutional factors. The exposure could be in the form of reduced water supply from the public system for domestic needs, including personal hygiene and sanitation. This could be due to one or more of the following reasons:

- Reduced water availability in natural system because of hydrological drought;
- Breakage/damage to water supply pipelines during heavy storms, cyclones and floods;
- Damage to sanitation infrastructure (toilets, sewerage systems) due to cyclones and floods;
- Damage to improved water sources and sanitation facilities due to flooding and cyclones;
- Contamination of potable water carried through pipes from sewage due to pipeline breakage,
- Contamination of water in shallow drinking water wells.

The degree of community vulnerability to climate induced risks in water supply and sanitation is determined by a whole range of natural, social, cultural, economic and institutional factors (Kabir et al., 2015). This vulnerability can be in the form of –

- Lack of alternate sources of fresh water private wells, ponds and hand pumps for drinking, domestic and livestock uses;
- Absence of buffer storage of water at the household level;
- Lack of facilities for treatment of contaminated water for potability;
- Lack of financial resources with communities and HHs to create temporary infrastructure for sanitation;
- Absence of information and community systems available to spread warnings about incoming floods, cyclones, potential water contamination, damage to water infrastructure, spread of water borne diseases, and the areas likely to be affected;
- Poor or lack of access to medical facilities to protect members of the communities from water borne diseases; and
- Absence of social ingenuity within the communities to overcome crisis situations arising out of WASH hazards.

Maharashtra displays a wide variability in its natural environment (climate, hydrology, geology, geohydrology, soils and topography) across regions. Weather pattern are also noticed to vary between years. This variation results in the occurrence of climate-induced hazards such as hydrological droughts, groundwater depletion, waterlogging, and floods. The low to medium rainfall regions experience higher variability, which poses possibility of meteorological droughts. The low to medium rainfall regions with hard rock aquifers very frequently experience groundwater droughts as a result of monsoon failure. This phenomenon influences water availability and its quality in natural system for water supply purposes. This in turn affects quality of drinking water and its availability for domestic use.

The difference in natural environment also has varying impact on environmental sanitation exposure. For instance, shallow groundwater areas with sandy soils are most exposed to bacteriological contamination of drinking water wells from faecal matter due to poor sanitation during floods. The natural environment also determines the community vulnerability to health problems associated with poor sanitation and hygiene through waterlogging, flooding, water contamination, temperature changes, etc. For instance, vector-borne diseases spread faster in cold and humid climates as compared to hot and arid ones. Under poor sanitation conditions, both water-borne and water-based diseases spread faster in high rainfall, humid, plain areas as compared to low rainfall and arid areas with good natural drainage.

There is also a wide variation in the physical factors governing the supply of water (with respect to space and time) and access to water supply and sanitation facilities across Maharashtra. Water control (flood control dams, reservoirs for water storage), distribution and supply infrastructure vary in terms of size and other technical features. To add to this, sanitation systems varies in terms of their ecological soundness - from simple, single pit latrines to double pit latrines to septic tanks to household latrines connected to sewerage systems. The type and characteristics of water control, supply and distribution, as also sanitation infrastructure, influences the magnitude of climate induced hazards. With this there is the likelihood of WASH systems getting exposed to these natural hazards.

The socio-economic and cultural profiles of the people affected by lack of access to water sources, sanitation facilities. Use of water for domestic and productive needs, also vary between the regions. This variation determines not only the exposure of the communities to climate induced water-related hazards, but also the vulnerability to these hazards. As to the exposure, poor communities living in low-lying areas, especially in cities and towns, generally fall victim to flooding and waterlogging problems and face the risks associated with water contamination and poor sanitation. This is mainly due to lack of proper drainage and sewerage networks. The poor communities in remote rural areas and urban fringes also bear the brunt of water scarcity caused by droughts, which result in poor personal hygiene and sanitation. This is because most of them do not enjoy individual household water connections and instead are served by local sources such as hand pumps, public wells and stand posts, which become dysfunctional during such natural events. Generally these areas also suffer from lack of adequate infrastructure for water transportation through tankers etc. Apart from compromising on personal hygiene needs, members of such HHs are generally unwilling to adopt improved toilets and resort to open defecation, as fetching large amount of water from distant sources for flushing toilets etc., increase their hardship (IRAP, GSDA & UNICEF, 2013).

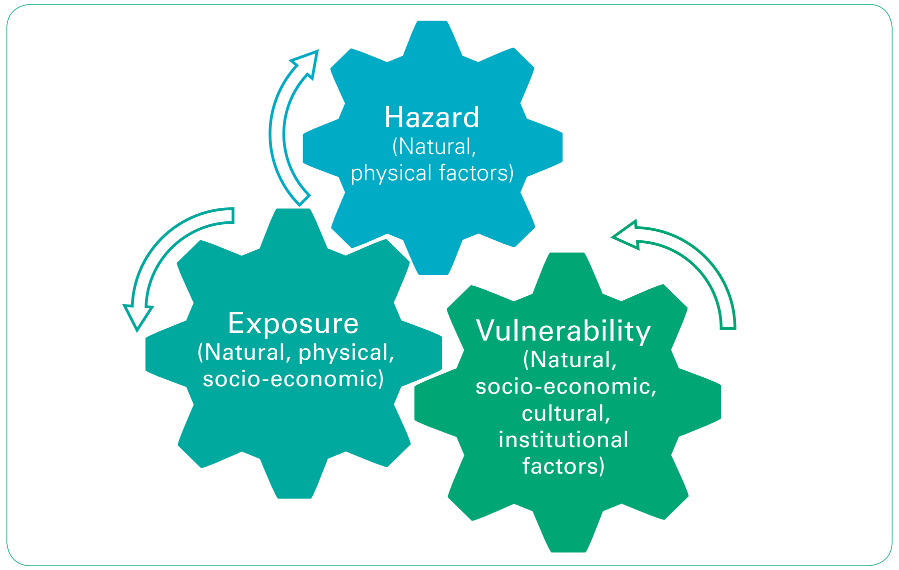
There is a linkage between socio-economic/ cultural profiles and 'vulnerability', during natural hazards. The socially and economically backward communities often receive the emergency aid from the local Governments, aid agencies, and NGOs in the form of clean drinking water, medicines, water purifiers, water treatment systems, temporary shelters, food, etc., very late owing to types of localities they live in. Because of this they are more vulnerable than people living in rich localities. On the other hand, certain cultural taboos come in the way of socio-economically rich communities from offering the most needed water supply and sanitation facilities support to their counterparts from backward communities during emergencies.

Enhanced institutional capabilities in WASH sector can greatly reduce the exposure and vulnerability of the communities to climate induced natural hazards through a variety of ways and means. These include the following:

01. Planning, design and building of river valley projects for water security and flood control;
02. Designing and building climate-resilient water supply and sanitation systems;
03. Designing and executing early warning systems for disasters (floods, cyclones, intense storms, etc.);
04. Employing an effective 'disaster response force'; promoting improved hygiene practices; and
05. Educating the masses about precautions to be exercised during disasters, with respect to use of water for drinking, sanitation and hygiene practices.

Though there isn't much variation in the institutional environment with respect to the capability of State institutions in the WASH sector across regions, the overall institutional environment and capability would change from region to region, owing to the presence of local institutions and external agencies promoting WASH activities in certain localities. This can have implications for both exposure to climate-induced hazards and to its vulnerability.

Diagram 1: The Framework for Assessment of Climate Risk



From the foregoing discussions, it is quite evident that for assessing climate induced risks in water and sanitation there is a need to develop theoretical understanding of the following:

01. How various natural (hydrology, climate, geology and topography) factors determine the degree of occurrence of climate hazards in different regions;

02. How various physical factors (types and characteristics of water and sanitation infrastructure) influence both the magnitude of climate-induced hazard and the exposure of communities to these hazards;

03. How various socio-economic factors determine exposure of entire WASH system and vulnerability of the communities to hazards; and

04. How institutional factors influence exposure and vulnerability of communities to climate induced hazards in water and sanitation.

Based on this theoretical understanding, along with a quantitative and qualitative mapping of the prevailing water and climate conditions with respect to natural environment of physical systems related to water and sanitation, the following factors were assessed and mapped for these regions:

- Socio-economic profile;
- Institutional environment prevailing in the two distinct regions of the State;
- Degree of hazards;
- Degree of exposure of communities and the vulnerability to water supply and sanitation hazards.

A composite index was developed to assess the overall 'climate-induced risk' in water and sanitation, which captures the degree of hazard, exposure, and vulnerability. The values of this index were computed for two distinct 'regions' - each one characterized by a unique natural, physical, socio-economic and institutional characteristic. The computed values were mapped on a GIS platform.

02. Mapping of WASH Institutions and Programmes

The existing Government institutions and programmes in WASH sector were mapped in relation to their ability to -

01. Check climate-induced hazards, including hydrological droughts, floods and waterlogging, groundwater contamination and groundwater mining through various technical and institutional measures;

02. Prevent or reduce the exposure of WASH systems to climate induced hazards such as hydrological droughts, floods, cyclones, waterlogging through various planning and design innovations, and technological and institutional measures; and,

03. Target the WASH programmes for the benefit of the most vulnerable communities, and implement measures to reduce their vulnerability to climate induced hazards.

The focus was on the unique features of these institutions (their structure, legal and regulatory powers, finance, HR capability, policies and strategies) and programmes (engineering solutions, size, target areas, investments) that enable them to alter the factors climate risk estimates are most sensitive to.

Following these assessments, which led to identification of institutional and programmatic inadequacies, a systematic review of international best practices in climate-resilient planning and design of WASH interventions was undertaken, with particular reference to the natural, socio-economic and institutional contexts in which they work. All these helped to identify the key technical and institutional interventions for climate resilient WASH programmes that are suitable for Maharashtra.

03. Costing of Climate Resilient WASH Interventions

After identifying the institutional change needs and required improvements in current technological strategies and engineering interventions for making the WASH systems 'climate-resilient', the cost estimates of introducing various technological improvements and new technical solutions in WASH were carried out. In costing, the focus was on the new structural features, capacity building and operational aspects of the technical systems[1].

04. Identification of Institutional Capability Building Requirements

An action plan for training and capacity building in the WASH sector was developed based on the identified institutional changes. The plan suggests improvements in technical strategies and engineering solutions for promoting climate-resilient WASH programme. The emphasis here was on planning, design, execution, operation, and management of those interventions.

1. This covered water storage infrastructure such as dams (including small dams), water conveyance and distribution systems, roof water harvesting systems, artificial recharge systems, household level water storage tanks, decentralized water treatment systems, various types of latrines, and decentralized sewage treatment and disposal systems.

IV

Climate Risk and Resilience: Review of Literature

01. Vulnerability and Risk Induced by Climate Hazards in WASH

A review of available literature was undertaken to -

- Identify the factors that influence -
  - Climate-induced hazards in water, sanitation and hygiene (WASH);
  - Exposure of water and sanitation systems to the hazards;
  - Vulnerability of communities to the problems associated with poor water supply and sanitation resulting from such exposure;
- How these factors influence the magnitude of hazards, and degree of HHs exposure and vulnerability.

The review is grouped under two themes: 1) regional studies on impact of climate risks for WASH sector; and 2) development and application of vulnerability indices to assess climate related hazards.

01.1 Studies on Climate Risk in WASH

Sisto et al. (2016) in their study evaluate the risk during sudden reduction in water supply in the Monterrey Metropolitan Area posed by climate threats and the vulnerability of its water supply system. The authors use long-term precipitation, water supply, and water availability data to show that the region has been subject to recurring period of exceptionally low precipitation and scarce surface water availability. The study identifies that during 1998-2013 the water supply system almost collapsed as reservoirs have deficient water due to abnormal dry weather condition. Precipitation data for the region was used to compute the Standardized Precipitation Index (SPI) to detect exceptionally dry or wet periods in the history. The Net Volume Index (NVI) was used to analyze vulnerability of the water supply systems by measuring the utilization rate of the system's effective storage capacity at a particular point in time. The authors argue that increased reliance on surface sources may have enhanced the water supply system's exposure to climate hazard. It is argued that surface water is more sensitive to climate variability than groundwater, especially in the short term, as low precipitation often results in scarce surface runoff and reservoir inflows. The study points to the existence of substantial water crisis risk in the region due to climate variability and its water supply system vulnerability. Climate change is expected to intensify this risk, while continued growth activity will amplify the consequences of a future water crisis. The authors argue that the risk associated with water shortages would increase in future due to climate change.

Gallina et al. (2016) review existing assessment methodologies for different types of risks used by different organizations for development of a single multi-risk methodology for climate change. This study reviews different research studies relating to multiple natural hazards assessment (e.g. flood, storms, droughts etc.) affecting the same region in different time periods. This study mainly focuses on the identification of multiple hazard types using different qualitative and quantitative approaches. The study reveals different assessment methodologies that capture vulnerability of multiple targets to natural hazards through vulnerability functions and indicators at the regional and local scale. The overall conclusion from the study is that multi-risk approaches do not capture the effects of climate change. They mostly rely on the analysis of static vulnerability. The main challenge is to develop a comprehensive list of indicators that is dynamic enough to account for different climate induced hazards and risks.

Satta et al. (2016) have developed an index based methodology for assessing climate related hazards. This regional coastal risk index was applied to a coastal area in Mediterranean Morocco at a regional scale. It provides a useful tool for local coastal planning and management. The tool explores the effects and extensions of the climate related and combining hazard, vulnerability, and exposure variables to identify areas where the likelihood of risk is relatively high. A panel of scientific experts and local policy makers were involved for assigning weights to each of coastal risk index indicators. The experts were asked to assign a score between 1 and 5 (5= high risk, 1= low risk) which described the relative contribution of each variable to the hazard, exposure and vulnerability. The results were presented on a GIS (geographical information system) platform. The study provided a set of maps that allowed identification of areas having higher risk from climate related hazards.

A handbook prepared by WaterAid and NIRAPAD (2012) focuses on safe water supply, sanitation and hygiene practices for rural areas in the wake of climate change. It highlights the basic concepts of the disaster risks in relation to climate change. Further, it discusses about the existing national policy structures and institutional systems for ensuring safe water, sanitation and hygiene practices as well the strategies to cope with the climate change disaster induced uncertainty. The strategies to manage climate change and disaster induced uncertainties are as follows:

01. Use of appropriate and effective technologies to ensure water supply, sanitation services and hygiene practices in the changing circumstances. The current and the traditional sources of water, and traditional technologies should be assessed to understand whether and to what extent they could serve the purposes.

02. Cost sharing through economic services. Disaster risk and climate risk will increase the cost of safe water supply and sanitation services. Therefore, service pricing should follow economic principles and make the consumers share a part of the cost.

03. Create cost-benefit awareness, as rising costs of the services may negatively influence the demand for water at household and personal levels.

04. Subsidise the poor and disadvantaged HHs as they may find it difficult to bear the increasing cost of the services. Therefore, affordability should be carefully assessed in promoting new technologies. It is important to ensure that the economic pricing doesn't deprive the disadvantaged and the poor HHs.

05. Accountability and community participation should be involved in both planning and implementation process. They should be built in at national level planning process.

06. There is a need for the local government bodies to take part in supply and distribution of water and sanitation programme. Private and voluntary agencies could also participate in their efforts.

01.2 Various Indices on Climate Vulnerability and Resilience

Study	Study Region	Vulnerability Index	Indicators	Methodology and Outcome
A) Multiple Use Water Services to Reduce Poverty and Vulnerability to Climate Variability and Change: A Collaborative Action Research Project in Maharashtra, India (IRAP, GSDA & UNICEF, 2013)	Maharashtra	Multiple Use Water Systems (MUWS) Vulnerability Index	Twenty parameters were identified and grouped under six sub- indices: **A. Water Supply & Use** (Access to water supply source, Frequency of water supply, Ownership of alternative source "owned", Access to other alternative source, Capacity of domestic storage systems, Quantity of water used, Quality of domestic water supplies, Total monthly water bill as a percentage of monthly income), **B. Family Occupation & Social Profile** (Family occupation, Social Profile, Health expenditure), **C. Social Institutions and Ingenuity** (Social institutions and Ingenuity), **D. Climate & Drought Proneness** (Climate of the regions, Aridity and drought proneness), **E. Condition of Water Resources** (Surface and groundwater availability in the area, Variability on resource conditions, Seasonal variation, Vulnerability of the resource to pollution or contamination) and **F. Financial Stability**	The MUWS Vulnerability Index is composed of six sub-indices which were identified based on expert knowledge and literature review. For computing the index, a survey was undertaken covering rural HHs in Maharashtra. The index has a maximum value of 10.0 representing lower vulnerability and minimum value of 0.0 representing higher vulnerability.
B) An index based methods to assess the risks of climate related hazards in coastal zones: The case of Tetouan (Satta et al., 2016)	Coastal zone of Tetouan Mediterranean Moroccan Coast	Multi-Scale Coastal Risk Index for Local Scale (CRI-LS)	Nineteen variables were categorized under three sub-indices: **A. Coastal Hazards** (Sea level rise, storms, Mean annual max daily precipitation, Droughts, population growth, Tourism arrivals), **B. Coastal Vulnerability** (Landforms, Coastal slope, Historical shoreline change, Elevation, distance from the shoreline, River flow regulation, Ecosystem health, Education level, Age of population, Coastal protection structures), **C. Coastal Exposure** (Land cover, Population density)	A panel of scientific experts and local policy makers were involved for assigning weights to each identified indicator for developing a coastal risk index. The experts assigned a score between 1 and 5 (5= high risk, 1= low risk) which described the relative contribution of each variable to hazard, vulnerability and exposure. The index values were used to prepare maps for identification of coastal areas with relative higher risk from climate related hazards.

Study	Study Region	Vulnerability Index	Indicators	Methodology and Outcome
C) The Socio-Economic Vulnerability Index: A pragmatic approach for assessing climate change led risks-A case study in the south western coastal Bangladesh (Ahsan and Warener, 2014)	Seven unions of Koyra Upazilla, South-Western Coastal Bangladesh	Socio-Economic Vulnerability Index (SeVI)	Five domains consisting of 27 indicators: A. Demographic (Population density, Percentage of old and children in sample, Male-Female ratio in sample, etc.), B. Social (Percentage of illiterate HHs in sample, Percentage of HHs not having brick built house in sample, etc.), C. Economic (Percentage of HHs depends on natural source for their income (fisheries, agriculture etc.) in sample, Percentage of consumption expenditure on food in sample, etc.), D. Physical (Percentage of HHs not getting electricity, Percentage of HHs not having sanitary latrine, Percentage of HHs using ponds, etc.), E. Exposure to Natural Hazards(Percentage of HHs not willing to go cyclone shelter, Percentage of HHs not having shelter in cyclone shelter or with neighbours, etc.)	The SeVI was developed using five domains which include physical, economic, social, demographic and exposure to natural hazards. Both primary and secondary data were used for development of the index. Indicators were identified based on the Focus Group Discussions (FGD) and through administering a questionnaire on 60 HHs from each region. The experts gave a relative weightage to each indicator, between 1 and 5 on the basis of importance of each indicator.
D) Climate Change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. (Dumenu and Obeng, 2016)	Four ecological zones of Ghana	Social Vulnerability Index (SVI)	Six indicators are grouped under three domains: A. Demographic (Household size, Literacy), B. Economic (Diversified sources of income, Climate sensitive occupation) and C. Social (Access to climate change information, Dependence on forest resources)	Authors use six demographic, social and economic indicators in assessing social vulnerability to climate change. Indicators were identified through expert judgment. Primary data was collected through questionnaire and interviews of 196 HHs in 14 rural communities. Qualitative and quantitative tools were used for data analysis.
E) Measuring household vulnerability to climate-induced stresses in pastoral rangelands in Kenya; implications for resilience programming (Opiyo et al., 2014)	Turkana County, North-Western rangelands of Kenya.	Household Vulnerability Index (HVI) matrix (Vulnerability= Adaptive capacity – (Sensitivity+-Exposure)	Twenty-seven indicators have been identified under three major domains A. Social Vulnerability variables (Sex of HH head: female headed, Age of HH head: 50+ years, Experiences in the area: less than five years, HH size: more than 5 persons etc.), B. Economic variables (Non-firm income: HH with no firm income, Herd size in TLU: own less than 2 TLUs, Herd structure: no milking herd, Distance to Market: more than 10 km away, etc.), C. Environmental variables (Climate change: experiencing change, Temperature: experiencing increase, Drought: noticed increasing events, Flood: notice change, etc.)	The study uses various statistical and economic tools to measure vulnerability in the region. Twenty-seven socio-economic and biophysical indicators were considered which were identified through questionnaire survey of 302 HHs. Principal Component Analysis (PCA) method was used for assigning weightage to each identified indicator and compute HVI to classify HH according to their level of vulnerability.

Study	Study Region	Vulnerability Index	Indicators	Methodology and Outcome
F) Climate Disaster Resilience of Dhaka City Corporation: An Empirical assessment at Zone Level (Parvin and Shaw, 2011)	Dhaka city, Bangladesh	Climate Disaster Resilience Index (CDRI)	The authors have identified 125 variables under 25 parameters in five main domains. A. Physical (Electricity, Water, Sanitation and solid waste disposal, Accessibility to roads, Housing and Land use) B. Social (Population, Health, Education and Awareness , Social Capital , Community preparedness during a disaster) C. Economic (Income, Employment, Household assets, Finance and saving, Budget and subsidy) D. Institutional (Mainstreaming of DRR and CCA , Effectiveness of cities crisis management framework , Knowledge dissemination and management , Institutional collaboration with other organizations and stakeholders , during disasters , Good Governance. E. Natural and related Parameters (Intensity/severity of natural hazards ,Frequency of natural hazards , Ecosystem services , Land use in natural terms , Environmental policies	Authors use Climate Disaster Resilience Index (CDRI) for analyzing risk for 10 zones of Bangladesh. The data was collected by administering questionnaire on the planners involved in preparation of Detailed Area Plan (2009) in Dhaka city.
G) Mapping Vulnerability to Climate Change (Heltberg and Osmolovskiy, 2010)	Tajikistan	Climate Change Vulnerability Index (CCVI = Adaptation + Exposure +Sensitivity /3)	Three determinants (Adaptive capacity, Sensitivity and Exposure) consists of 23 indicators A. Adaptive Capacity (HH consumption per capita, Share of population with higher education, Negative Herfindahl index of income diversification, Share of HH having trust in people etc.), B. Sensitivity (Negative of the amount of irrigated land per capita, Herfindahl index of agricultural land use diversification, share of HHs depending on agriculture, Share of population under age 5etc), C. Exposure (Variability of average temperature in month, Variability of average precipitation in month, Range between maximum and minimum average temperature in month, Frequency of extremely hot months, when average temperature higher than 300C, Frequency of extremely cold months etc.)	Authors map areas which are most vulnerable to the impacts of climate change and variability. Vulnerability index has been derived as a function of the exposure to climate change variability and natural disasters; sensitive to impacts of that exposure and capacity to adapt to ongoing and future climate changes. The index can be used for decision making about adaptation responses that might benefit from an assessment of how and why vulnerability to climate change varies regionally.

Study	Study Region	Vulnerability Index	Indicators	Methodology and Outcome
H) Water and Poverty in Rural China: Developing an Instrument to assess Multi dimensions of Water and Poverty (Cohen and Sullivan, 2010)	Rural areas of China	Water, Economy, Investment and Learning Assessment Indicator (WEILAI)	Twenty-three sub-components identified under nine components A. Water Resources (Primary HH water source for HH use and limited HH agricultural use, etc.), B. Water Access (Is water affordable if HH were required to pay, Distance travelled to collect water, Time needed to collect water etc.), C. Water resource management capacity (Existence of a water user group in AV and awareness of it, HH's participation in any type of water management/use etc.), D. Sanitation (Type of sanitation facilities, HH perceptions of their sanitation etc.), E. Education (Children access to education, Student/teacher ratio, Teachers level of training), F. Health and Hygiene (Access to healthcare, Affordability of healthcare etc.), G. Food Security (Area of arable land HH uses/had access to, HH is a net food consumer or exporter, etc.), H. Environment (Degree of erosion due to environmental deterioration, Secondary measures of deteriorating environment around HHs: insects etc.)	The paper describes the theoretical developmental of a multidimensional, water-focused, thematic indicator of rural poverty. It is based on the identification of indicators, assigning weightage to indicators, methodology, field studies and statistical analysis. For the purpose, 534 HHs across 71 villages in China were surveyed. PCA was used for assigning weightage to each indicator. Based on the assigned weightage, the vulnerability index was developed.
I) Quantitative Assessment of Vulnerability to Flood Hazards in Downstream Area of Mono Basin, South-Eastern Togo: Yoto District (Kissi et al., 2015)	North-East Maritime Region, Yoto District	Flood Vulnerability Index (FVI)	Twenty-four indicators identified in three sub domain: A. Exposure (Flood frequency, Flood Duration, Flood water level, Closeness to river body, Altitude), B. Susceptibility (Percentage of Education: no schooling, Household size(more than 10%), Female headed, Farmers, Poor building material, HH with affected land, Community Awareness, HH coping mechanisms, Emergency services, HH past experience, HH preparedness), C. Resilience (Percentage of Warning systems, HH perception on flood risk, HH evacuation capability, HH flood training, Recovery capacity, Recovery time, Long term resident 10 year +, Environmental recovery)	Focus is on development of vulnerability framework and distinguishing three main components (exposure, susceptibility and resilience), to allow an in depth analysis and interpolation of indicators. For normalization, the actual data was transformed to a standardized score (between 0 and 1).

Study	Study Region	Vulnerability Index	Indicators	Methodology and Outcome
J) Identifying and Visualizing Resilience to Flooding via a Composite Flooding Disaster Resilience Index (Perfrement and Lloyd, nd)	Sixteen municipalities in the Greater Amsterdam	Flood Disaster Resilience Index (FDRI)	The FDRI has developed 11 indicators in four domains: A. Social Environment (Age, Transportation Access, Net Migration), B. Built Environment (Medical Capacity, Transportation network), C. Natural Environment (Runoff, Soil Permeability, Elevation (water level)), D. Economic Environment (Employment, Wealth, Economic damage for flood volumes)	Study developed a composite flooding disaster resilience index (FDRI) by aggregating individual resilience indicators under social, natural, built and economic categories. Sixteen municipalities across the Greater Amsterdam region were surveyed. The FDRI is a single figure summarizing a region's status on 11 indicators that influence the resilience of a region to natural hazards. A panel of 18 flood experts were asked to rate each indicator based on its correlation to the resilience level. Each indicator was ranked between 1 and 4.

02. Innovations and Best Practices for Improving Climate Resilience in WASH: Global Review

02.1 Managing Water Quantity

Small scale rainwater harvesting is being promoted as a measure for improving climate resilience in all sectors of water use, particularly agriculture and domestic water supply (see, Barron, 2009: p X). However, such prescriptions are not based on a scientific evaluation of its effectiveness in the physical environment vis-à-vis hydrology, geology, geohydrology, topography and soils. Globally there is no study on its effectiveness in regions that currently experience or likely to experience climate extremes.

In regions with high rainfall, rainwater harvesting increases climate resilience because it expands the capacity to store water. It is also an effective option particularly in areas where annual rainfall has poor reliability and water supply infrastructure is poorly developed, as in sub-Saharan Africa. Rainwater is collected from rooftops to provide drinking water to the household, irrigation and the like. The systems used for harvesting rainwater are being managed and operated at the household level. Along with providing a safe and sufficient water supply, rainwater harvesting also reduces burden of fetching water. HHs can also spend more time on educational and social activities. Multiple years of storage may be required to bridge low rainfall periods. This will build in redundancy for possible low rainfall and longer dry seasons. It also ensures flood protection.

For runoff harvesting, rainfall has to exceed a threshold. This threshold would vary according to nature of the soil and land cover of the area. However, the actual runoff rates would depend on strength of the correlation between rainfall and runoff in a given basin. This relation weakens if there is a major year to year change in rainfall intensity and pattern (Kumar et al., 2006). Regions with lower mean annual rainfall experience higher variability and vice versa (Sharma, 2012). Hence, in regions with lower mean annual rainfalls, rainwater harvesting as a dependable source of water is likely to be low.

In the Indian context, it has been generally found that a greater magnitude of annual rainfall means more rainy days and smaller magnitude of annual rainfall means less rainy days (Pisharoty, 1990). This relationship holds true for the geographical area of Maharashtra as well. Fewer rainy days also means longer dry spells and thus greater losses from evaporation for the same region. Higher intensity of rainfall can lead to greater runoff occurring in short durations, limiting the effective storage capacity of rainwater harvesting systems to almost equal their actual storage size.

Evaporation is an important factor which adversely affects the performance of small water harvesting bodies. A significant proportion of the annual potential evaporation occurs during the rainy season, especially in the semi-arid and arid areas. High evaporation during the rainy season means losses from surface storage structures. It also means a faster rate of soil moisture depletion through both evaporation from barren soils and evapo-transpiration, which increase the rate and quantum of soil infiltration. This reduces the generation potential of runoff (Kumar et al., 2006).

Soil infiltration capacity can be a limiting factor for recharge. In sandy and sandy loam soils, the infiltration capacity of the recharge area can be sustained through a continuous removal of soils. But clayey soils have inherent limitations. Results obtained from short-term infiltration tests carried out in dug wells in Andhra Pradesh, in two different soil conditions, showed that the infiltration rate turns out negligible (< 0.60 mm/hour) within 10 minutes of starting the test in the case of silty clay, whereas infiltration stabilizes at a rate of 129.1 mm/hour up to the initial 25 minutes in the case of sandy loam (NGRI, 2000). If the infiltration rate approaches zero fast, it will negatively affect the recharge efficiency of percolation ponds. Thin soil cover has a low infiltration (Muralidharan and Athavale, 1998), the extent of the problem would be larger in hard-rock areas (ideal for percolation ponds) with thin soil cover. Based on several infiltration studies, Dickenson and Bachman (1994) have shown that the rate of infiltration declines to a minimum value within 4-5 days of ponding. This also will have adverse effects on the performance of structures built in areas experiencing flash floods and high evaporation rates. The solutions for this would be wetting or drying of pond-beds through the regulation of inflows.

For artificial recharge, storage potential of an aquifer vis-à-vis the additional recharge is determined by the characteristics in geological formations, and the likely depth of the dewatered zone. In hilly watersheds, the area available for cultivation is generally very low, keeping agricultural water demand low. At the same time, the surface water potential available for harvesting is generally high due to high rainfall and runoff coefficients. On the contrary, in valleys and plains, the area available for cultivation increases, raising agricultural water demand. The surface water potential available for harnessing is generally low in the plains due to lower rainfall, and low runoff coefficients owing to mild slopes, high PET, and deeper soil profiles.

02.2 Managing Water Quality

A. **Household water treatment and safe storage (HWTS):** HWTS treats water at home to improve the quality of drinking water and reduce waterborne diseases. Various treatment technologies from filters to disinfectants can be used for the purpose. It is cost effective and there are also simple systems available. It improves water quality at the point of use and increases climate resilience as it can still be used when other water sources are affected by a climate hazard.

B. **Boiling:** In an emergency, boiling is the best way to disinfect water that is unsafe due to the presence of protozoan parasites, bacteria, or viruses. Water should be filtered before boiling if it is cloudy. Filters designed for use when camping, coffee filters, towels (paper or cotton), cheese cloth, or a cotton plug in a funnel are effective ways to filter cloudy water. Place the water in a clean container and bring it to a full boil and continue boiling for at least three minutes (covering the container will help reduce evaporation). If people are more than 5000 feet above sea level, they must increase the boiling time to at least five minutes (plus about a minute for each additional 1000 feet). Boiled water should be kept covered while cooling. The advantage of boiling is removal of pathogens in water. Boiling also drives out some of the Volatile Organic Compounds (VOCs) that may be present in the water. This method works well for contaminated water with living organisms. Yet, boiling is not routinely used to treat drinking water except in emergencies because of the inconvenience.

C. **Distillation:** To remove impurities from water by distillation, the water is usually boiled in a chamber causing water to vaporize, and the pure (or mostly pure) steam leaves the non-volatile contaminants behind. The steam moves to a different part of the unit and is cooled until it condenses as liquid water. The resulting distillate drips into a storage container. Salts, sediment, metals - anything that won't boil or evaporate - remain in the distiller and must be removed. VOCs are good examples of contaminants that will evaporate and condense with water vapour. A vapour trap, carbon filter, or other devices must be used along with a distiller to ensure a more complete removal of contaminants. A good distillation unit produces very pure water with zero salt concentration. This is one of the few practical ways to remove heavy metals, nitrates, chloride, and other salts that carbon filtration cannot remove. But distillation takes time to purify water. It can take 2-5 hours to make a gallon of distilled water.

D. **Reverse osmosis:** RO systems are generally used when water has very high salt concentration (like in brine) and may not find many takers in Maharashtra. The average RO system is a unit consisting of a sediment/chlorine pre-filter, the reverse-osmosis membrane, a water storage tank, and an activated-carbon post filter. The advantage of reverse osmosis is that it significantly reduces salt, most other inorganic material present in the water, and some organic compounds. With a quality carbon filter to remove any organic material that gets through the filter, the purity of the treated water approaches to that produced by distillation.

E. **Water filtration:** Although there are many types of filters, the basic concept behind their working is fairly simple. The contaminants are physically prevented from moving through the filter either by screening them out with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles through the process of adsorption.

(Source: Drinking Water Methods, www.cyber-nook.com)

02.3 Improving Sanitation and Hygiene

A. **Pit latrines:** Pit latrines can be adapted to reduce vulnerability to floods and rising groundwater. A number of adaptations need to be made for the purpose. Latrines can be located on mounds, above the highest water level, or pits can be emptied regularly. Various designs are available to accomplish this. The adaptation can be based on specific environmental conditions.

B. **Raised or step latrines:** A raised or step latrine is the most appropriate option for on-site sanitation in areas with high water table. This is ideal for Konkan region of Maharashtra, which is endowed with high rainfall and excessive recharge from precipitation. The latrine pit should be dug at the end of the dry season to maximise the available depth of unsaturated soil. The pit can be lined with fired clay bricks, porous concrete, precast concrete rings, or ferro-cement. The lining can be extended above ground level to provide the required pit volume. The excavated material can be used to build up a mound or embankment around the latrine. This embankment (excluding the top 1.5 m) can be used for seepage of effluent from the pit if it is formed with permeable soil, and is well compacted with a stable side slope not exceeding 1:1.5. Embankment has to be thick enough to ensure that the effluent does not seep out of the sides of the mound. A slab should be constructed at least 0.5 meters above the highest water level. In case suitable fill material is not available to build up an embankment, it may be necessary to make the lining impermeable by plastering inner and outer sides of the pit/tank with cement. Raised pit latrine is a relatively expensive option and in areas which are prone to heavy flooding the pit may be rendered useless due to pit filling up with silt during rainy season, if not lined with cement or concrete.

C. **Shallow unlined or lined latrines:** Construction of shallow pit latrines of around 1.5m depth can be relatively cheap. This may be the best option available to HHs in areas where latrines are prone to flooding and get filled with silt. If land is readily available then an unlined pit would generally be abandoned when it becomes full and the household would dig a new one on their plot. If land is costly or if the pit is lined, then HHs may consider emptying out a pit when full. There is an obvious health risk associated with manual excavation and disposal of the contents.

D. **Aqua-privy latrines:** An aqua-privy consists of a latrine constructed above or adjacent to a watertight tank which collects the liquid effluent from the toilet. The excreta along with the water which is used for flushing fall into the tank through a vertical pipe. This pipe should extend at least 75 mm into the liquid so that a water seal is formed. In order to maintain the water seal, the fluid level in the tank must be maintained and this requires a bucketful of water each day to compensate for evaporation losses. The overflow pipe should be connected to a soak away drainage trench or sewer. Since this type of latrine has a very low water usage the volume of effluent discharging from tank will be small, but the effluent will be very concentrated. The tank needs to be periodically de-sludged and therefore it must be provided with removable cover.

V

An Index for Assessing Climate Induced Risk in Water and Sanitation

01. Index Development for Assessing Climate Induced Risk in WASH

For index development to assess climate induced risk in WASH, the factors influencing the three different dimensions in rural water and sanitation were identified and grouped as natural, physical, socio-economic, and institutional factors. These factors and relevant variables were identified based on the literature review, expert knowledge, and understanding of the study regions. Various factors and the ways in which they can influence climate-induced hazard, and exposure and vulnerability of the communities to these hazards are discussed in the subsequent sub-sections. A summary of discussion is also presented in Table 1.

01.1 Factors Influencing Climate-induced Hazard in WASH

Occurrence of hazards, droughts, floods and cyclone are mainly influenced by natural factors. These include rainfall and its variability, flood proneness, aridity, and overall renewable water availability. Above the normal rainfall usually reduces the probability of drought occurrence and helps in relieving water scarcity, and vice versa. As pointed out by Maliva & Missimer (2012), areas which receive low annual rainfall are at greater risk of having frequent droughts. In India, inter-annual variability in rainfall is found to be higher in regions of lower magnitude of (mean) annual rainfall (Sharma, 2012). Hence, such regions are likely to experience droughts more frequently as compared to those with lower variability (Kumar et al, 2006 & 2008).

Further, given the nature of relationship between rainfall and runoff in semi-arid and arid tropics, the impact of meteorological droughts in terms of hydrological stress in areas experiencing low (mean) annual rainfall is greater as compared to their counterparts receiving higher (mean) annual rainfall, for the same intensity of drought (in terms of SPI) (Source: based on Deshpande et al., 2016; James et al., 2015).

Flood prone areas are at a greater risk of recurring floods due to excessively high rainfall (Brouwer et al., 2007). Heavy rainfalls in the area can have adverse effect on surface water quality and groundwater which can contaminate water supply (Zimmerman et al., 2008; Brouwer et al, 2007). Another factor that influences water scarcity (during droughts) is the overall availability of annual renewable water in a region (Rijsberman, 2006). Renewable water availability of more than 1700 cum/capita/year is considered as secure (Falkenmark et al., 1989).

01.2 Factors Influencing Community's Exposure to Hazards

Community exposure to any hazard is influenced by several factors. Natural factors include depth to water table, climate, and groundwater stock. Groundwater at shallow depth will be susceptible to biological contamination during floods. High groundwater stock can play a vital role in buffering the effects of the risks posed during droughts (Calow et al., 2010). In areas with cold climate, exposure of community to the risks posed during a bad rainfall year will be low as overall water requirements will be less (Kabir et al., 2016a, 2016b). Areas with humid climate have a greater chance of outbreak of water borne diseases during floods (Githeko et al., 2016).

There are several physical factors influencing community exposure to hazards and they include characteristics of the water source, age of the water supply system, provision of buffer storage of water in reservoirs per capita, proportion of HHs covered by tap water supply, proportion of HHs having access to modern toilets, flood control measures such as dams and water pumping facilities. A perennial water source would significantly reduce community exposure to droughts. Further, an ageing water supply system is at a greater risk of damage and disruption during natural calamities such as floods and cyclones. Adequate provision of buffer water storage in reservoirs is one other important factor that can reduce exposure to water scarcity conditions during droughts (Kumar, 2010, 2016; McCartney & Smakhtin, 2010). Similarly, HHs' access to tap water supply and modern toilets will help in counteracting prolonged

exposure to climate induced risks (Hunter et al., 2010; Montgomery & Elimelech, 2007; WHO, 2002). Further, flood control measures such as embankments, dykes, dams and water pumping infrastructure will help in reducing severity of floods.

Socio-economic factors in the context include the proportion of people living in low-lying areas, and the proportion of people having access to water supply source within the dwelling premise. Low lying areas, due to its topographical disadvantage, will be more prone to floods (Patz and Kovats, 2002). Nevertheless, people having access to water supply within their premises will have less exposure to risk posed by droughts or floods, owing to the fact that there will be lesser chance of water contamination that normally happens during collection, conveyance and storage, if the source is available (WHO, 2002). Also, people who follow good hygiene will also be less exposed to risks such as food contamination.

Institutional and policy factors also play an important role in regulating community exposure to climate induced risks. Policy to hire private tankers for emergency water supply in rural areas and number of such tankers being made available will help community to face water stress induced by droughts. Further, provision of disaster risk reduction measures such as flood and cyclone warning, drought prediction, and evacuation measures will help community to prepare better for any adverse eventuality (Pollner et al., 2010).

01.3 Factors Influencing Community Vulnerability to Hazards

Community vulnerability factors to hazards are mainly natural, socio-economic and institutional in nature. Climate is the single most important natural factor that influence in the context. For instance, cold climate and humidity increase flood related health risks such as diarrhoea caused by bacteriological contamination of water and food. (Haines et al, 2006; Githeko et al., 2016).Inadequate personal and community hygiene resulting from water shortages can result in diseases such as diarrhoea (Esrey et al., 1985; Howard, 2005). But in hot, arid, and semi-arid climates breeding of water-related insect vectors that can cause such diseases would be less (Hunter, 2003). Hot and arid areas are more prone to drought related health risks such as dehydration (Haines et al., 2006).

Population density is a key socio-economic variable that affect community vulnerability to the health risks associated with climate related hazards. More densely populated areas have greater faecal loadings within the environment, and these are associated with greater vulnerability to infectious disease (Woodward et al., 2000).

Burden of waterborne diseases is often closely linked to poverty (Fass, 1993; Stephens et al., 1997) and malnutrition. The poor tend to be more vulnerable to diseases and have least access to basic services(WHO & UNICEF, 2000).This could be due to high proportion of them living under poverty, lack the wherewithal to have access to alternate sources of water, and are also generally unhealthy. There is greater prevalence of undernourishment in general and malnourishment among children. Nevertheless, better access to primary health services will make them less vulnerable. People with malnutrition are more vulnerable to water borne diseases.

Institutional and policy factors such as availability of greater number of institutions with ability to provide relief and rehabilitation measures to people affected during floods and cyclones (including Government, private and NGOs) improve community adaptive capacity against climate induced vulnerabilities. Similarly, presence of adequate number of public health infrastructure decreases population vulnerability to the severity of diseases caused during hazards (Haines et al., 2006). Finally, social ingenuity also matters in its adapting to natural disasters and reducing the vulnerability. Social cohesion, which is characteristic of homogeneous communities, also helps in adaptation and vulnerability reduction (IRAP, GSDA & UNICEF, 2013).

Table 1: Identified Factors Influencing Climate Induced Risk in Rural Water and Sanitation

S. No	Sub-Indices (Factor)	Variable (Indicators)	Rationale	Impact on severity of Risk (Negative or Positive)
A	Hazard Sub-index			
1	Natural	Rainfall	In high rainfall areas, the drought impacts on hydrology will be less as compared to low rainfall areas and vice versa in low rainfall areas.	Negative
		Rainfall variability	In areas of high rainfall variability, the frequency of occurrence of severe droughts will be higher	Positive
		Flood proneness	'Flood prone' areas are more susceptible to hazards associated with high rainfall	Positive
		Aridity	Impact of droughts in areas having high aridity in terms of hydrological changes will be more as compared to areas of low aridity	Positive
		Annual Renewable Water Availability	Renewable water availability of more than 1700 cum/capita/year is considered as secure	Negative
B	Exposure Sub-Index			
1	Natural	Depth to groundwater table	Groundwater at shallow depth will be susceptible to biological contamination during floods	Negative
		Temperature and humidity	In areas with cold and humid climate there is high chance of water and food contamination due to unhygienic conditions and spreading of insect vectors	Positive
		Groundwater stock	Act as buffer during droughts. Normally available in the alluvial areas, and as valley fills along rivers	Negative
2	Physical	Characteristics of water resources	Perennial water source would significantly reduce community exposure to droughts	Negative
		Condition of water supply system	Old water supply systems are more susceptible to disruption and damage during floods and cyclones	Negative
		Provision of buffer storage of water in reservoirs per capita	Reduces exposure to water scarcity conditions during droughts	Negative
		Proportion of HHs covered by tap water supply	Reduces chances of contamination of water during collection & storage	Negative
		Proportion of HHs having access to modern toilets	Reduces chances of vector borne diseases through food contamination etc.	Negative
		Flood control measures such as embankments, dykes, dams and water pumping facilities	Reduces severity of floods	Negative
3	Socio-Economic	Proportion of people living in low-lying areas	Relatively more exposed to flood hazards	Positive
		Proportion of people having access to water supply source within the dwelling premise	Less exposure to risk posed by droughts or floods	Negative
		Hand washing before and after food and after toilet use	Hand washing before and after food intake and after toilet use will help reduce chances of food contamination with faecal matter.	Negative
4	Institutional & Policy	Existence of policy to hire private tankers for emergency water supply	Help community to face water stress induced by droughts	Negative
		Provision for tanker water supply in rural areas in terms of number of tankers	Increases community's ability to tide over the crisis caused by reduced water supply from public systems	Negative
		Disaster risk reduction measures available	Helps community to prepare better for any adverse eventuality	Negative
C	Vulnerability Sub-Index			
1	Natural	Climate	In cold and humid areas, communities will be more prone to flood and water scarcity related health risks	Positive
			In hot and arid areas, communities are more prone to heat stroke, dehydration	Positive
2	Socio-Economic	Population density	High population density increases vulnerability	Positive
		Proportion of people living under poverty	Vulnerability will be high for those who lack wherewithal to have access to alternate sources of water including purchased water	Positive
		Proportion of people who are unhealthy	Undernourishment in general and malnourishment, especially among children, make community more vulnerable	Positive
		Access to primary health services	Good access to primary health facilities make community less vulnerable	Negative
		Percentage of children under the age of 5 with stunting (Height-for-age)	Physical growth of children (under the age 5), an indicator of the nutritional well-being of the population, influences vulnerability to diseases	Negative

S. No	Sub-Indices (Factor)	Variable (Indicators)	Rationale	Impact on severity of Risk (Negative or Positive)
3	Institutional & Policy	Ability to provide relief and rehabilitation measures for floods and cyclones (number of agencies, including Government, private and NGOs)	Improve community adaptive capacity	Negative
		Social ingenuity and cohesion	Improves community adaptive capacity	Negative
		Adequate number of primary and other health infrastructure	Decreases community vulnerability to diseases	Negative

The matrix in Table 2 suggests the quantitative criteria for assigning values to various sub-indices for computing the climate risk index for different types of areas.

Table 2: Matrix for Computing the Values of Various Indices for Assessing the Climate-Induced Risk in Water and Sanitation in Maharashtra

Sub-Index (Factors)	Variable (Indicators)	Impact on severity of Risk (Negative or Positive)	Score			Score given	Remarks
			1 = Low	2 = Moderate	3 = High		
A. Hazard Sub-Index							
Natural	Rainfall	Negative	Average annual rainfall greater than or equal to 1000 mm	Average annual rainfall between 500-1000 mm.	Average annual rainfall less than equal to 500 mm.		The hazard is drought
	Rainfall Variability	Positive	Coefficient of variation in rainfall is less than 17%	Coefficient of variation in rainfall is equal to/between 17 and 40%	Coefficient of variation in rainfall is greater than 40%		As per guide-lines of IMD
	Aridity	Positive	Humid-sub-hu-mid	Semi-arid	Arid to Hyper-ar-id		As per guide-lines of IMD
	Annual Renewable Water Avail-ability	Negative	Renewable water availability of more than equal to 1700 cum/capita/year	Renewable water availabil-ity of between 1000-1700 cum/capita/year	Renewable water availabil-ity of less than equal to 1000 cum/capita/year		

Sub-Index (Factors)	Variable (Indicators)	Impact on severity of Risk (Negative or Positive)	Score			Score given	Remarks
			1 = Low	2 = Moderate	3 = High		
B. Exposure Sub-Index							
Natural	Depth to ground water table	Negative	Depth to ground water table is greater than or equal to 30 m	Depth to ground water table is between to 5-30 m	Depth to ground water table is less than equal to 5 m		The exposure is in the form of bacteriolog-ical contami-nation
	Temperature and Humidity	Positive	Tempera-ture ranging between 30 and 350C; Humidity ranging from 30±5% to 50±3%.	Temperature ranging between 27 and 300C and Humidity ranging 30±5% to 50±3%	Tempera-ture ranging between 23 and 270C; Humidity ranging from 60±8% to 80±6% most favorable condition for unhygienic conditions		
	Groundwater stock	Negative	Groundwater stock is five times more than annual recharge	Groundwater Stock is two times more than the annual recharge	Groundwater stock is equal to or less than the annual recharge		As per guide-lines of CGWB
Physical	Character-istics of natural water resources	Negative	Perennial Water source with low inter-an-nual variability (Example. river)	Perennial source with high inter-annual variability	Seasonal water sources (ephem-eral rivers, lakes, ponds etc,)		
	Condition of the water supply system	Negative	New water supply pipeline systems (Less than 5 years)	Medium aged water supply pipeline systems (between 5 and 15 years)	Old aged water supply pipelines systems (more than 15 years)		
	Provision of buffer storage of water in reservoirs per capita	Negative	Provision of buffer storage in a reservoir minimum 36 m3/capita/year	Provision of buffer storage in a reservoir between 15m3 cum/capita/year	Provision of buffer storage in a reservoir less than 9m3 m/capita/year		
	Proportion of HHs covered by tap water supply	Negative	More than 75% of HHs are covered by tap water supply	40-60% of HHs are covered by tap water supply	Less than equal to 40% of HHs are covered by tap water supply		

Sub-Index (Factors)	Variable (Indicators)	Impact on severity of Risk (Negative or Positive)	Score			Score given	Remarks
			1 = Low	2 = Moderate	3 = High		
	Proportion of HHs having access to modern toilets	Negative	More than 90% of HHs having access to improved sanitation and usage is more than 90%	60%-80% of HHs having access to improved sanitation and usage is between 70%-90%	Less than equal to 60% of HHs having access to improved sanitation and usage is more than 70%		
	Flood control measures such as embankments, dykes, dams and water pumping facilities	Negative	Flood control measures available		No Flood control measures available		
Socio-Economic	Proportion of people living in low-lying areas	Positive	Less than or equal to 25% of people living in low-lying areas	25-50% of people living in low-lying areas	Greater than or equal to 50% of people living in low-lying areas		
	Proportion of people having access to water supply source within the dwelling premise	Negative	More than 75% of people Access to water supply source within the dwelling premise	40-75% of people having Access to water supply source within the dwelling premise	Less than 25% of people having Access to water supply source within the dwelling premise		
	Hand-washing before eating or preparing food and after toilet use	Negative	Hand-washing before eating or preparing food and after toilet use	Hand-washing after toilet use only	No hand washing after food/no hand washing after toilet usage		
Institutional & Policy	Existence of policy to hire private tankers for emergency water supply	Negative	Policy exist to hire private tankers for emergency water supply		No Policy exist to hire private tankers for emergency water supply		
	Provision for tanker water supply in rural areas in terms of no. of tankers	Negative	More than 1 tanker for 20 HHs	1 tanker for 20-50-HHs	Less than one tanker for 50 HHs		1 tanker capacity of 7000 liters meet requirement of 20 HHs (70 liters/capita/day)

Sub-Index (Factors)	Variable (Indicators)	Impact on severity of Risk (Negative or Positive)	Score			Score given	Remarks
			1 = Low	2 = Moderate	3 = High		
	Disaster risk reduction measures available	Negative	Disaster risk reduction force available within a radius of 100 km	Disaster reduction force available within a radius of 100-500 km radius	Disaster risk reduction force available outside 500 km radius		
C. Vulnerability Sub-Index							
Natural	Climate	Positive	Temperature ranging between 30 and 350C; Humidity ranging from 30±5% to 50±3% ./ Mean annual temperature less than 330C and humidity above 90%	Temperature ranging between 27 and 300C; Humidity ranging from 30±5% to 50±3% / Mean annual temperature between 33 and 400C and Humidity between 50 and 65%	Temperature ranging between 23-270C and Humidity ranging 60±8% to 80±6% / Temperature less than 40-460C and Humidity less than 50%		
Socio-Economic	Population density	Positive	Population Density less than 200 persons/sq. km	Population Density in the range of 200-500 person/sq. km	More than 500 persons/sq. km		
	Proportion of people living under poverty	Positive	Less than equal to 25% of people living under poverty	25-60% of people living under poverty	Greater than 60% of people living under poverty		
	Proportion of people who are unhealthy	Positive	Infant mortality rate less than equal to 12.0 (per 1000 people)	Infant mortality rate between 12.0 to 60.0 (per 1000 people)	Infant Mortality rate greater than 60.0 (per 1000 people)		
	Access to primary health services	Negative	More than 60% people having access to primary health services	25-60% of people having access to primary health services	Less than 25% of people having access to primary health services		
	Percentage of children under the age of 5 with stunting (low height-for-age ratio)	Negative	Average height of children below the age of 5 as a % of the median is 95 to 110	Average height of children below the age of five as a % of the median is 85 to 89	Average height of children below the age of five as a % of the median is less than 85		For the median, we would consider the State as a whole

Sub-Index (Factors)	Variable (Indicators)	Impact on severity of Risk (Negative or Positive)	Score			Score given	Remarks
			1 = Low	2 = Moderate	3 = High		
Institutional & Policy	Ability to provide relief and rehabilitation measures for floods and cyclones (no. of agencies, including Government, private and NGOs)	Negative	More than one NGO for 1,000 people	One NGO for 1,000-2000 people	Less than one NGO for 2000 people		As per NGO regulations one NGO covered 600 peoples
	Social ingenuity and cohesion	Negative	Settled and homogenous communities, exposed to natural disasters	Settled, but heterogeneous communities exposed to natural disasters	Settled, but heterogeneous communities not exposed to natural disasters		
	Adequate number of primary and other health infrastructure	Negative	One Sub Health Centre covered 3000 to 5000 of rural population	One Sub Health Centre covered 6000 to 8000 of rural population	One Sub Health Centre covered more than 8000 of rural population		As per Ministry of FHW guidelines one Sub-centre (health centre covered 3000-5000 rural population

02 Computation of the Composite Index

The composite index has three sub-indices (one for hazard, one for exposure, and one for vulnerability). Each sub-index has several variables (indicators) whose numerical values (scores) together characterize the attribute represented by the sub-index (say, climate hazard) in quantitative terms. To begin with, a maximum score of '3' (three) will be assigned to any variable in the case of highest risk situation, and the minimum score of '1' (one) will be assigned to the variable for the lowest risk situation. For obtaining numerical value of each sub-index, score for each indicator will be added up. It can be represented as:

$$\text{Sub Index value } \Sigma_{i-1}^{n} = S_i \quad \text{.........................(1)}$$

Where, S is the product of score and weightage obtained by each variable under the sub-index and n is the total number of variables (indicators) considered for assessing the value of each sub-index.

Values computed for each sub-index will be normalized by dividing it by the highest possible value possible for that sub-index. For instance, a sub-index which has five independent variables (indicators) will have a maximum computed value of 15 (i.e., 5 X 3). This means the highest normalized value possible for any sub-index will be 1.0.

The composite climate risk index for water and sanitation (R_WASH) will be computed by multiplying the values of the three sub-indices viz., hazard (HWASH-SI), exposure (EWASH-SI) and vulnerability (VWASH-SI). It can be mathematically represented as:

$$R_{(WASH\text{-}INDEX)} = H_{WASH\text{-}SUB\text{-}INDEX} \times E_{WASH\text{-}SUB\text{-}INDEX} \times V_{WASH\text{-}SUB\text{-}INDEX} \quad \text{....(2)}$$

VI

Climate-Induced Risk in WASH for Marathwada and Vidarbha Divisions of Maharashtra

01. Data Types and Source

The data for assessing climate-induced WASH risks in the two divisions of Maharashtra pertaining to 28 different variables were obtained from various secondary sources, except for one variable. The only variable on which primary data were collected (from individual HHs through sample survey) was 'hand-washing practice' as secondary data pertaining to this were not available with official sources. For rest of the variables, data were available at the district level and hence computation of the risk index was done at the district level. The data sources included:

- Climate atlas of Water Resources Department of Maharashtra;
- Ground Water Survey and Development Agency of Maharashtra;
- Maharashtra Water Supply & Sanitation Department,
- Water and Sanitation Organization (WSSO) of Maharashtra; and,
- Maharashtra State Disaster Management Department.

02. Results and Discussions

The climate-induced risk in WASH was assessed at district level for eight districts of Marathwada and 11 districts of Vidarbha divisions using the composite climate risk index. The index takes into consideration the degree of climate induced hazard, the exposure of the district population to the hazard, and vulnerability of the community to the hazard. Complex variables are used to describe each one of the three factors, as explained in Section VI on 'Development of an index on climate-induced risk in WASH' (see Table 1). The index is defined based on the natural, physical, socio-economic, and institutional parameters that determine the three dimensions of climate-induced risk in WASH such as hazard, exposure and vulnerability. The scores are assigned to the indicators representing each one of these parameters depending on their absolute values for the district concerned as per the criteria already defined in Table 2.

The values of different sub-indices of the climate risk index were computed using the values/scores assigned to each indicator representing several physical, social, economic and institutional variables, which together describe these sub-indices. In the case of climate related hazard only five physical variables were considered. They include mean annual rainfall, rainfall variability, flood proneness, aridity, and annual renewable water resource availability. Their values were computed by analyzing the secondary data pertaining to these variables available at the district level. Similarly, in the case of exposure, a total of 14 variables were considered. Three of them from natural sub-index, two physical, six socio-economic, and three institutional and policy related. The values of all except one variable were computed using secondary data pertaining to these variables available at the district level. In the case of the variable relating to 'hand washing', primary data were collected from representative districts using primary survey of sample houses. In the case of vulnerability, a total of nine variables were considered - one natural, five socio-economic and three institution and policy related. All these data were secondary in nature collected at the district level.

A discussion on the estimation of different parameters used for the computation of various sub-indices and the corresponding results are presented in Annexure 1. The computed values of all these 28 parameters and the respective sub-indices and composite index computed using them for all the districts of Marathwada and Vidarbha are presented in Table 3 and Table 4, respectively. The computed values of composite risk index for the districts of Marathwada and Vidarbha are presented in Figure 1 and Figure 2, respectively. The computed values of the sub-indices for hazard, exposure and vulnerability for each of the districts of Marathwada and Vidarbha are graphically represented by Figure 3 and Figure 4, respectively.

A value of 0.33 or less for any sub-index signifies low magnitude; a value in the range of 0.33 to 0.67 is considered to be a moderate magnitude; and the value greater than 0.67 high magnitude. Total score of less than 0.04 implies low risk, a score in the range of 0.05 to 0.30 moderate risk, and an 'overall risk' greater than 0.30 implies high risk.

The results show that the climate-induced risk in WASH for Marathwada and Vidarbha regions considered together varies spatially between 0.22

in Chandrapur (Vidarbha) and 0.35 in Parbhani (Marathwada). In the case of Marathwada region, which is historically known for droughts, the value of risk index varies from a lowest of 0.23 in Jalna to a highest of 0.35 in Parbhani. In the case of Vidarbha, which is relatively better in water resources endowment, as compared to Marathwada, but characterized by poor water supply and infrastructure, the value of the district level risk index ranges from a lowest of 0.22 in Chandrapur to a highest of 0.33 in Washim.

The values for different components of the composite risk index, viz., hazard, exposure and vulnerability indices, also vary drastically from region to region and also amongst districts within each region. The range of scores for components in Marathwada is larger, as compared to Vidarbha region. These are discussed separately in the subsequent paragraphs.

As regards the 'hazard' component of the composite risk index, in the case of Marathwada, the value varies from a lowest of 0. 53 for Jalna district to a highest of 0.73 for Osmanabad district. In the case of Vidarbha, the value of the sub-index for hazard ranges from a lowest of 0.60 (in seven districts) to the highest of 0.67 for the remaining five districts. The variation in the degree of hazard is more (the difference in the value of sub-index being 0.20) amongst the districts of Marathwada as compared to their counterparts in Vidarbha (the difference being only 0.07).

Figure 1: Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Marathwada Region, Maharashtra

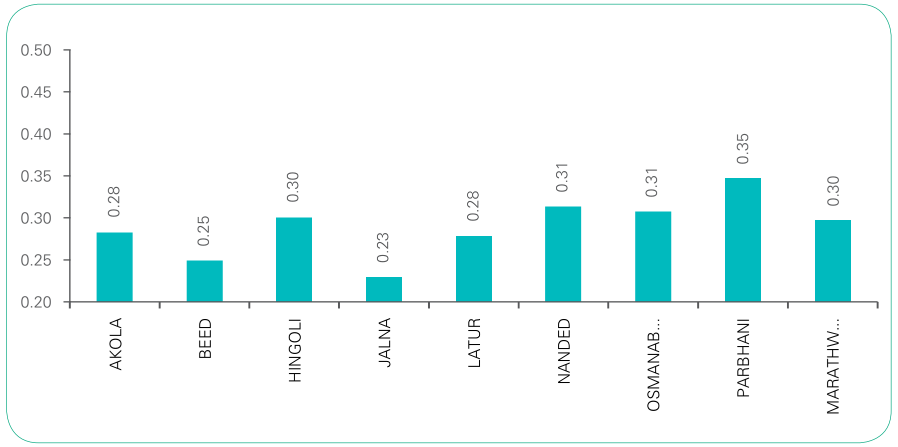
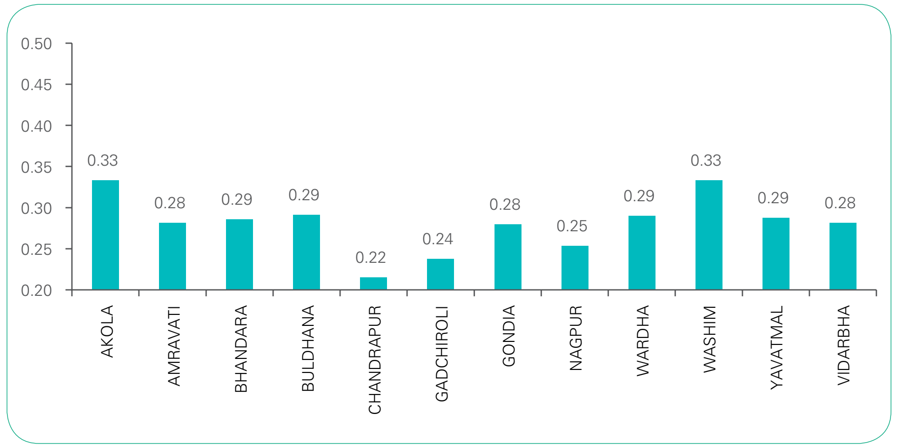


Figure 2: Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Vidarbha Region, Maharashtra



As regards exposure, in the case of Marathwada, the value of the sub-index ranges from 0.57 for Aurangabad and Osmanabad to a highest of 0.67 for Nanded. The corresponding values for Vidarbha division districts range from 0.60 for Amravati to 0.74 for Gondia. Hence, the districts in Vidarbha region are more exposed to climate induced WASH risks.

As regards vulnerability, in the case of Marathwada division, the range of the sub-index varies from 0.67 for Bid to 0.78 for Nanded. Nanded therefore not only is more exposed to climate induced hazards but also has high vulnerability. For Vidarbha, the value of the sub-index for vulnerability ranges from a lowest of 0.56 for Chandrapur to 0.70 for Akola, Amravati, Buldhana, Wardha and Washim. By comparing the two divisions, it can be inferred that the vulnerability to climate induced hazards is generally lower for the districts of Vidarbha division as opposed to those of Marathwada. The average value for Vidarbha region is 0.66 against 0.71 for Marathwada.

Figure 3: Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Marathwada Region, Maharashtra

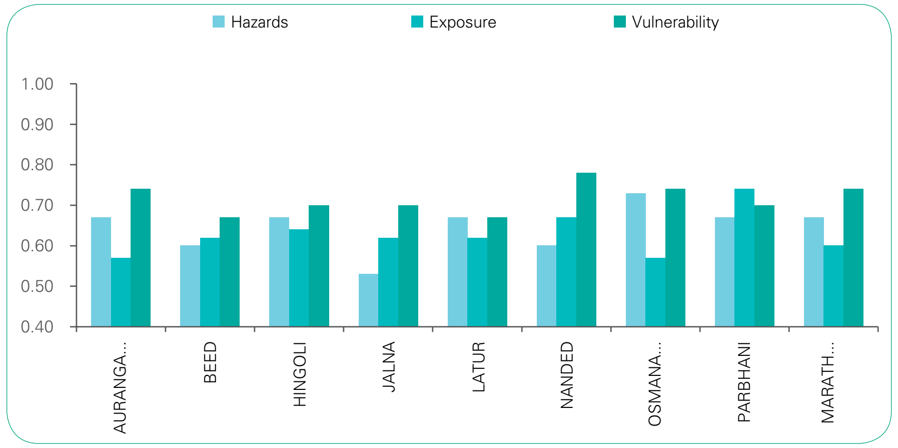
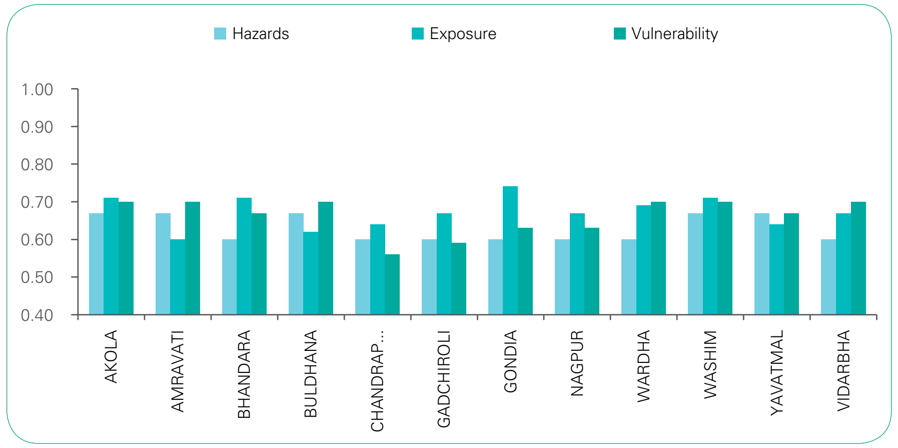


Figure 4: Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Vidarbha Region, Maharashtra



03. The Factors Causing High Climate Risk in Certain Districts and the Ways to Reduce it

To sum up, as per our estimates, the highest climate-induced WASH risk is in the districts of Parbhani (0.35), Osmanabad (0.31), and Nanded (0.31) in Marathwada, while Akola and Washim districts of Vidarbha also have a high risk of 0.33 each. It is important to understand the factors responsible for the differential values of climate induced risks amongst districts, in order to reduce the risk in districts where it is high. Osmanabad district experiences high incidence of climate hazards, while Parbhani, Akola and Washim districts are characterized by high incidence of climate exposure. Osmanabad, Parbhani, Akola, Washim and Nanded districts are also highly vulnerable to climate induced hazards.

The annual renewable water availability in Osmanabad is in the range of 1501 and 3001 m3/ha, rendering it water-deficit region. This variable in particular makes the district prone to high climate-induced hazard. Further, Osmanabad is also highly vulnerable because of the high percentage of children under the age of five with stunting, and poor ability to provide relief and rehabilitation measures during floods and cyclones. Similarly high vulnerability is observed for Parbhani, Nanded, Akola and Washim. The exposure to climate hazard is highest in Parbhani district of Marathwada, while Akola and Washim districts of Vidarbha region also show high exposure. This can be attributed to a number of factors. These districts score very low in indicators such as proportion of HHs covered by tap water supply, access to modern toilets, provision of tanker water supply in rural areas and groundwater stock. Additionally the Parbhani district has a high proportion of its population living in the low-lying areas.

A careful analysis shows that water infrastructure can play a significant role in reducing the hazard and exposure. For Marathwada region, import of surface water from water-rich regions such as the western Ghat which has a rich endowment of river flows, would help reduce the hazard caused by meteorological droughts in the region, which is in the form of reduced water resource availability for every use. Dependable sources of water for irrigation as well as water supply would be required for improving food and nutritional security and water supply, so as to reduce malnutrition and infant mortality. This can only reduce the vulnerability of the region to drought impacts.

On the other hand, Vidarbha region requires better infrastructure for improving access to drinking water supply and sanitation, though water endowment of the region is good with several perennial rivers. This can be in the form of more large and medium reservoirs for storing surface runoff of the region. Infrastructure for pumping and transporting the stored good quality water to the rural areas, and building of proper village level water distribution systems are the other requirements. It is to be kept in mind that overdependence on groundwater resources for domestic water supply is not desirable for the region, as the wells run dry towards the end of winter even in normal rainfall years. If dependable sources of good quality water are made available to the villagers, it will drastically reduce need for water tanker supply during droughts and summer months. Also, once this is done, the community members will have greater motivation to go for individual HH level tap water connections and pay for it, as they would be sure of getting adequate supplies of good quality water every year and in every season. As earlier studies in Maharashtra suggests, with access to individual HH level water connections, the families will have strong incentive to go for improved toilets.

Table 3: Computation of Various Sub-indices of Climate Risk Index and the Associated Variables for Districts of Marathwada Division

Composite Index for Assessing the Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Marathwada Region, Maharashtra

RISK	Sub-Indicies	SL No	Risk Indicators	Aurangabad	Bid	Hingoli	Jalna	Latur	Nanded	Osmanabad	Parbhani	Marathwada
		1	Rainfall	2	2	2	2	2	2	2	2	2
		2	Rainfall Variability	2	2	2	2	2	2	2	2	2
		3	Flood Proneness	2	2	2	1	1	2	2	2	2
		4	Aridity	2	2	2	2	2	2	2	2	2
		5	Annual Renewable Water Availability	2	1	2	1	3	1	3	2	2
	Overall Hazard			0.67	0.60	0.67	0.53	0.67	0.60	0.73	0.67	0.67
		6	Depth of groundwater table	2	1	1	1	1	1	1	2	1
		7	Temperature and Humidity	2	2	2	2	2	2	2	2	2
		8	Groundwater stock	3	3	3	3	3	3	3	3	3
	Physical	9	Characteristics of natural water resources	1	3	2	1	1	2	2	2	2
		10	Provision of buffer storage of water in reservoirs per capita	1	2	2	3	3	1	1	3	1
		11	Proportion of HHs covered by tap water supply	3	3	3	3	3	3	3	3	3
		12	Proportion of HHs having access to modern toilets	3	3	3	3	3	3	3	3	3
		13	Flood control measures such as embankments, dykes, dams and water pumping facilities	1	1	1	1	1	1	1	1	1
		14	Proportion of people living in low-lying areas	1	1	1	1	1	3	1	3	1
		15	Proportion of people having access to water supply source within the dwelling premise	2	2	3	3	2	3	2	2	2
		16	Hand-washing before and after food and after toilet use	1	1	1	1	1	1	1	1	1
		17	Existence of policy to hire private tankers for emergency water supply	1	1	1	1	1	1	1	1	1
		18	Provision for tanker water supply in rural areas in terms of no. of tankers	2	2	3	2	3	3	2	3	3
		19	Disaster risk reduction measures available	1	1	1	1	1	1	1	2	1
	Overall Exposure			0.57	0.62	0.64	0.62	0.62	0.67	0.57	0.74	0.60

RISK	Sub-Indicies	SL No	Risk Indicators	Aurangabad	Bid	Hingoli	Jalna	Latur	Nanded	Osmanabad	Parbhani	Marathwada
	Natural	20	Climate	2	2	2	2	2	2	2	2	2
		21	Population density	2	2	2	2	2	2	2	2	2
		22	Proportion of people living under poverty	2	2	2	2	2	2	2	2	2
		23	Proportion of people who are unhealthy	2	2	2	2	2	2	2	2	2
		24	Access to primary health services	2	1	1	1	1	3	2	1	2
		25	Percentage of children under the age of 5 with stunting (low height-for-age ratio)	3	2	3	3	2	3	3	3	3
		26	Ability to provide relief and rehabilitation measures for floods and cyclones (no. of agencies, including Government, private and NGOs)	3	3	3	3	3	3	3	3	3
		27	Social ingenuity and cohesion	2	2	2	2	2	2	2	2	2
		28	Adequate no. of primary and other health infra-structure	2	2	2	2	2	2	2	2	2
	Overall Vulnerability			0.74	0.67	0.70	0.70	0.67	0.78	0.74	0.70	0.71
Risk Index				0.28	0.25	0.30	0.23	0.28	0.31	0.31	0.35	0.29

Table 4: Computation of Various Sub-indices of Climate Risk Index and the Associated Variables for Districts of Vidarbha Division

Composite Index for Assessing the Climate-Induced Risk in Water, Sanitation and Hygiene (WASH) in Vidarbha Region, Maharashtra

RISK	Sub-Indicies	SL No	Risk Indicators	Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal	Vidarbha
		1	Rainfall	2	2	1	2	1	1	1	1	1	2	2	1
		2	Rainfall Variability	2	2	2	2	2	2	2	2	2	2	2	2
		3	Flood Proneness	2	2	2	2	2	2	2	2	2	2	2	2
		4	Aridity	2	2	2	2	2	2	2	2	2	2	2	2
		5	Annual Renewable Water Availability	2	2	2	2	2	2	2	2	2	2	2	2
	Overall Hazard			0.67	0.67	0.60	0.67	0.60	0.60	0.60	0.60	0.60	0.67	0.67	0.60

RISK	Sub-Indicies	SL No	Risk Indicators	Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal	Vidarbha
		6	Depth to ground water table	2	2	1	1	1	1	1	1	1	1	1	1
		7	Temperature and Humidity	2	2	2	2	2	2	3	3	2	2	2	2
		8	Groundwater stock	2	2	3	3	3	2	3	3	3	3	3	3
	Physical	9	Characteristics of natural water resources	2	1	1	1	2	2	3	2	2	2	1	2
		10	Provision of buffer storage of water in reservoirs per capita	3	1	3	2	1	1	1	1	2	2	2	2
		11	Proportion of HHs covered by tap water supply	3	2	3	3	3	3	3	3	3	3	3	3
		12	Proportion of HHs having access to modern toilets	3	2	3	3	3	3	3	2	3	3	3	3
		13	Flood control measures such as embankments, dykes, dams and water pumping facilities	3	3	1	1	1	1	1	1	1	3	1	1
		14	Proportion of people living in low-lying areas	1	1	2	1	2	1	1	1	1	1	1	1
		15	Proportion of people having access to water supply source within the dwelling premise	2	2	2	2	2	3	3	2	2	3	3	2
		16	Hand-washing before and after food and after toilet use	1	1	1	1	1	1	1	1	1	1	1	1
		17	Existence of policy to hire private tankers for emergency water supply	1	1	3	1	1	3	3	3	3	1	1	2
		18	Provision for tanker water supply in rural areas in terms of number of tankers	3	3	3	3	3	3	3	3	3	3	3	3
		19	Disaster risk reduction measures available	2	2	2	2	2	2	2	2	2	2	2	2
	Overall Exposure			0.71	0.60	0.71	0.62	0.64	0.67	0.74	0.67	0.69	0.71	0.64	0.67

RISK	Sub-Indicies	SL No	Risk Indicators	Akola	Amravati	Bhandara	Buldhana	Chandrapur	Gadchiroli	Gondia	Nagpur	Wardha	Washim	Yavatmal	Vidarbha
	Natural	20	Climate	2	2	2	2	2	2	2	1	2	2	2	2
		21	Population density	2	2	2	2	1	1	2	2	2	2	2	2
		22	Proportion of people living under poverty	2	2	2	2	2	2	2	2	2	2	2	2
		23	Proportion of people who are unhealthy	2	2	2	2	2	2	2	2	2	2	2	2
		24	Access to primary health services	1	1	1	1	1	1	1	2	3	1	1	2
		25	Percentage of children under the age of five with stunting (low height-for-age ratio)	3	3	2	3	1	2	2	2	2	3	3	2
		26	Ability to provide relief and rehabilitation measures for floods and cyclones (number of agencies, including Government, private and NGOs)	3	3	3	3	3	3	3	3	3	3	3	3
		27	Social ingenuity and cohesion	2	2	2	2	2	2	2	2	2	2	2	2
		28	Adequate number of primary and other health infrastructure	2	2	2	2	1	1	1	1	1	2	1	2
	Overall Vulnerability			0.70	0.70	0.67	0.70	0.56	0.59	0.63	0.63	0.70	0.70	0.67	0.66
Risk Index				0.34	0.28	0.29	0.29	0.21	0.24	0.28	0.25	0.29	0.34	0.29	0.28

VII

Improving Climate Resilience of WASH Programmes in Maharashtra

01. Introduction

Water is the primary medium through which climate influences the Earth's ecosystem and thus the livelihood and well-being of societies. Climate variability and change directly impact water resources. Water resources are important to both society and ecosystems. People depend on a reliable, clean supply of drinking water. Water is required for agriculture, energy production, navigation, recreation, and manufacturing processes. Many of these uses put pressure on water resources. These stresses are likely to be exacerbated by climate variability and change. In many areas reduction in precipitation and increase in temperature is likely to increase demand for water, with shrinking supplies. In some areas, water shortages are relatively smaller problem than increased runoff, flooding, or sea level rise. These effects can reduce the quality of water and can damage the infrastructure that we use to transport and deliver water (Rance and Walmsley, 2014).

WASH sector is already affected in many different ways by weather and climate events such as variability, seasonality and extreme events. This adversely impacts on drinking water availability, its quality, and performance of sanitation and hygiene services. These are intrinsically connected with public health. When there is decline in water supplies (e.g. dry wells), people may be forced to drink contaminated water (e.g. untreated water from ponds and streams) or compromise on personal hygiene and environmental sanitation . Risks to water safety emanate primarily from unsafe water because of poor sanitation (proliferation of open defecation), and contaminated water at source or at point of use. This can be due to chemical/ microbial contamination, inadequate household storage and inappropriate personal hygiene practices (UNICEF, 2016: p 41).

Pollution of wells and flooding of latrines also increase the risk of higher incidence of infectious diseases. In addition, a reduction in water availability makes hygiene practices more challenging and behavioural change campaigns might not work in areas where access to water is increasingly constrained by the changing climate. A higher incidence of extreme events poses additional stress to the sustainability of both sanitation and hygiene practices. Examples of impact of hazards on the WASH sector are presented in Table 5. All these impacts result in higher delivery and maintenance costs for climate resilient services.

It is important to reckon with the fact that large areas in Maharashtra experience climate extremes such as prolonged droughts, cyclones and coastal flooding with adverse impacts on water supply, sanitation and hygiene. This is especially true for the rural areas. The State during 2015 received only 59.4% of the normal rainfall. Out of 355 talukas (excluding talukas in Mumbai City & Mumbai suburban districts) in the State; 278 received deficient; 75 received normal; and, two received excess rainfall. During kharif season of 2015, sowing was completed in 141.46 lac ha, six per cent less than the previous year (GoM, 2016).

2. As reported by UNICEF (2016) on drought monitoring in Maharashtra during the summer of 2016, with surface storage fast drying up, the humans as well as the livestock reportedly resorted to the same available sources, mainly in the tribal belts. Multiple uses of drinking water sources, including their use for washing and bathing, put these sources at risk of high contamination (UNICEF, 2016: p 45). Lack of adequate water was forcing people in the drought-affected regions to compromise on personal hygiene and environmental sanitation, despite awareness about it (UNICEF, 2016: p 47).

Table 1: Identified Factors Influencing Climate Induced Risk in Rural Water and Sanitation

Climate effect	Hazard	Impact on WASH sector
Decrease in precipitation	Drought	Reduction in raw water supplies, reduced flow in rivers, less dilution/ increased concentration of pollutants in water, challenge to hygiene practices.
Increase in precipitation and severe weather	Flooding	Contamination of well water, inundation of wells, inaccessibility of water sources, flooding of latrines, damage to infrastructure, landslides around water sources, sedimentation and turbidity, challenges to sustainability of *sanitation and hygiene behaviours, and waterborne diseases.
Cyclones	High winds and Flooding	Damage to water supply infrastructure, water contamination, access to water supply sources becomes difficult
Increase in temperature	Heatwave	Damage to infrastructure, increase in pathogens in water leading to increased risk of disease.
	Melting and thawing of glaciers, snow, sea ice and frozen ground	Seasonality of river flows affected leading to a reduction in water availability in summer in the long run, while summer flows would increase in the short run.
Sea-level rise	Flooding and saline intrusion into freshwater aquifers	Reduction in availability of drinking water, with high impacts on quality.

(Source: Global Water Partnership and UNICEF, 2014)

Resilience can be defined as the people and system's ability to adapt and recover from negative effects of shocks and stresses (including natural disasters and climate change) in a manner that reduces vulnerability, protects livelihoods, accelerates and sustains recovery, and supports economic and social development, while preserving cultural integrity (Rance and Walmsley, 2014). With respect to the WASH sector, climate resilience requires a focus on:

A. A reduction in the effect of climate change and related shocks onindividuals;

B. Strengthening reliability of WASH services;

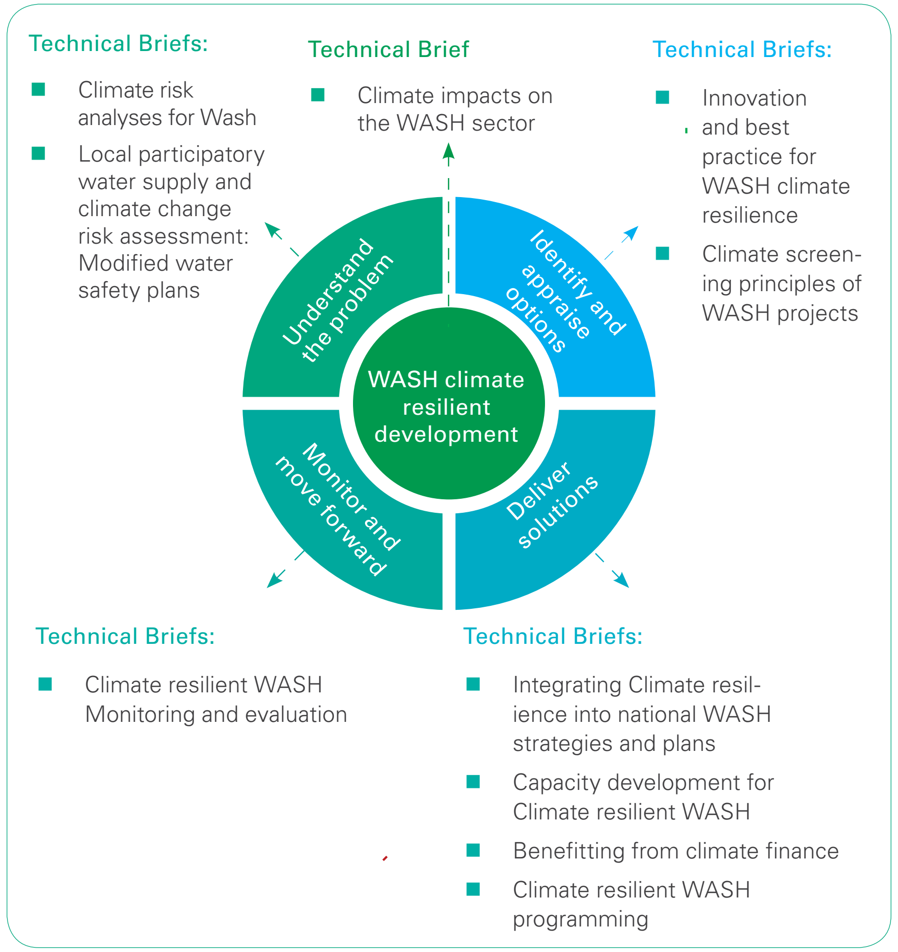
C. Strengthening Government cap acities and increase climate avresilience of communities overtime; and

D. Evolving strategic framework by Governments and their development partners to respond to growing demands brought about by the changing situations.

02. Strategic Framework for Climate ResilientWASH Development

A strategic framework for climate resilient WASH development is presented in Figure 5. The framework is grounded on the core objective to provide sustainable WASH service delivery, both at present and in the future. The emphasis is on climate resilient development, including strengthening resilience of WASH systems and on investments to manage current climate variability, as well as long-term changes in climate. The strategic framework acknowledges the multi-level Governance structures inherent in the WASH sector. It recognises that each level has a different part to play in WASH delivery and that climate resilience needs to be addressed at all levels. The framework advances sector thinking around WASH and climate change. It is a resource for the WASH sector as a whole and it aims to inform and reinforce existing planning processes, and is not a new process in itself. It highlights 'Why' climate resilient development is important and catalyses selected elements of 'What to do' in terms of action that can be taken now to strengthen resilience.

Figure 5: Strategic Framework for Climate Resilient WASH Development



(Source: Global Water Partnership and UNICEF, 2014)

03. Analysis of Disaster Reduction Approaches and Measures in India

National Disaster Management Authority (NDMA) is an agency of the Ministry of Home Affairs whose primary purpose is to coordinate response to natural or man-made disasters and for capacity-building in disaster resiliency and crisis response. NDMA was established through the Disaster Management Act (DMA) enacted by the Government of India in December 2005.

The Prime Minister is the ex-officio chairperson of NDMA. The agency is responsible for framing policies, laying down guidelines and best-practices and coordinating with the State Disaster Management Authorities (SDMAs) to ensure a holistic and distributed approach to disaster management. The remainder of the board consists of members nominated based on their expertise in areas such as, planning, infrastructure management, communications, meteorology and natural sciences. Day-to-day management of the Agency is overseen by office of the Vice Chair. NDMA is operationally organized under the following divisions: policy & planning; mitigation; operations & communications; administration; and capacity building.

NDMA equips and trains Government officials, institutions and the community to mitigate and respond during a crisis or a disastersituation. It operates the National Institute of Disaster Management, which develops practices, delivers hands-on training and organizes drills for disaster management. It also equips and trains disaster management cells at the State and local levels.

The National Disaster Response Force (NDRF) is a specialised force constituted "for the purpose of specialist response to a threatening disaster situation or disaster" under the Disaster Management Act, 2005. The Prime Minister is the Chairman of NDMA. The responsibility for Disaster Management in India's federal system is that of the State Government. The 'nodal Ministry' in the Central Government for management of natural disasters is the Ministry of Home Affairs (MHA). When 'calamities of severe nature' occur, the Central Government is responsible for providing aid and assistance to the affected State including deployment, at the State's request, of Armed Forces, Central Paramilitary Forces, NDRF, and communication, air and such other assets as are available and needed.

03.1 Indian Disaster Resource Network (IDRN) State database

IDRN is a decision-making tool for Government administrators and crisis managers to coordinate effective emergency response operations in the shortest possible time. A web-enabled centralized IDRN database is operational. The network enables quick access to resources to minimize response time in emergencies. The system gives the location of specific equipment /specialist resources as well as controlling authority for that resource so that it can be mobilized for response in the shortest possible time. The database is made available at the district, state and national levels and used for all emergencies and day-to-day operations (GoI, 2011; http://idrn.gov.in).

03.2 Standard Operating Procedure for responding to natural disasters-Rural drinking water supply and sanitation-2011

At the National level, the Ministry of Home Affairs and Ministry of Agriculture are the nodal ministries for management of disasters in the country. The Ministry of Drinking Water & Sanitation (MDWS) is responsible for providing technical and financial support to State RWSS/PHED/Board while responding to natural calamities for restoration of damaged water supply and sanitation systems. The MDWS participates in all technical coordination and linkages with the State rural development departments, SDMAs, NGOs, international agencies, etc. At the National level, MDWS in coordination with concerned national and international agencies informs departmental contingency/preparedness plans to concerned nodal officers in the National Disaster Management Authority to avoid or minimize overlap or duplication of efforts and improve coordination. All agencies involved in emergency relief and disaster management activities will have to operate within the framework laid down in the disaster management policy and other related laws, codes and Government notifications in force and guidelines issued from time to time (GoI,2011) .

03.3 Preparedness

The most important component of preparedness is planning for all hazards. The plans have to be linked with those of other support departments, and also at various levels. The MDWS is expected to technically advice State PHED/RWSS Departments about the equipment and resources to be used for emergency provision of water and sanitation during a response. The MDWS also identifies key institutions/resource centres/ATI's including those run by non-governmental agencies for human resource development and training for the State Departments.

The MDWS must have disaster management plans to tackle all disaster situations. It also maintains a roster of personnel whose services might be required for making assessment of disasters. Additionally, it is expected to develop manuals on water conservation/recharging as part of preparedness measures. The MDWS is empowered to monitor the activities of the concerned State Government Department dealing with rural water supply and sanitation. If necessary, MDWS can depute technical experts/officers to assist State RWSS Departments and also conduct a quick assessment of the situation. Financial assistance from the calamity fund can be allocated, subject to approved procedure, immediately in case of major emergency situations (GoM, n.d).

3. Disaster responses in the case of Agriculture Ministry are for drought, pest attack and hailstorm.

04. Existing Government Institutions in Maharashtra WASH Sector

04.1 Agencies and organizational structures

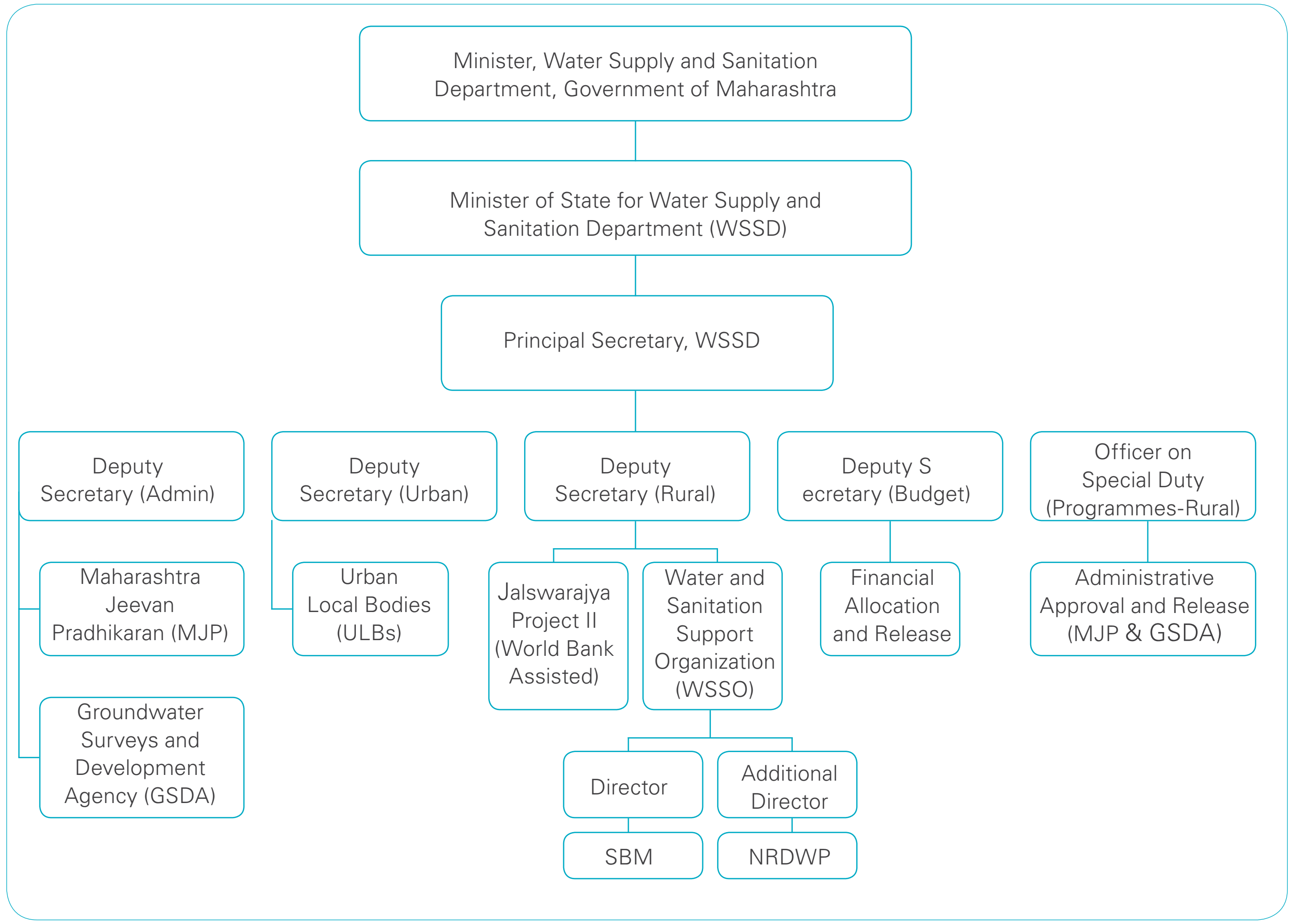
Water Supply and Sanitation Department (WSSD), Government of Maharashtra (GoM) is the State nodal agency for formulating, implementing, operating and maintaining regional water supply schemes in both rural and urban areas (Figure 6). The Groundwater Surveys and Development Agency (GSDA), the Maharashtra Jeevan Pradhikaran (MJP), and Water Supply and Sanitation Organization (WSSO) are the three line agencies supporting the Water Supply and Sanitation Department.

The GSDA is a technical agency (mostly consisting of geologists), and entrusted with the responsibility of overall development and management of groundwater. Its directorate is located in Pune, which is assisted by six regional and 33 district level offices. As per the GoM Resolution of 30th June 2003, there are a total of 1365 sanctioned posts in GSDA, including 892 technical and 473 non-technical ones. In addition, there are 869 posts which had been transferred to ZP but are under the administrative control of GSDA. At present, GSDA employs professional and support staff in various disciplines including hydro-geology (with remote sensing & GIS specialization), chemistry, cartography, and field expertise. For more thanthe last 40 years GSDA is engaged in the exploration, development and augmentation of groundwater resources in the State through various schemes.

MJP mainly consists of engineers and implements piped water supply schemes. The MJP with central office in Mumbai and Navi Mumbai has field offices spread across the State. Overall, there are five Zonal offices, 16 circle offices, 44 work/project divisions and 151 sub-divisions. The primary responsibility of MJP is planning, design, investigation, detailed engineering, and execution of water supply and sewerage schemes in the State. Additionally, MJP arranges finances for these schemes. On successful completion of these projects, MJP hands them over to the respective local bodies. To settle the administrative expenses, MJP receives a fixed amount on total project costs which has been currently fixed by GoM at 17.5% of the value of projects.

As per the Government Resolution (GR) of June 2003, some of the functions and functionaries of the GSDA and MJP were transferred to Zilla Parishads (ZP). The Water Supply Department of Zilla Parishads mainly comprises these transferred functionaries and is responsible for implementing water supply and sanitation reform programmes. A Reform Support and Project Management Unit (RSPMU) was also set up in order to facilitate the RWSS reforms process. The RSPMU operates at the State and the district level.

Figure 6: Organogram of Water Resources Department, Government of Maharashtra



(Source: UNICEF/IRAP, 2013)

In order to successfully implement State level and national level rural water supply programme in the State of Maharashtra as per guidelines of the Central Government and implement and monitor rural water supply programmes in general, the Government has decided to establish State level Water Supply and Sanitation Organization. The main responsibilities of WSSO include preparing annual action plan, providing technical and administrative assistance to local organizations in planning and implementation of schemes, developing Information, Communication and Education (ICE), and also developing Management Information System (MIS) for monitoring of rural water supply and sanitation programmes.

The WSSO is responsible for implementing the policy guidelines of rural water supply and sanitation Programmes and State Water Supply Mission. It will act as the Directorate for water supply and sanitation department in all respects. The organization was formed in 2009 and is still evolving.

4.2 Supply and cost norms for rural water supply and sanitation schemes

As per the GoM Resolution dated 27 July 2000, delivery of 40 litres per capita per day (lpcd) was established as a water supply norm for the rural areas. From within this, three litres are to be provided for drinking purpose, five litres for cooking, 15 litres for bathing, seven litre for washing utensils and house, and 10 litres for ablution. Villages or habitations with no source within 1.6 km in plain area and 100 m elevation in hilly area were selected to be covered by the RWSP. The 12th Finance Plan approach suggests enhancement in per capita supply from 40 lpcd to 55 lpcd for rural areas. However, GoM continues to use the norm of 40 lpcd citing groundwater scarcity. The Water Quality Standards as per IS: 10500 are followed in the context. Regarding the cost norms for implementing piped water supply schemes across the State, GoM has recommended standards in 1999 (Table 6). Since then, these norms have not been revised and no provision for inflation was made to be considered while planning the new schemes (World Bank, 2012).

Table 6: Cost norms for implementing piped water supply schemes in Maharashtra

Type of Scheme	Cost Norms in Rs. Per Capita	
	Non-Konkan Area	Konkan Area
Hilly Areas	2 ,120	2,320
PWS with static lift of more than 30m	1,790	1,970
PWS with static lift up to 30m	1,390	1,530

(Source: World Bank, 2012)

4.3 Administrative procedures

Once a rural water supply schemes is planned, its implementation is taken up with administrative approval and technical sanction of the designated authorities. For a single village piped scheme up to 50 Million, GP has the responsibility to execute with the technical support from ZP and MJP. Whereas for the single village schemes costing above Rs. 50 million, MJP is in charge of execution and role of GP is confined to operation and maintenance. For multi-village schemes costing up to Rs. 25 million, ZP is responsible for the entire execution and role of GP is confined to O & M, and that too under the technical supervision of ZP. For the multi-village schemes above 25 million, responsibility of execution shifts to MJP. Here again role of GP is restricted to O&M of the system. Thus, it is quite clear that the role of GP/VWSC is mainly restricted to O&M of the schemes. For the project with high cost, even the O&M function is performed under the technical supervision of ZP or MJP.

4.4 Legal and policy framework relating to rural water supply and sanitation

GoM established Groundwater Survey and Development Agency (GSDA) in 1972 to scientifically tap groundwater resources in the State. Soon after, the Maharashtra Water Supply and Sewerage Board Act (MWSSB Act) was passed in 1976. Under the Act, Maharashtra Water Supply and Sewerage Board (MWSSB) was set up in 1977 to take over the functions and assets of the Public Health Engineering (PHE) department of GoM.

Due to groundwater over-exploitation and resulting water scarcity in many areas during 1990s, a large number of settlements in Maharashtra had to depend on tankers to meet their drinking water needs, especially during summer months. In order to manage the groundwater for protection of public drinking water sources, the Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act, was passed in 1993. The Act prohibited construction of wells within a radius of 500m from a public drinking water source, if both are in the area of the same watershed. Further, the Act empowered the appropriate authority (District Collector in this case) to restrict or prohibit extraction of water (for any purpose other than for drinking) from any well in an identified 'water scarce' area (as advised by GSDA) during the scarcity period, if such well is within a distance of one kilometer from the public drinking water source (GoM, 1993). However, the Act was not preventive but only corrective in nature (Phansalkar and Kher, 2006) .

The White Paper on the State's water situation attributed the drinking water scarcity problems to inadequate infrastructure development and to the excessive dependence on unreliable sources. Further it identified the need for massive capital investments for developing the required infrastructure for fulfilling the drinking water requirements of the State. As a result, the then State Government amended the MWSSB Act and established Maharashtra Jeevan Pradhikaran (MJP), a statutory body constituted from erstwhile MWSSB in 1997, giving the State GoM authority to raise capital from the open market. With the help of the MJP and the GSDA, GoM embarked on a mission to provide sustainable water supplies for both urban and rural areas. In 2003, Maharashtra became one of the few States in India to adopt State Water Policy. It laid emphasis on management, operation, and maintenance of these services by community level organizations and appropriate local level bodies (GoM, 2003).

In 2013, GoM passed the Maharashtra Groundwater (Management and Development) Act 2009, which replaced the groundwater Act of 1993. This new Act is more comprehensive and aims at "facilitating and ensuring sustainable equitable and adequate supply of groundwater of prescribed quality, for various category of users, through supply and demand management measures, protecting public drinking water sources and establishing the State Groundwater and District Level Authority to manage and to regulate, with community participation, the exploitation of groundwater within the State of Maharashtra". As per the section 3(1) of the Act, the Maharashtra Water Resources Regulatory Authority (established under section 3 of the Maharashtra Water Resources Regulatory Authority Act, 2005) shall be the State Groundwater Authority. GSDA has also been provided with more footholds under the Act.

In contrast to the Groundwater Act of 1993, which empowered the District Collector in consultation with a technical officer to notify the area as 'over-exploited' or 'water scarce', the new groundwater Act empowers the State Groundwater Authority to notify an area but only on the basis of: recommendations from the GSDA; views of various institutions working in groundwater field; and views of the users of the groundwater of the area. The decision to notify an area has to be based on scientific studies on groundwater balance and quality; and groundwater estimation. The Act calls for establishment of a Watershed Water Resources Committee (WWRC) to promote and regulate development and management of groundwater in the notified area. The Act envisaged several restrictions such as, ban on construction of wells; prohibition on groundwater pumping from the existing deep-wells (more than sixty metre deep); stipulation on deep-well users to follow the groundwater use plan, and crop plan. All these measures are now in operation in notified areas. Unlike the earlier Act which was silent on groundwater quality, the new Act puts emphasis on protection and preservation of groundwater quality of all the existing drinking water sources in the State.

Further, in both notified and un-notified areas, registration of well owners is made mandatory (section 7 of the Act), and drilling deep wells for agriculture and industrial use is prohibited (section 8.1 of the Act). Additionally, section 12 of the Act made it compulsory for registration of drilling rig owners and operators in the State. The Act also empowers the District Authority (officer not below the rank of Tahsildar) to enforce the decisions of WWRC. Though, Maharashtra Groundwater (Management and Development) Act 2009 is a major improvement over the earlier Act, its effectiveness in arresting groundwater exploitation can only be judged once it is implemented across the State.

4. For instance, the provisions of the Act were only enforceable either in watersheds declared as 'overexploited' or if a specific locality was notified as scarcity affected in a particular year. There were no provisions for registration of wells or for making applications mandatory for sinking new wells. It did not even provide for compulsory licensing of drilling companies or agencies (Phansalkar and Kher, 2003).

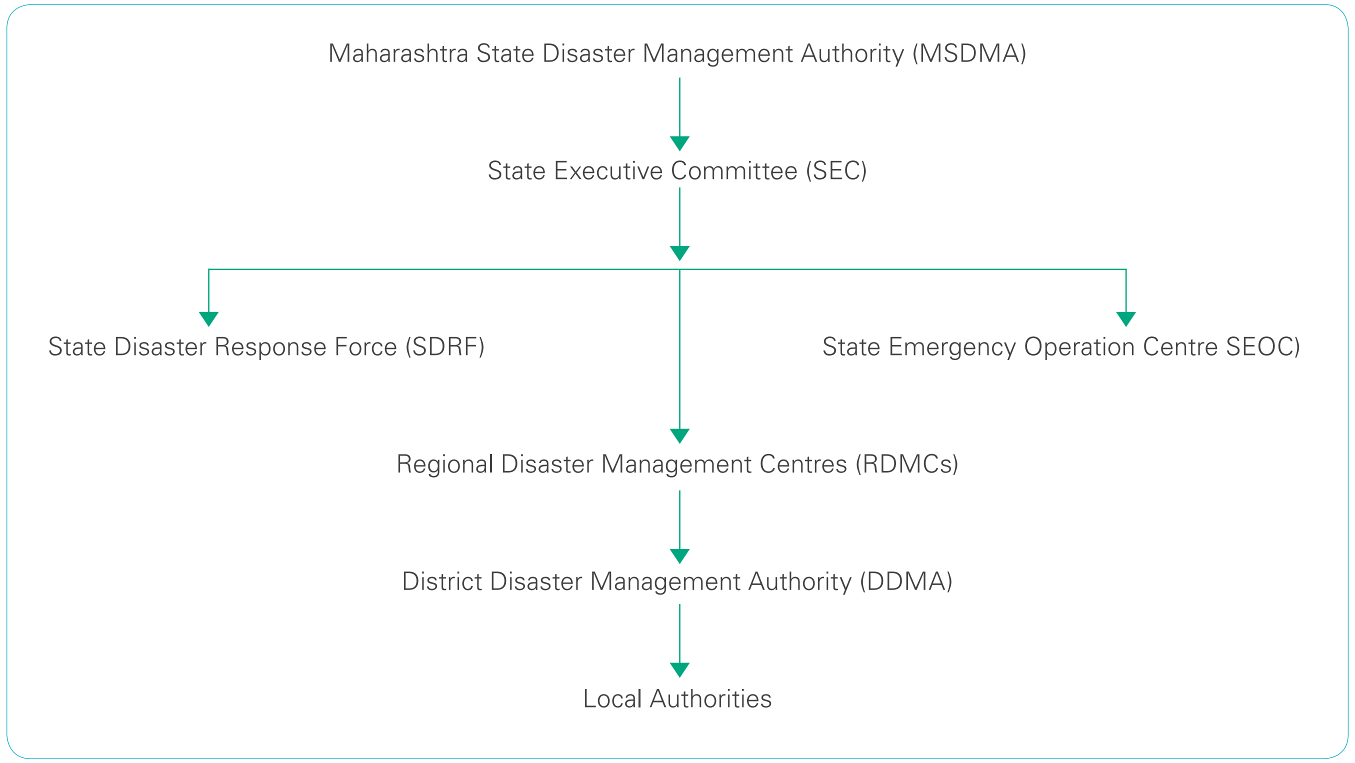
05. Overview of Disaster Management Measures in Maharashtra

All State Governments are mandated under Section 14 of the DMA, 2005, to establish a State Disaster Management Authority (SDMA). SDMA consists of Chief Minister of the State, who is the Chairperson, and no more than eight members appointed by the Chief Minister. The State Executive Committee is responsible (as per section 22 of the DMA, 2005) for drawing up the State Disaster Management Plan, and implementing the National Plan. SDMA is mandated under section 28 of the DMA, 2005, to ensure that all the departments of the State prepare Disaster Management Plans as prescribed by the National and State Authorities (GoM, n.d).

05.1 Institutional preparedness and programmes to check climate-induced hazards in Maharashtra

05.1.1 Institutional arrangement for disaster management

Figure 7: Institutional Arrangement for Disaster Management in Maharashtra



(Source: GoM, n.d)

Maharashtra SDMA was constituted on 24th May 2006. SDMA is chaired by the State Chief Minister, and the State Deputy Chief Minister is the vice-chairperson. Its other members include three state ministers, three unofficial members and the State Chief Secretary who is also the Chief Executive Officer. Simultaneously State Executive Committee (SEC) was formed as an implementation wing of SDMA. SEC also acts as the coordinating and monitoring body for management of disaster in the State. For effective communication and information management during disaster, State Emergency Operation Centre (EOC) was established. A separate State Disaster Response Force (SDRF) for effective response during disasters was also constituted (DMU, n. d).

Secretariat for both SDMA and SEC was established under the chairmanship of Additional Chief Secretary (Relief and Rehabilitation). Initially, Relief and Rehabilitation Division under the Revenue and Forest Department, GoM, was appointed as the nodal agency for disaster management in the State. Later a separate Relief and Rehabilitation Department (RRD), GoM, was formed.

Each district also has a District Disaster Management Authority (DDMA) and District EOC. While SDMA is responsible for policy/decisions making, resource/budget allocation and monitoring through the State EOC, DDMA is responsible for preparedness and mitigation at the district level. The district level response is co-ordinated under the guidance of the District Collector, who acts as a District Disaster Manager (GoM, n. d).

05.1.2 Maharashtra State Disaster Management Plan

Maharashtra is one of the first States to prepare a comprehensive State Disaster Management Plan (SDMP) which was approved in April, 2016. The SDMP was prepared by the Disaster Management Unit (DMU) at RRD, GoM. The plan also contains hazard, risk and vulnerability analysis for various districts, talukas within these districts, and clusters of villages in these districts to earthquakes, floods and cyclones, epidemics, road accidents, chemical and industrial disasters. A separate volume on Standard Operating Procedures (SOP) was also prepared which include the manuals for various departments to be activated during an emergency (GoM, n. d).

05.2. Measures to reduce exposure of WASH systems to climate induced hazards

Maharashtra SDMP mentions various structural and non-structural measures and the responsible line departments intended to reduce risks that arise from climate related natural hazards. These measures are intended to shield assets from exposure, injury or destruction. Some of the proposed measures for hazards, such as floods and droughts, including departments responsible for implementing these actions are presented in Table 7 and Table 8.

Table 7: Proposed Structural and non-structural Measures to Reduce Exposure to Floods

S. No	Task	Activities	Responsibilities
A	**Structural Measures**		
1	Construction Works	■ Construction of dams, flood protection wall, flood diverting channels ■ Improvement of design for irrigation and flood protective structures ■ Strengthening/repair of existing roads and bridges and other critical infrastructure in flood plain ■ Strengthening of dams and canals	■ Revenue Dept. ■ Secretary, R & R ■ Irrigation Dept. ■ PWD Dept. ■ All line Depts.
2.	Development of catchment area	■ Development of catchment area of the flood plain through forestation, land sloping, small reservoirs/check dams/ponds etc.	■ Revenue Dept. ■ Irrigation Dept. ■ Forest & Environment Dept.
B	**Non-structural Measures**		
1.	Forecasting and warning	■ Strengthening and up gradation of existing flood forecasting system ■ Establish infrastructure for flood warning and dissemination	■ Director DMU ■ Irrigation Dept ■ CWC ■ IMD
2.	Techno-legal regime	■ Enactment and enforcement of laws regulating developmental activities in flood plain ■ Specific building by-laws for flood plains	■ Revenue Dept. ■ Secretary R & R ■ Irrigation Dept. ■ UD Dept, Panchayat & Rural Housing ■ Local Urban Bodies

It is interesting to note that most of the recommended structural measures on flood and drought proofing have a major emphasis on the irrigation infrastructure (including crop security). Water supply and sanitation systems are not mentioned specifically, as infrastructure to be protected in the event of floods. Another important concern relate to the role of small water harvesting structures in climate resilience of WASH systems. While check dams store some runoff in the small reservoirs which recharge shallow groundwater in the area, this is mainly benefiting the irrigators whose wells get replenished. Farm ponds that are constructed in large numbers in the drought prone regions of the State capture runoff from the small local catchments. These are being used by the farmers to pump and store groundwater and adversely affecting water availability for domestic uses from wells (Kale, 2017). Thus, these interventions only increase the exposure of WASH systems during droughts.

The institutions in-charge of planning, developing and managing rural water supply and sanitation systems such as the Groundwater Surveys and Development Agency, the Maharashtra Jeevan Pradhikaran, and the Water Supply and Sanitation Organization are mentioned as the agencies responsible for handling disaster situations. Lack of integration of these institutions associated with provision of WASH services in rural Maharashtra with the SDMP results in institutions having a limited role in preventing or reducing the exposure of WASH systems to climate induced hazards such as hydrological droughts and floods.

The non-structural measures lay emphasis on strengthening of flood and drought forecasting, warning and dissemination systems. However, its linkages with rural water supply and sanitations systems is missing (please refer Table 7 and Table 8).

Table 8: Proposed Structural and non-structural Measures to Reduce Exposure to Droughts

S. No	Task	Activities	Responsibilities
A	**Structural Measures**		
1	Construction	■ Construction of dams, reservoirs, lift irrigation, water sheds, tube wells and canals for surface irrigation ■ Construction of percolation tanks, check dams, farm ponds, etc. ■ Construction of warehouses and cold storages for preservation/storage of food grains.	■ Revenue Dept. ■ Secretary R & R ■ Irrigation Dept ■ Agriculture Dept. ■ Civil Supply Dept.

S. No	Task	Activities	Responsibilities
2.	Repair, up gradation and strengthening	■ Repairs, upgrading and strengthening of dams, reservoirs, lift irrigation and canals for surface irrigation ■ Repair, upgrading and strengthening of percolation tanks, check dams, farm ponds, etc.	■ Revenue Dept. ■ Secretary R & R ■ Irrigation Dept ■ Agriculture Dept.
3.	Adaptation of new technology	■ Application of advanced agro-science technology and agro-engineering inputs to improve agriculture production	■ Revenue Dept. ■ Secretary. R & R ■ Agriculture Dept.
B	Non-Structural Measures		
1.	Techno-legal regime	■ Enactment and enforcement of laws regulating ground water level and exploitation of natural resources.	■ Revenue Dept. ■ Secretary-R & R ■ Irrigation Dept. ■ UD Dept, ■ Panchayat ■ Urban Local Bodies
2.	Forecasting and Warning	■ Strengthening and up gradation of existing drought forecasting system ■ Establish infrastructure for drought warning and dissemination	■ Revenue Dept. Director DMU ■ Irrigation Dept ■ IMD

(Source: Maharashtra State Disaster Management Plan)

5.3 Measures to reduce community vulnerability to climate-induced hazards

Most of the measures to reduce vulnerability of communities to climate-induced hazards are based on capacity building and awareness programmes (Table 4). As is the case with measures to reduce exposure, there is no specific activity to reduce community vulnerability to damaged water supply and sanitation systems, or inadequate water supply (reduced availability of water for drinking and other domestic purposes or water contamination) and poor sanitation. Most of these measures relate to rescue operations (in case of floods) and supporting agricultural produce (in case of droughts).

The ideas such as promoting water harvesting and encouraging farmers to go for water-efficient crops, as capacity building measures to deal with droughts (see Table 9) are also ill-conceived. As regards the former, the reason is that during droughts, water harvesting systems fail, given the unique hydrological settings of regions, which experience droughts (Kumar et al., 2008). As to the latter, farmers have no special incentive to switch to water-efficient crops, given the existing institutional and policy environment governing water use in agriculture, and even if they do, it cannot ensure sufficient water for domestic sector as they can expand the area under irrigation. Similarly, the ideas such as the 'Jalyukta Shivar Abhiyan' launched by the State Government recently with the aims of making Maharashtra 'a drought-free State by 2019' (which involves deepening and widening of streams, construction of cement and earthen stop dams, works on nullahs and digging of farm ponds (GoM, 2016: p 10)) have no scientific footing.

Table 9: Various Measures to Reduce Community Vulnerability to Climate Induced Hazards

S. No	Task	Activities	Responsibilities
A	During Floods		
1	Capacity Building	■ Ensure flood search and rescue materials are purchased and kept at local level ■ Departmental flood contingency plan ■ Flood related departmental action plan and SOP ■ Imparting training to the stakeholders involved in flood mitigation and management ■ Organize mock drills on flood rescue	■ Revenue Dept. ■ Director DMU ■ Irrigation Dept ■ Line Dept.
2.	Awareness	■ Dissemination of flood risk to general public residing in flood prone areas ■ Campaign for flood safety tips ■ Develop IEC materials on dos and don'ts	■ Revenue Dept. ■ Director DMU ■ Irrigation Dept ■ SDMA ■ Information Dept. ■ Line Dept.

S. No	Task	Activities	Responsibilities
B	During Droughts		
1.	Capacity Building	■ Departmental drought contingency plan ■ Drought related departmental action plan and SOP ■ Imparting training to the stakeholders involved in drought mitigation and management ■ Encourage people to use advance technology for drip and sprinkler irrigation ■ Encourage water harvesting ■ Encourage farmers to understand crop pattern to be adapted in their areas. ■ Rational use of fertilizers and pesticides. ■ Encourage the adaptation of technique for preservation of green folder	■ Revenue Dept. ■ Director DMU ■ Irrigation Dept. ■ Agriculture Dept. ■ Forest & Environment Dept. ■ Rural Development ■ All line Dept.
2.	Awareness	■ Dissemination of drought risk to general public residing in drought prone zones ■ Campaign for drought tips for agriculture, general public and industries ■ Motivate farmers to adapt the drought resistant crops, new technology and off-farming activities	■ SDMA ■ Revenue Dept. ■ Director DMU Irrigation Dept ■ Agriculture Dept. ■ Information Dept. ■ All line Dept.

(Source: Maharashtra State Disaster Management Plan)

Further, during any disaster, financial aid is provided to the affected community in the State through the Natural Calamity Relief Fund. Under this head, relief is provided to compensate for human loss, death of animals and damaged crops and for repairing damaged houses, purchasing utensils, food items, clothes and necessary household goods (Kumar and van Dam, 2013).

The State Government also provides State Disaster Mitigation Fund to all 35 districts and 10 Regional Disaster Management Centres (RDMCs) working for city areas for strengthening EOCs and purchasing search and rescue equipment, organizing capacity building training programmes and awareness programmes for various target groups. However, no specific financial aid is provided for water supply and sanitation systems to reduce the vulnerability of communities depending on them during climate-induced hazards.

As per the recommendation of "The High Level Committee on Balanced Regional Development Issues in Maharashtra", the funds required for additional water supply infrastructure in Maharashtra is about Rs 28,608 crore (GoM, 2013). Vidarbha requires about 22.5% and Marathwada about 23% of the total proposed fund allocation (please refer to Table 10 for more details). The financial provisions for the required level of water supply are worked out considering the water supply gap between 2011 and 2030, based on the norm of minimum water supply of 140 litres per day per capita for both rural (including livestock water needs) and urban areas; and, the Maharashtra Jeevan Pradhikaran norm of Rs 137 per cubic metre of development of new water supply infrastructure.

One recommendation of the Committee, which is important from the perspective of climate resilience, is that it had considered a water supply level of 140 lpcd for rural as well as urban areas, while working out the investment needs in water supply sector. This marks a major departure from the past trend of using the norm of keeping 40 lpcd of water for rural areas, and up to a maximum of 55 lpcd in case of special projects. This is far less than what is required to meet the basic needs of rural HHs in hot and arid climates, which includes the productive need of watering animals (IRAP, GSDA & UNICEF, 2013). There are two reasons for this. First: the water requirements per unit of human and livestock population would be high in such climates.

Second: livestock rearing is becoming a dominant economic activity of rural areas in such climatic zones, increasing the average per capita water demand of HHs.

However, an important issue that requires special attention is that the cost of water supply per unit volume of water supplied would be much higher in water-scarce regions as compared to water-rich regions, given the poor dependability of water from internal sources and the need for importing water from exogenous sources for meeting the demands on a sustainable basis (Kumar, 2014) . Going by this analysis, we would require allocation of larger amount of funds to such regions than what is demanded by the gap in infrastructure. The drought-prone regions such as Marathwada and Vidarbha would require larger amount of funds per cubic metre of water supplied to meet the drinking water supply requirement in future. In view of this, the State also needs to allocate a greater proportion of its budget towards increasing climate resilience of existing WASH systems in rural Marathwada and Vidarbha.

Table 10: Proposed Financial Provision for Drinking Water Sector in Maharashtra

S. No.	Water Sector components	Funds required in different regions of the State (in Rs crore)						
		Konkan	Nashik	Pune	Aurangabad	Amravati	Nagpur	State
1.	Rural water supply	706	706	661	564	154	321	3112
2.	Urban water supply	4343	2086	4594	5280	3128	1993	21424
3.	Highly water stressed talukas	0	531	767	450	50	0	1798
4.	Talukas of unfavourable strata	724	258	243	290	59	158	1732
5.	Water supply schemes for saline areas	0	0	0	0	542	0	542
	Overall	**5773**	**3581**	**6265**	**6584**	**3933**	**2472**	**28608**

5. This was illustrated by an empirical analysis of 301 cities and towns in India.

(Source: GoM, 2013)

06. Creating Enabling Environments for Improving Climate Resilience of WASH Systems in Maharashtra

6.1 Capacity building

Creating an enabling environment is fundamental to making sustainable changes in the WASH sector. To improve climate resilience of WASH systems, capacity needs to be built at all levels –

- Central - Ministry of Drinking Water and Sanitation,
- State - State Government Agencies dealing with water supply & sanitation such as MJP, GSDA and WSSO, the State Disaster Management Agency, the State level NGOs,
- District - District administration, Gram Panchayats and the water users who are the primary stakeholders.

The following are the measures that can be taken in the context: i) knowledge generation through training and education; ii) knowledge dissemination; and, iii) informed action through pilot projects. These should include the following:

- Building partnerships and engaging stakeholders to support more resilient development and avoid conflicts and inequalities.
- Decision-makers should use local case studies, adopt simple language, and encourage interaction in the capacity development programme, and also ensure that the learning material is accessible to a wide range of participants.
- Maintaining commitment of the various stakeholders in implementation of the capacity development programmes. Programme has to be adaptive, and has to engage and communicate with stakeholders on a continuous basis.
- Media involvement is also very important.

Along with training and education, institutional capacities are to be developed at various levels, in order to ensure that climate change variables are effectively integrated into planning of water supply and sanitation systems. The past literature on the topic has, however, focused on the capacity building of local institutions such as the Gram Panchayats, the Watershed Committees and the village Self Help Groups for reducing the exposure and vulnerability to droughts. Again, the emphasis has been on improving the effectiveness of MNREGS (Mahatma Gandhi Rural Employment Guarantee Scheme) and watershed development activities implemented under National Watershed Development Programme (NWDP) through greater convergence (See Vedeld et al., 2014).

Some of the possible measures and the required inputs to improve climate resilience of WASH systems are presented in Table 11. These measures fall under three categories namely, capacity building of stakeholders, technical interventions, and disaster preparedness.

Table 11: Capacity Building Measures in WASH

Capacity building of stakeholders	■ Support for diversification of water supply from HH to municipal levels. ■ Promotion of advocacy for waste water recycling at HH and city wide levels to reduce demand on stressed water sources. ■ Promotion of advocacy for increasing multi-annual storage through surface reservoirs in drought prone areas and increasing flood cushioning in flood prone areas. ■ Training of hydrologists on climate modelling to predict the changes in hydrology of river basins due to climate variability and change ■ Training of engineers in WRD on design and operation of reservoirs for greater flood cushioning (for flood prone areas); and design of reservoirs for enhanced multi-annual storage (for drought prone areas)
Capacity building of stakeholders (Continued...)	■ Training of water supply engineers on designingwater supply systems resilient to reduced water flows due to climate variability (particularly droughts) decentralized desalination systems, leakage detection & prevention measures in pipelines; and design and operation of decentralized WWT systems. ■ Training of sanitation engineers on designing sanitation infrastructure which pose least environmental pollution risk to groundwater ■ Training of water supply engineers on design of cyclone- resistant infrastructure such as water distribution pipelines, overhead water tanks, etc. ■ Establish and undertake capacity building of local water committees for maintenance and resource management.
Disaster preparedness	■ Raising awareness among local communities about disaster and climate change risk, through education and training programmes. ■ Provision of training and equipment to local and municipal disaster response personnel. ■ Support for development of community level early warning and evacuation systems using appropriate media and technology.
Technical interventions	■ Rehabilitate damaged water distribution networks using hazard-and stress-resilient materials and designs. ■ Building surface reservoirs with enhanced capacity for multi-annual storage of inflows ■ Building projects for transfer of water from water-rich Western Ghat region to chronically drought-hit Marathwada region ■ Raised hand-pumps and well-head protection in flood-prone areas, to ensure continuity of access to water during flooding. ■ Rain water harvesting and storage systems for populations in areas without piped water, but receiving heavy rainfall over long time periods. ■ Building of 1) decentralized desalination systems in coastal areas not served by piped water supply schemes, run by solar power; 2) decentralized wastewater treatment systems ■ De-silting of water troughs for use by livestock during drought. ■ Promotion of household water filters and education on their use. ■ Raised latrines placed at a safe distance from water sources to prevent overflow and contamination during flooding. ■ Hygiene and hand-washing campaigns among at-risk populations. ■ Cleaning-up of drainage canals prior to predicted tropical storms and flash floods.

The principles that need to be followed for disaster risk reduction related to climate and the guidance for applying the same, as proposed by Turnbull et al. (2013) are given below.

A. Increase understanding of climate induced hazard and identify the projected effects of climate change on water availability at a wider geographical scale, as well as in the project location. Analyse the hazard profile of the programme location using the best available information on how hydro-meteorological hazards are likely to be affected by climate change. In the context of Maharashtra, the specific climate hazards which need to be profiled at the regional scale are droughts, showing their frequency and intensity, and the likely impact on surface runoff and groundwater recharge.

B. Increase understanding of exposure and vulnerability and also the capacity to adapt. Assess the extent to which current WASH systems in the programme location are exposed to hazards and to the projected impacts of climate change on surface and groundwater sources. Assess the degree of access of the target population to water and sanitation services, its impact on their health and nutritional status, and how it changes their vulnerability to hazards and the effects of climate variability. A climate risk assessment mapping, similar to what is being done under this project in two divisions of Maharashtra, for the entire State is required.

C. Recognize rights and responsibilities. Share the results of climate risk assessment mapping with the population that are vulnerable and other relevant stakeholders such as private companies contracted to provide WASH services.Raise awareness among at-risk populations of their rights to water and sanitation and how these are affected by climate induced disasters.

D. Strengthen participation of, and action by, population at risk. Develop the capacity of local health personnel to provide information on measures to take before, during and after common hazards. Support the formation of WASH committees within at-risk populations; and train them to monitor and maintain WASH systems and to negotiate with the State level line agencies in the WASH sector.

E. Promote systemic engagement and change. Advocate for the engagement of WASH actors (Governmental, non-governmental and private sector) in national platforms/forums for disaster risk reduction and climate change adaptation.

F. Foster synergy amongst multiple levels.Identify national laws and policies relevant to WASH issues and climate and disaster risk mitigation, support the populations at risk to advocate for their implementation. Promote coordination between all water users and authorities within river basin catchments and aquifer recharge zones.

G. Draw on and build diverse sources of knowledge. Before designing interventions, obtain technical assessments of current groundwater and surface water sources, and the potential impact of climate change on them. Share examples of hazard- and climate-resilient WASH systems in other locations, to encourage replication where appropriate.

H. Instil flexibility and responsiveness. in the design/retrofit of WASH systems to be functional in a range of predicted climate scenarios. Promote systematic monitoring of WASH installations following hazards and in different climatic conditions, and undertake/advocate for improvements where necessary.

I. Address different time scales. Support users and service providers to identify early warning indicators for hazards that may affect WASH systems, and to develop contingency plans. Reduce longer-term vulnerability and exposure by combining emergency measures and the development of sustainable, resilient systems in post-disaster WASH interventions.

J. Do No Harm.Undertake an environmental impact assessment prior to any WASH intervention; systematically monitor the potability of sources being tapped for drinking water supply (surface and groundwater) to prevent consumption of contaminated water.Promote communication and coordination between different water user groups (say between irrigators and domestic water users in urban areas) whose access to water is likely to be affected by climate variability and change.

Source: adapted from Turnbull et al. (2013)

6.2. Training Plan for the Line Agencies

Training for human resource development is one of the important instruments for capacity building. A detailed training plan, covering various themes mentioned under the capacity building programme for climate resilience in WASH is furnished in Table 12.

Table 12: Training Plan with Theme, Objectives, Topics and Target Audience

S. No	Training Theme	Topics to be Covered	Objectives	Target Audience	Agency	Proposed Duration (days)
1	Hydrological modelling of river basins for climate change scenarios	Basin characterisation; Identifying key water management issues; Selection of appropriate hydrological models for gauged and un-gauged catchments; Identifying data requirements; Establishing conceptual rainfall-runoff models; Developing base case; Analysis of historical trends in rainfall & climate; Generating scenarios to assess impact of climate variability and change.	To orient the water engineers to the concept of hydrological modelling, for different types of stresses, including climate variability and change; Equip them with skills for choosing appropriate models for different situations; Strengthen their skills for analysis of basic data for setting up hydrological models	Civil Engineers (preferably Hydrologists) at the level of AEE and EE	Water Resources Department	3 days
2	Flood Management	Integrated flood management; Estimation of design flood; Computation of carrying capacity of rivers; Relationship between flood discharge and flood damage; Structural design of flood control counter-measures (such as reservoirs in flood prone areas); alignment of existing structures and river channel improvement; Non-structural measures (flood forecasting); Preparation of flood management plan; Integrating WASH systems in flood management planning.	To orient the water engineers to the concept of IFM; Equip them with skills for assessing flood hazards; Inform them about various measures for integrated flood management, including structural and non-structural; Inform about measures for making WASH systems flood proof	Civil Engineers Hydrologists working in the Flood Control wings at the level of AEE and EE	Water Resources Department	7 days

S. No	Training Theme	Topics to be Covered	Objectives	Target Audience	Agency	Proposed Duration (days)
3	Drought Proofing	Need for drought-proofing plan; Statistical analysis to determine the frequency of meteorological droughts; Use of drought prediction tools; Drought assessment and prediction; Groundwater behaviour in hard rock regions; Design of reservoirs to increase the multi annual storage of inflows; Ascertaining technical feasibility and economic viability of regional water transfers; Preparation of drought management plan	To orient the professionals to the concept of drought-proofing; Strengthen their ability to carry out analysis of meteorological data, for assessing droughts; Equip them with skills for using drought prediction tools; Informing about design considerations for planning reservoirs for multi annual storage	Senior Geologists; AEEs and EEs working in Water Supply & Sanitation Dept., AEEs and EEs working in WRD and middle level officials in disaster management	MJP/GSDA/ WRD/ SDMA	7 days
4	Leakage detection and prevention in water distribution pipes of regional water supply systems	Methods of leakage detection and measurement in pipelines; Leakage management strategy including early detection & repair, and community role; Leakage monitoring and control; Measures for leakage prevention; Economics of leakage prevention	Equip the engineers in the water supply dept. with skills for leakage detection and leakage estimation; Inform them about various engineering measures for leakage prevention; Orient them to the concept of economic efficiency in leakage prevention	AEEs, and EEs working in water supply & sanitation department	MJP	5 days
5	Design and operation of decentralized desalination systems	Introduction to different types of desalination technologies; Renewable energy driven decentralized desalination systems; Region identification and site selection; Government policies and programmes; Economic evaluation of decentralised desalination systems; Installation and commissioning; operation and maintenance including community role	Inform the rural water supply engineers about various desalination technologies; Equip them with skills for technology selection to suit different situations; Equip them with skills for system design; Inform them about the operation and maintenance aspects	AEEs, and EEs working in water supply and sanitation department	MJP	7 days
6	Design of sustainable rural water supply systems for multiple uses	Introduction to multiple use water systems; Design considerations for water supply systems for domestic and productive uses; Different techno-institutional models for sustainable water supply in rural areas; Retrofitting of existing water systems for multiple uses	Orient the rural water supply engineers to the concept of multiple uses; Inform them about various criteria for design of MUWS; Equip them with skills for designing sustainable water systems in different situations	EEs and Superintend-ing Engineers working in water supply & sanitation departments	MJP	5 days

S. No	Training Theme	Topics to be Covered	Objectives	Target Audience	Agency	Proposed Duration (days)
7	Design of ecologically sound sanitation infrastructure	Linkage between climate, ecology and health impacts of onsite sanitation; Concept of ecologically sound on-site sanitation systems; Toilet technologies for flood-prone areas and high water table areas; Toilet technologies for black cotton soils & hard rock strata	Orient the sanitation engineers to the concept of ecologically sound sanitation; Inform them about the criteria for design of ecologically sound sanitation systems; Strengthen their skills to build ecologically sound sanitation systems for difficult areas	AEEs and EEs working in WSSO Middle level officials of NGOs working on rural sanitation	WSSO	5 days
8	Planning, design, execution and operation of wastewater treatment systems	Physical and economic criteria for technology selection in WWT systems; Technology and site selection; Design of WWT systems; Construction; Cost and energy requirements; Operation and maintenance	Inform water supply and sanitation engineers about the criteria for selection of WWT technologies; Equip them with skills for design of WWT systems; Inform about the O & M aspects	Environmental Engineers working with water supply and sanitation department	MJP/ WRD of ZP	5 days

(Source: Based on: IRAP 's own analysis; Farley 2001; JICA 2003; NDMA 2010; WaterAid 2011; CPHEEO and JICA 2012; Kumar, 2014; GSDA/IRAP/UNICEF, 2015; UNICEF & Water Supply and Sanitation Department, 2014)

6.3 New WASH Infrastructure for Improving Climate Resilience

The previous section listed several technical interventions for improving climate resilience of WASH systems. Many of them,including building of large reservoirs for multi-annual storage of flows, and implementing inter-basin water transfer projects are not new.They are, in fact, part of existing water management and flood management interventions in India. What is required is a change in orientation of the agencies concerned in the wake of the emerging situation,- so that they understand the need to make such interventions as integral part of their water resources development and management activities comprising planning, design, execution and O & M. This can be achieved through awareness raising and training. However, there are a few interventions, which are based on relatively new concepts from Indian perspective. They are discussed here.

6.3.1 Improved Sanitation Systems for Flood Prone areas and Areas with High Water Table

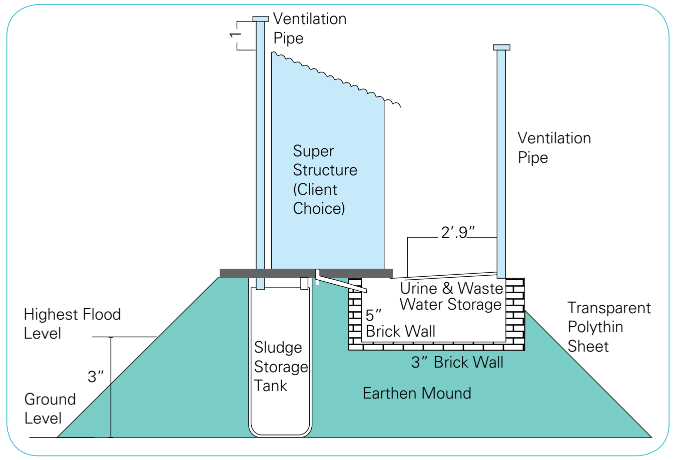
This section explores various technology options for environmental sanitation for areas that are flood prone and / or with shallow groundwater table. The Sante-Brac project in Bangladesh-had experimented with five different sanitation solution for flood prone and high groundwater table areas, including old concepts like mounds and sand envelopes. The 'mounds' are primarily used for preventing pits to be filled with either groundwater or floods, and have been practiced all over the world. A mound can be erected by the people themselves and it does not require craftsmanship.

The 'sand envelope' is a simple technology used to create environmental condition around seepage pits for treating the sewage water while it seeps through the envelope, using adsorption and biological filtration[6]. Both solutions (mounds and sand envelopes) are not very expensive and can be built by the HHs themselves as own contribution. The sand envelopes, which are basically slow sand filers, are effective in removing bacteria, protozoa and viruses (WHO n.y.). If the effluent turbidity is below 1.0 nephelometric turbidity units (NTU), a 90 to 99% reduction in bacteria and viruses is achieved (NDWC, 2000). Though itis generally not effective for the majority of chemicals (WHO n. y.), it can be argued that chemical standards for drinking water are of secondary concern in water supply subject to bacterial contamination during floods.

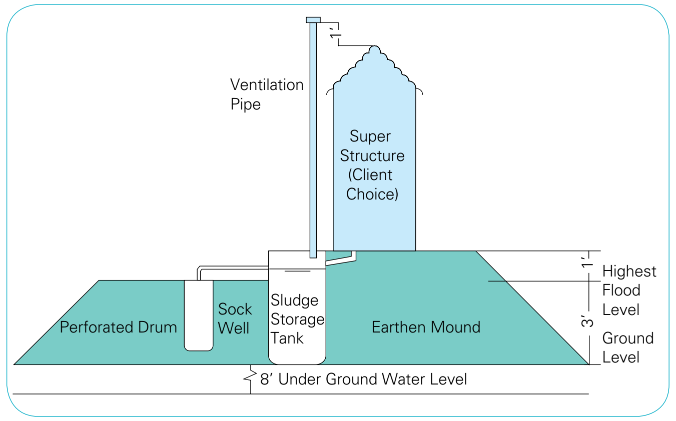
Table 13 describes five different technologies suggested for flood-prone areas with their technical components and specifications. They are - modified urine diversion toilet; offset seepage pit (double plastic drum system); offset seepage pit (double plastic drum system); single offset pit with biogas system; and step latrine (raised pit with earthen mound). Toilet designs for black cotton soils (suitable for many areas covered by black cotton soil) and coastal areas.

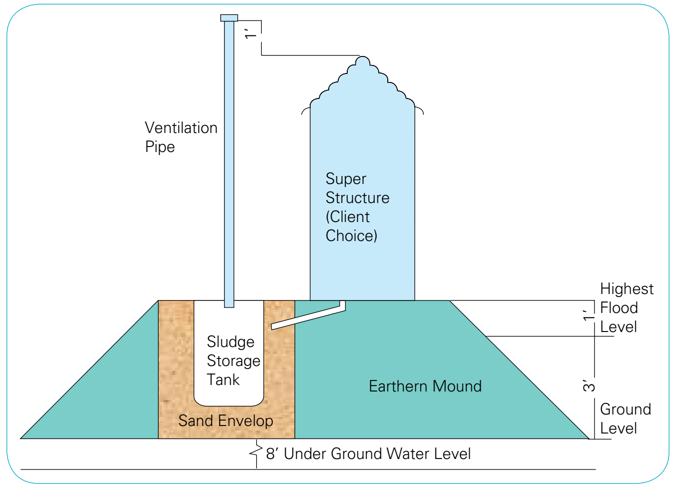
6. *When the contaminated water flows through a layer of sand, it not only gets physically filtered but also biologically treated, removing sediments and pathogens. This process is based on the ability of organisms to remove pathogens. The top layers of the sand become biologically active by the establishment of a microbial community, also referred to as 'schmutzdecke'. These microbes come from the source of the waste water and establish the community within a matter of months. The fine sand and slow filtration rate facilitate the establishment of this microbial community. The majority of the community are predatory bacteria that feed on water-borne microbes passing through the filter. As the process of biological filtration requires a fair amount of time, SSFs usually operate at slow flow rates between 0.1 – 0.3 m3/hour/m2 of surface. The water thus remains in the space above the medium for several hours and larger particles are allowed to separate and settle. It then passes through the sand-bed where it goes through a number of purification processes (WHO, 1996).*

Table 13: Technologies Suggested for Toilets in Flood-Prone Areas

<table>
<tr><th>Description</th><th>Technical Components</th><th>Specifications</th></tr>
<tr><td colspan="3">1. Modified Urine Diversion Toilet, forced dehydration:</td></tr>
<tr><td>

- The system is designed to actively reduce the liquid component of excreta and wash-water by means of heat radiation by the sun and forced aeration.
- Both the liquid and the solid wastes are separated (by means of a urine diversion toilet bowl) and stored in separate chambers. Both are immediately exposed to a flow of air that's driven through the chambers. The movement of air is generated by the vent pipes with air being drawn into the chamber via the openings in the toilet bowl. As the air moves through the system, it dehydrates the wastes similar to the regular urine diversion toilet systems.</td>
<td>- Urine diversion toilet bowl, special bowl with 2 holes: one for the faeces and one for the urine.
- Storage chamber, in the storage chamber the solids are being collected. Washing water and urine are not stored in this container.
- The storage chamber can be constructed with 2 types of materials: bricks and polyethylene.
- Evaporation Chamber, including the black / transparent celluloid cover.
- Evaporation tank can be constructed with 2 types of materials: bricks or polyethylene.
- Vent Pipes: the vent pipes
- Earthen mound</td>
<td>Water level at Peak monsoon is 8' below the ground level.
Sludge storage reservoir:
Height: 4'-0''
Dia:3'-0''
Capacity: 800 litres
Urine and Waste Water storage chamber:
Length: 4'-0''
Width:4'-0''
Height: 2'-0''
Capacity: 900 litre
Wall and Bottom is Brick Wall. Wall and Bottom is Water Proof.
Estimated Cost:
Material cost-10,500, transport and labour cost 9500 = approximately BDT 20,000/-excluding super structure.</td></tr>
</table>

<table>
<tr><th>Description</th><th>Technical Components</th><th>Specifications</th></tr>
<tr><td colspan="3">2. Offset seepage pit: Double Plastic Drum System</td></tr>
<tr><td>

- This system is to increase the user-time of the storage chamber without having to empty it and a controlled release of contaminants into the surroundings. This design is only applicable where there is no danger for contamination of groundwater.
- The liquids are diverted into a seepage pit through an overflow. By using durable materials for the storage and seepage chambers the system will not collapse during floods and high water occasions.
- (This design is only applicable where there is no danger for contamination of groundwater)</td>
<td>- Storage chamber
- Seepage Chamber
- Earthen mound
- Vent Pipe</td>
<td>Specifications:
Water Level at Peak Monsoon is 8' below the Ground Level
Sludge Storage Reservoir
Height: 4'-0''
Dia: 3'-0''
Capacity: 800 litre
Solid Plastic Drum
Drum is covered with Cover
Soak Well:
Height: 2'-6''
Dia: 1'-4''
Capacity: 100 litre
Wall and Bottom of Drum is Perforated.
Estimated Cost:
Approximately BDT 3,550. (Material cost is 2400+transport and labour cost is 600)</td></tr>
<tr><td colspan="3">3. Single Plastic Drum System</td></tr>
<tr><td>

- This system is designed to extend filling time of the storage chamber without having to empty it. By using durable materials for the storage and seepage chambers the system will not collapse during floods and high water occasions.</td>
<td>- Storage Chamber
- Sand envelope
- Vent pipe</td>
<td>Water Level at Peak Monsoon is 8' below the ground level.
Height: 3'-0''
Dia: 2'-8''
Capacity: 800 litre
Wall and Bottom of drum is perforated.
Drum is covered with Cover
Total cost:
3200 including (material cost 2150 + labor cost450 + transport cost 150)</td></tr>
</table>

<table>
<tr><th>Description</th><th>Technical Components</th><th>Specifications</th></tr>
<tr><td colspan="3">3. Single Plastic Drum System (Continued...)</td></tr>
<tr><td>

- Assumption is that the liquid faction of the excreta seeps into the sand envelope and is not stored in the storage chamber. Only the solid faction remains in the storage tank. In case of flooding the level in the storage tank will not become much higher than the flood level, because the waste water will continue to flow into the sand envelope (which is still above flood level).

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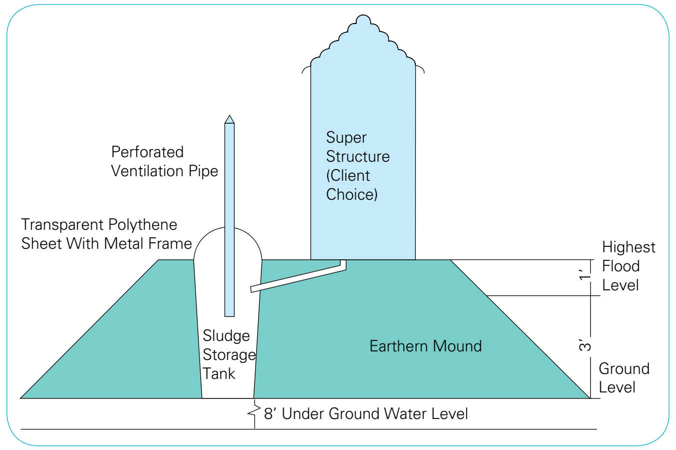
<tr><td colspan="3">4. Single Offset Pit with Biogas System</td></tr>
<tr><td>



- In this system conventional cistern-flush and pour-flush toilets can be linked to a biogas digester.
- The human waste flows into biogas plant by gravity through a separate pipeline from the toilet into the digester unit.
- Since the quantity of human faeces generated by a small family is too little, a biogas plant linked only to a toilet will generate very little quantity of gas, thus making a biogas plant solely based on human waste of a family technically unsuitable and economically unviable. Thus, it is necessary to mix human waste with animal waste or cow dung (and preferably kitchen waste). Thus, a biogas digester cannot be considered as a primary faecal treatment unit of a flush toilet, but it can be said that a toilet is an auxiliary supply unit of a biogas plant.

</td><td>

- Storage Chamber or Reactor is a closed vessel (chamber) and in this form it is the simplest form of digestion.
- The ferro cement reactor is equipped with a reinforced concrete (RCC) dome shape cover.
- The earthen mound prevents filling of the reactor during flooding.
- Gas outlet, valve and piping

</td><td>

Water Level at Peak Monsoon is 8' below the Ground level.

Sludge Storage Reservoir:

Height: 4'-0''

Average Dia: 2'-3''

Capacity: 450 litre

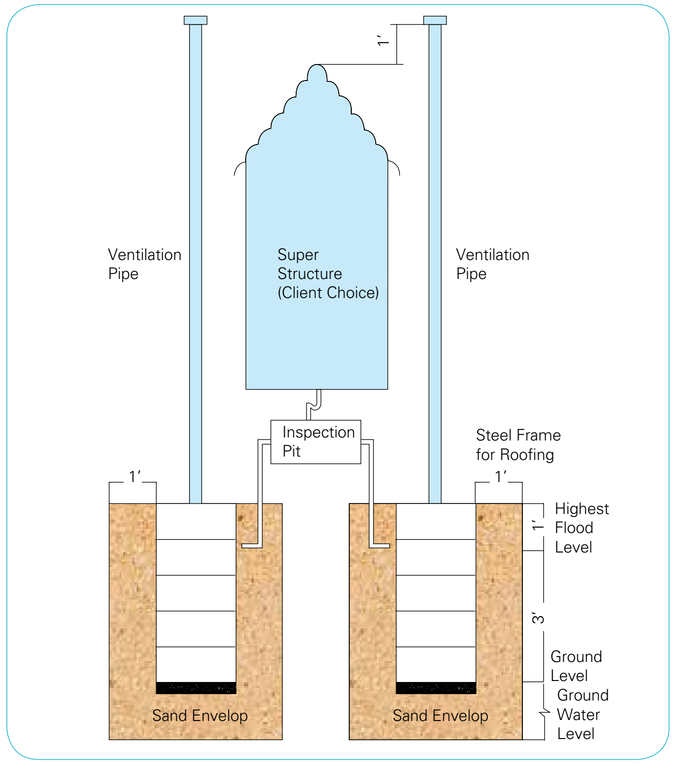
Wall and Bottom of Well is Ferro-cement

Estimated Cost:

Approximately 7,355 in which 5,555 is material cost and 1200 is transport and labour cost)

</td></tr>
</table>

<table>
<tr><th>Description</th><th>Technical Components</th><th>Specifications</th></tr>
<tr><td colspan="3">5. Step latrine (Raised Pit with earthen mound)</td></tr>
<tr><td>



- The extended portion of the lining provides additional volume of pit for sludge accumulation. Raising the pit also prevents splashing of the users or blockage of the pit inlet pipe by floating scum.
- The lining (RCC or Plastic ring) of pit will be sealed with the clay so as to prevent the contact of sludge with water table. The bottom of the lining will be sealed by plastic sheet or clay seal. The pit will be connected with soak well to allow the liquid part to be connected with soak well.

</td><td></td><td>

Sludge Storage Reservoir (Each)

Height: 4'-4''

Dia: 3'-0''

Capacity: 850 litre

Twin Pit Latrine System

Wall and Bottom are water sealed.

Estimated Cost:

5,933 (4,383 material cost + transport& labour cost 1000)

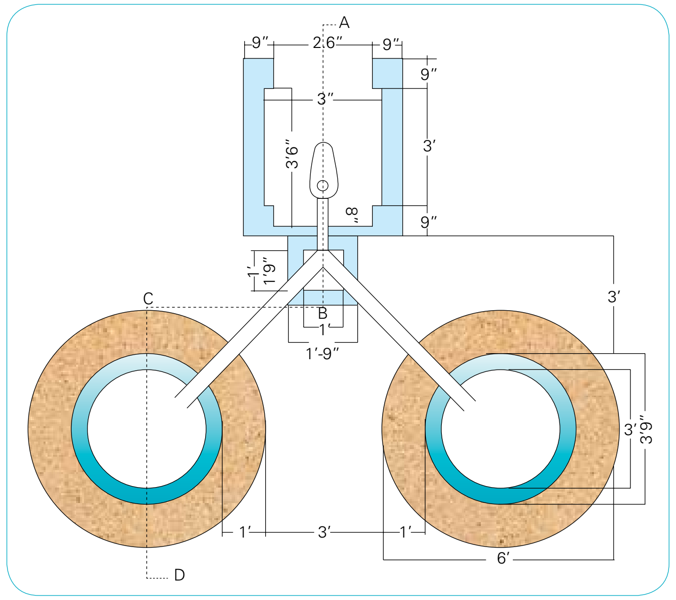
</td></tr>
<tr><td colspan="3">6. Twin Pit Toilet in Black Cotton Soil</td></tr>
<tr><td>

- This system is designed where the rate of expansion in rainy season and that of contraction in summer season is much higher in black cotton soil as compared to other types. This exerts pressure on any type of construction which causes development of cracks in the same.

</td><td colspan="2">

- Storage chamber
- Keep the distance between two pits as 1 ft. By this the final distance between two constructed pits will be 3 ft.
- This will leave a gap of 1 ft all around the constructed leach pit.
- Reduce the size of honeycombing (holes in the wall) to 1 inch & increase the number of holes correspondingly.

</td></tr>
</table>

Description	Technical Components	Specifications
6. Twin Pit Toilet in Black Cotton Soil (Continued...)		
 ■ Black cotton soil also has a tendency to hold water for a longer time. Both these characteristics of Black cotton soil affect the normal functioning of a pit latrine. However these constraints can be overcome by adopting following modifications.	■ After the entire construction is over, fill the gap around the brick work with coarse sand (remnants after sieving) up to pipe level. This sand envelope protects the pit wall from the pressure of expanding soil. It also facilitates seepage of liquids from the pit. ■ The sand should be clean and free from silt & clay. ■ The space above pipe level can be filled with Murom and compacted.	
7. Twin Pit Toilet for Coastal Regions		
■ The twin pit toilet requires easy seepage of water from the leach pit in the surrounding soil. If this is affected by certain physiological conditions it will certainly hamper the functioning of twin pit toilet. ■ In coastal region there is a possibility of high water level in the soil and due precautions must be taken in such a situation. It has been observed that in coastal region the water levels in subsurface zone vary greatly from one place to another place. ■ If need be a test pit of 4 feet depth may be taken to ascertain the water level in the region.	1. No water observed 2. Only moisture observed 3. Water in subsurface region at the time of high tides only. 4. Water in subsurface region at the time of low as well as high tides. 5. Water in subsurface region for most part of the year/occasional flooding of water over the ground. 6. Dense location of houses coupled with high ground water levels.	Twin pit toilet Twin pit toilet Twin Pit Toilet modified for high water table areas. 1. Twin pit toilet modified for high water table areas with due precaution or 2. Biogas linked toilet with proper arrangement for management of slurry or eco-san toilet 3. Ecosan toilet 4. Biogas linked toilet with proper arrangement for management of slurry. 5. Community biogas plant with proper arrangement for management of slurry. 6. Small bore sewer system with proper treatment plant

Source: based on Mamani et al. (2014)

6.3.2 Decentralized Wastewater Treatment Systems and their Economics

In the chronically drought hit, naturally water-scarce regions, every option to increase the effective availability of water through reuse should be tried. This is particularly so as the marginal cost of production and supply of new source of water will be prohibitively high, owing to high development cost. Treatment of domestic wastewater for irrigation is also one of them (Kumar, 2014). This can reduce the pressure on the extremely limited freshwater resources for meeting demands from sectors such as irrigation, which does not require high quality water. At present, wastewater treatment is a feasible option for urban areas, where HHs are connected to a centralized sewerage system. Over the next 10-15 years, rural areas are also poised for great transformation, as economic conditions of rural population improve. This would result in greater drive for improving the standard of living.

Some of the consequences of this would be an increase in per capita demand of water for domestic uses (given the income elasticity of domestic water demand), and demand for better quality of water supply (vis-à-vis physical, chemical and bacteriological quality of the water and the nature of access) and environmental sanitation, as willingness to pay for water supplies and wastewater disposal would be high, at high income levels. With larger quantum of wastewater generated from villages, decentralized, village-level wastewater treatment could become technically feasible.

Indiandata on economics of wastewater treatment systems is very scanty. A Water Environment Research Foundation study (Parten, 2008) examined the performance of large-scale decentralized and small community wastewater systems from different parts of the United States with flows from 5,000 to 50,000 gallons per day that have operated for at least five years. The results of the study showed that both construction and operational costs per unit volume of treated wastewater vary widely for large scale decentralized wastewater systems, with little correlation found between money spent and system performance or reliability. The actual cost of wastewater treatment system depends on the type of system, the physical environment and the land prices (for most systems). The cost of two WWT systems that use the same biological processes with the same treatment capacity in two different locations can vary widely depending on the type of climate, especially temperature and aridity (Kumar, 2014).

A system with an optimal design that takes into account actual flow rate, quality of the wastewater, and design variables (some of them are flow rates, quality of raw wastewater, climatic parameters, soil characteristics, depth to water table, etc., depending on the type of system) would cost much less than a poorly designed or over-designed system.

Parten (2008) found that the capital costs vary from US $ 18 to 492 per gallon of treated wastewater per day. We consider an average cost of US $ 100 per gallon or Rs 1200 per gallon of daily wastewater inflow (assuming a ppp adjusted conversion ratio of US $ 1= 12 Rs). As per Parten (2008), the operating cost (electricity cost) is US $ 0.01 to 0.81 per gallon of daily flow of wastewater. The electricity usage per gallon of treated wastewater tended to be more for activated sludge plants than for systems using some type of packed media/filtration process as the principal method of secondary or advanced treatment. The sludge removal cost was in the range of US $ 0.0034 and 0.92 per gallon of daily wastewater flow.

For a village with a population of 1000 persons, the total daily wastewater outflow, if all the HHs are connected to a sewerage system would be around 1.2 lac litres or 26,315 gallons of wastewater. The total cost would be Rs. 3.18 crore. If we allow the wastewater from the kitchen, bathroom etc., to be diverted for irrigating the kitchen garden and not connected to the sewerage system, the cost of the wastewater treatment system can be significantly brought down. If we assume that out of the 150 litres of daily water use, nearly 20% goes for flushing the toilets, then the wastewater generation would be only 30 litres instead of the 120 litres we have earlier assumed. The cost of the system can then be brought down to 0.79 crore Rupees (Rs. 7.9 million). Another option is to treat the entire wastewater and sell it to irrigators in the village. The price of the treated wastewater, which can be used by farmers to grow high value fruits and vegetables, can be kept at Rs. 10/m3 of water. The revenue that can be generated per year would be Rs. 4.38 lac Rupees.

To begin with we need to identify the cost of toilets can be in the range of Rs. 15,000 to Rs. 20,000 per unit. Hence the total cost for the entire village would be Rs 15 million to Rs. 20 million.

6.4 Public-Private Partnerships (PPP)

There is a need to identify areas and strategies for investments by public and private partnerships (PPPs) based on an enhanced understanding of how the resilience of WASH systems to water-related hazards (e.g. floods and water scarcity) can be improved. Some of the specific areas for investments by such partnership include 1) building and running large desalination systems;2) detection and prevention of leakages in water distribution lines, especially long distance pipelines used for regional water supply schemes; and, 3) design, building and operation of decentralized wastewater treatment systems. Investments must not only focus on access and provision of WASH services through infrastructure development, but should also be much more strongly coordinated with activities of stakeholders across the entire river basin to which WASH system is linked through ecosystem services, such as hydrological flows, purification and waste treatment, flood and drought control, etc. (Johannessenet al., 2014).

The provision of safe and resilient WASH services is intrinsically linked to processes of water management, land use planning, and disaster risk reduction across the entire river basin and even beyond, including to the urban area in which they are located. Health-related costs are often given little weightage in decisions about specific interventions to protect against hazards such as floods. PPPs are increasingly seen as a way to motivate private sector investment in urban WASH infrastructure projects that lack public funding. PPPs have the potential to expand the range of service providers beyond traditional public sector monopolies and inject a measure of efficiency, dynamism, innovation, quality improvement, increase of access, cost-recovery and consumer responsiveness. Currently, the proportion of private investment in the water and sanitation sectors in developing countries is low, representing only 35% of the market compared to 80% in the developed world. PPPs have also recently emerged as important and necessary mechanisms to strengthen DRR efforts in general. This has been motivated by an improved understanding of the vulnerabilities of supply chains and infrastructure assets to hazards among the private sector enterprises. The enormous potential for private sector engagement in building resilience through corporate social responsibility (CSR) and philanthropy has recently been demonstrated by the United Nations

Office for Disaster Risk Reduction's Private Sector Partnerships.

Corporate India has responded enthusiastically to the Government's call-to-action on WASH issues. Ninety per cent of the companies reported at least one CSR intervention in WASH during 2008-2011 with a total of 164 programmes being carried out. Of these, 38% were public sector undertakings (Table 14).Industries with strategic interest in WASH lead the way (Table 15). Heavy Engineering, Manufacturing and Fast Moving Consumer Goods (FMCG) companies were more likely to support WASH programs than other industries. This higher level of interest can be explained by the strategic importance of WASH to both these industries, FMCG companies have products such as soaps, disinfectants and sanitizers that are closely aligned to WASH agenda and were most likely to conduct programmes aimed at influencing attitudeand behaviour (Parekh et al., 2015).Heavy engineering and manufacturing companies have an incentive to provide facilities for communities residing around their factories as well as the resources to construct these facilities.

Most of the CSR programmes in WASH are broadly aligned to the needs of States, although North-East India has been ignored. Data indicate that the most popular States for CSR in WASH were Gujarat, Karnataka,Maharashtra, Rajasthan, Tamil Nadu and Uttar Pradesh. These States also reported high rates of open defecation. However, States such as Arunachal Pradesh,Assam, and Jammu and Kashmir were neglected, despite high incidence of reportedopen defecation. The North-East, in general, saw low levels of corporate interest. Further, most of the CSR programs in WASH focus on rural areas. Of the 86 companies, 52% focused exclusively on rural areas, compared to only 17%, which focused on urban areas. The WASH related CSR of the remaining 31% were spread across mixed geographies

CSR in WASH is focused on the creation of infrastructure, but focus very little on behavioural change aspects. Also, the operation and maintenance (O&M) of toilets is neglected and programmes on influencing behaviour appear tokenistic. Only a few companies, which include Tata Consultancy Services, National Thermal Power Corporation, Coal India, National Mineral Development Corporation, Hindustan Zinc, Rural Electrification Corporation, GAIL India, Punjab National Bank, Cipla, Bosch Petronet LNG, Bajaj Finance and Titan Industries, were reported to be implementing O&M programmes. Ambuja Cement Foundation, Gas Authority of India Limited, Hindustan Zinc and Bharat Heavy Electricals Limited were some of the companies that reported interventions in waste management. Companies that reported behavioural change programmes include, ITC, Hindustan Unilever, Titan Industries, Jindal Steel and Power, and Hindustan Zinc.

Table 14: Number of Companies Active in WASH Sector with their Budget Range

CSR budget range	No. of companies
Less than 1 crore Rupees	8
1-5 crore	11
5-15 crore	6
More than 15 crore	8
Total	33
Top 5 companies with largest budgets in WASH	
Top 5 PSUs	**Top 5 Non-PSUs**
Coal India	Tata Consultancy Services
Power Finance Corporation	BhartiAirtel
ONGC	BhartiInfratel
GAIL India	Tata Steel
State Bank of India	Mahindra & Mahindra

Table 15: Characteristics of Companies with Interest in WASH Sector

Strategic interest	Impact-oriented companies	Catalytic competencies
There are two types of companies with strategic interest: A)Companies that have relevant products or services (FMCG, Pharmaceutical, Healthcare) – such as soaps, detergents, medicines and have a marketing or business goal in addition to on-ground impact. Such companies may be open to partnering with other players to create collaborative WASH programmes. B)Companies (Mining, Manufacturing, Oil & Gas) that invest in comprehensive programmes which benefit communities around their areas of operation.	These include companies that may not have a direct stakeholder interest or a location interest such as Banking Financial Services and Insurance (BFSI) companies or those in the service industry. Such companies may have an interest in replicating or scaling existing programs that have reported high levels of impact. They may also wish to invest in innovative WASH models or follow the Government guidelines. These companies may need support to focus on long-term maintenance and behaviour change.	These include companies that seek to leverage their core competencies to execute strategies for change and include Media companies with specialized programming, IT companies developing products or monitoring tools etc.

Source: Parekhet al. (2015)

6.5. Social learning

Social learning is widely argued to have the potential to share knowledge and lessons, both formally and informallyat many levels and across different sectors. As such, insights and knowledge can transfer beyond the individual to organizations or communities of practice. Social learning has a great potential in underpinning the strategic innovation needed to radically improve the modus operandi of private sector involvement for more resilient WASH systems (Johannessenet al., 2014).

6.6 Micro-insurance

Micro insurance schemes are mechanisms that can help vulnerable populations in developing countries to deal with financial risks from disaster. They are increasingly seen as a way forward in spreading and transferring risk. Micro insurance could help many of the poorest people. 2.4 billion people lived on less than US2 $ per day in 2010, to escape poverty and fill gaps in risk management. Micro insurance schemes normally involve a number of partners from the private sector, Governments, NGOs, and others. These schemes are particularly important in places where people are not bankable. In many developing countries, less than half the population has access to formal financial services and in most of Africa less than one in five HHs has access. Micro insurance for health, in some African cases, seems to have a much greater chance of becoming a growing market than insurance for WASH systems per se. However, indirectly, micro- insurance can play a key role for WASH systems (Johannessen et al., 2014).Risk of eviction is one of the biggest barriers for infrastructure development in slums, and micro insurance in housing could help to manage this risk better. For example, people living in slum will have an incentive to improve the facilities, which often are of poorest quality and very unhygienic.

6.7 Investment strategy

Building resilient WASH systems to water-related hazards and resulting health risks requires a broader set of investments across the entire socio-economic system to which the system is linked. This system includes river basin and wider urban area in which WASH system is located, right down to the point of access for individual user. Building resilience to hazards consequently requires better coordination and collaboration between stakeholders engaged in a broad range of different sectors that influence the way in which land and water resources are used for different areas, such as agriculture, energy provision, natural resource extraction, conservation, housing and infrastructure development, industrial development, and disaster risk management (Johannessen et al., 2014).

A number of business strategies could help reduce vulnerability of people and businesses to water-related hazards in urban areas, and that would have direct and indirect impacts on enhancing the resilience of urban WASH systems, emphasizing the important social learningrole. These strategies include the following:

A. Re-examining profitability of existing WASH investments in the light of expected losses and damages caused by water-related hazards. Cost-benefit analysis and strategic environmental assessment tools can help raise awareness to the benefits of investing in ecosystems.

B. Replicating and up scaling approaches that acknowledge the water needs to have adequate space. This entails more integrated social and technical programmes that incorporate flood preparedness and non-structural mitigation, and a multifunctional land use approach.

C. Creating an institutional culture for private sector investment based on accountability, facilitated by quality assurance approaches and methods. Strive towards a greener and resilient city environment, and promoting concerns about the continuity and long-term reliability of investments.

D. Developing a better understanding of customer base, including world views, needs and preferences, motivations, and purchasing power. Exploring how the 'Bottom of the pyramid' investments can become profitable through strategic innovation, especially in poor urban communities.

E. Supporting a new segment of private entrepreneurs through legislation, as well as empowerment of and dialog with (informal) small private actors. This calls for creating an enabling policy, and a support in practice in building trust, capacity and dialogue.

Source: Johannessen et al. (2014)

VIII

Findings and Conclusions

This study developed a composite index for assessing climate induced risk in WASH, which take into account a wide range of physical, technical, socio-economic and institutional factors that determine the three dimensions of risk, viz., exposure, hazard, and vulnerability. This is the first of its kind in India's effort towards evolving strategies for designing WASH systems that are climate-resilient. The study mapped climate-induced risk in WASH for the two divisions of Maharashtra, viz., Marathwada and Vidarbha, comprising 19 districtsusing this composite index. Overall, the computed valueof the risk index was higher for Marathwada region (0.30) when compared to Vidarbha region (0.28). As regards the districts, the climate risk index variesfrom0.22 in Chandrapur district (Vidarbha) to 0.35 in Parbhani (Marathwada). This mappinghelped identify the key interventions that need to be made in areas identified as having 'high climate-risk', in order to reduce the three different dimensions of climate risks and to improve the climate-resilience of WASH systems there.

Disaster risk reduction plans and measures exist in Maharashtra. They are both structural and non-structural. However, they are not specific to risks associated with poor water supply and sanitation related risks, resulting from climate extremes -floods, droughts and cyclones. Research and past experience suggest that these measures to reduce the exposure to droughts comprising structural measures such as construction of dams, and small water harvesting structures, and non-structural measures such as drought forecasting systems and drought warning alone are unlikely to have any significant impact on reducing the risks in WASH. On the contrary, they can increase the exposure of WASH systems to droughts, as the recent experience with farm ponds in the State suggests. Similarly, the measures being proposed for reducing community vulnerability to droughts under 'capacity building and awareness', such as mere awareness creation about drought-resistant crops and use of micro irrigation systems are also not going to be effective in reducing WASH related risks.

Nevertheless, recent experience from other parts of India with disaster management responses suggests that the measures being proposed for reducing exposure to flood hazards and community vulnerability to the same will be effective in the State of Maharashtra. Particularly, the non-structural measures for reducing exposure to floods such as strengthening the flood forecasting systems and creating additional infrastructure for flood warnings are very useful. On the vulnerability front, imparting training to the stakeholders involved in flood mitigation and management, organizing mock drills on flood rescue operations, and the like, will be effective.

The decision to change the water supply norm for rural areas to 140 lpcd which is at par with urban areas is a major reform initiative. While the average per capita cost norm of Rs. 137 per m3 of water supply for the whole of Maharashtra as suggested by the 'High Level Committee on Balanced Regional Development Issues in Maharashtra' is also an encouraging one for future investments in WASH sector, research suggests that the unit cost (Rs/m3 of water) for drought-prone regions such as Marathwada and Vidarbha will have to be much higher than that for water-rich areas such as Konkan and Western Ghat region for ensuring sustainable water supply, in lieu of the fact that water endowment is limited locally and water will have to be imported from exogenous sources.

Capacity building of communities for reducing their vulnerability to climate-induced WASH hazards poses a significant challenge to Government agencies. In many cases the different components of WASH and the manifestations of its mis-management within the population is not recognized in its entirety. There is low appreciation of the environmental and health impacts of poor environmental sanitation and unacceptable hygiene practices among communities with low levels of literacy and high incidence of poverty. It requires a more eclectic approach where all stakeholders need to be apprised of different aspects of risk and how they affect them. Further, no 'one-fit-for-all' solution exists and in most cases interventions for reducing the vulnerability need to be customized for the existing physical, socio-economic and institutional environment.

The current over-emphasis on small-scale rainwater harvesting and watershed development as drought proofing measure isa matter of concern.They will be quite ineffective in chronically drought-prone region of Marathwada, given the conditions that exist there vis-à-vis the rainfall, its yearly variations, aridity, and the high degree of water resources exploitation.As being observed in drought prone areas of Maharashtra, structuressuch asfarm ponds can actually increase the exposure of WASH systems to droughts in rural areas.This is because farm ponds can reduce the amount of water in natural system that can be tapped by surface and groundwater based water supply schemes, given the manner in which they are used.

At the Government level, capacity building of the agencies concerned (viz., Water Resources Department and the Water Supply and Sanitation Department) for designing and executing projects that reduce the climate-induced hazards and exposure is important. The first and the foremost step is to build the skills of technical officers of MJP to design reliable and dependable rural water supply systems in areas experiencing climatic extremes. The areas for skill building are the following:

A. Hydrological modelling of river basins for climate change scenarios;

B. Designing of surface reservoirs in flood prone areas for greater flood cushioning;

C. Designing of reservoirs to increase the multi annual storage of inflows from catchments in drought prone areas;

D. Import of water from water-rich regions to chronically drought-hit region of Marathwada;

E. Leakage detection and prevention in water distribution pipes of regional water supply systems;

F. Design and operation of decentralized desalination systems;

G. Design of ecologically sound sanitation infrastructure; and,

H. Design, execution, and operation of wastewater treatment systems.

These measures should be complimented by strengthening financial capabilities to execute the related infrastructure projects. The type of infrastructure projects required to improve climate resilience in WASH include,

I. Large reservoirs having multi-annual storage capacity, in regions experiencing high inter-annual variability in rainfall and streamflows;

II. Building infrastructure for transfer of water from water-rich regions of the State to chronically drought-prone areas;

III. Building decentralized desalination systems in coastal areas affected by severe salinity and not served by piped water supply schemes;

IV. Building decentralized wastewater treatment systems for enabling reuse of water from domestic sector;

V. Rainwater harvesting in high rainfall hilly areas;

VI. Rehabilitation of dilapidated water distribution pipes in large water supply schemes; and,

VII. Raised hand-pumps, well-head protection walls, and raised latrines placed at a safe distance from water sources in flood prone areas.

Among these measures, improving the buffer stock of water through import from water-surplus regions is extremely crucialfor increasing the water supply access of the poor in quantitative terms.Merely having the supply infrastructure (water connections) will not help. This is evident from the study by UNICEF/IRAP (2013) on rural water supply in Maharashtra.The study has shownsignificant inter-regional difference in access to water supply from public systems in terms of type of access and level of supply.The proportion of rural HHs having access to PWS varied from a lowest of 44% in Nagpur and Konkan to a highest of 72% in Amravati. The percentage of HHshaving individual tap connections was also as low as 21% in three divisions, viz., Marathwada, Konkan and Nagpur.Yet,the per capita water supply was highest for Konkan division, with 129 lpcd, against a mere 21 lpcd for Nagpur. The rich water resource endowment with a good number of surface reservoirs, adequate capacity of water supply infrastructure, and high affordability of the rural communities to pay for the services might have helped improve water supply situation in Konkan region (UNICEF/IRAP, 2013). Assured water supply encourages families to go for household water connections. Access to household tap connections will in turn motivate rural families to adopt and use modern toilets, as the same study showed.

Finally, the strengthening of various institutions engaged in WASH systems throughcapacity building and integration with other sectors is of prime importance. Particularly, the integration of WASH sector with water resources development and management sector is extremely crucialgiven the criticality of the latter for sustaining WASH interventions. The ability of water utility to manage domestic water supply in terms of quantity and quality on sustainable basis will be largely determined by how well the water resources are managed, and how equitably their allocation across sectors is done with the support of infrastructure and institutions (MacKay, 2003). It is equally important to recognize the significance of community based knowledge, create opportunities for innovations from within communities and organisations, and integrating them with local needs and practices. Autonomy to enter into partnership with (and or collaborate in the CSR activities of) the private sector companies for planning, design, execution and operation and maintenance of WASH related projects through appropriate institutional models would be key to institutional capacity building of the agencies in the WASH sector.

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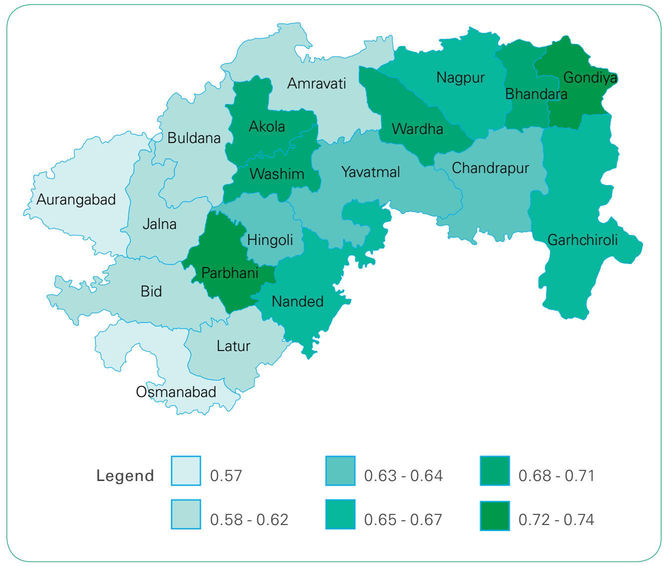
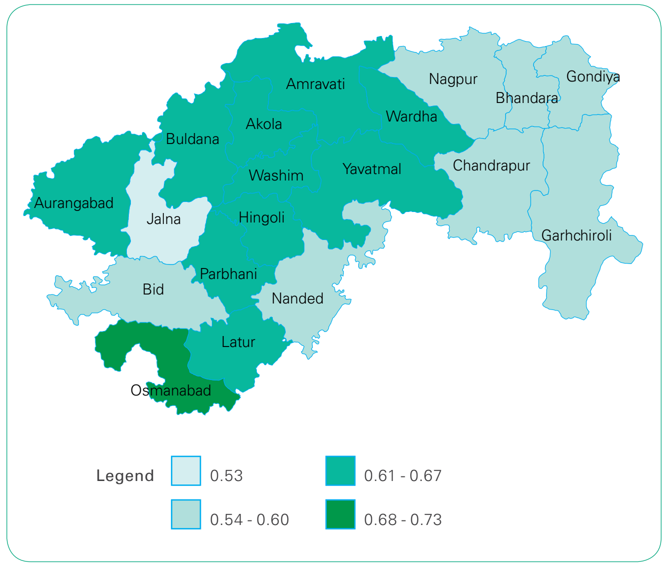
Annexure 1: Maps Representing Analysis for different components of Risk in WASH

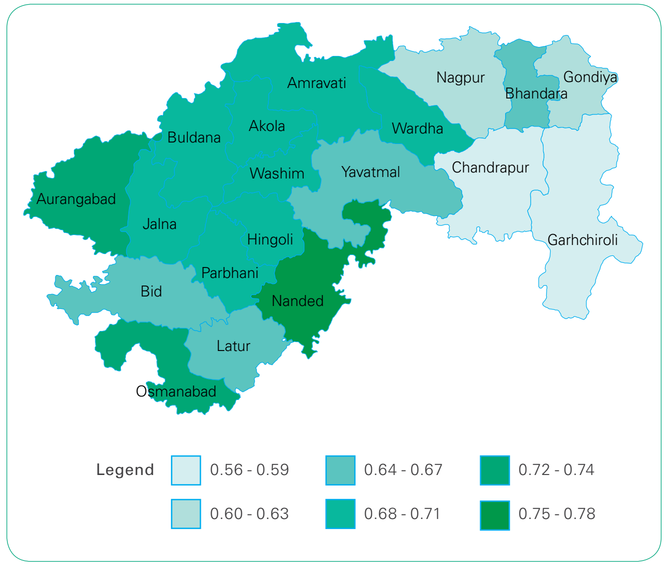
Map 1: Exposure of WASH Systems to Hazard



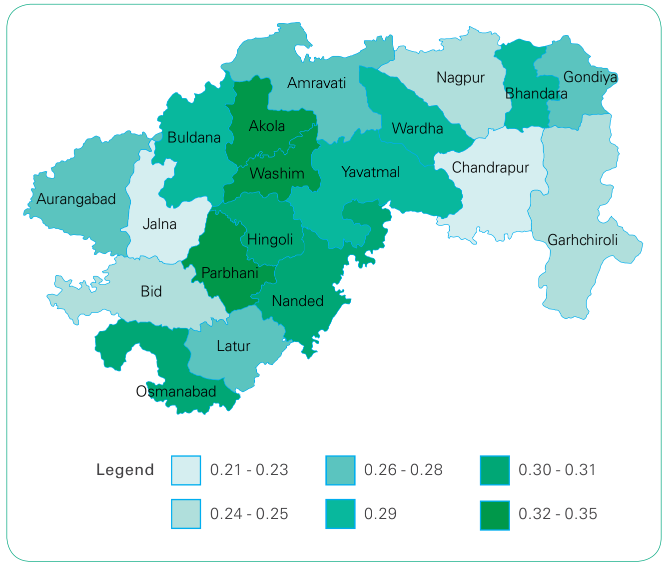
Map 2: Climate Hazard in WASH Systems



Map 3: Vulnerability of Communities to Hazard



Map 4: Climate Risk in WASH



Annexure 2: Analysis of Climate Parameters of Marathwada and Vidarbha Region, Maharashtra

The rainfall characteristics of the regions are presented in Figure 1 & Figure 2. It seems that the rainfall in the regions is uneven and there is a considerable region-wise as also yearly variations. It is observed that 88% of the total annual average rainfall occurs during the monsoon months in both the regions. The high annual average rainfall in districts Bhandara, Chandrapur, Gadchiroli, Gondia, Nagpur and Wardha of Vidarbha region indicates lowest hazard (Figure 8); while in the Marathwada districts annual average rainfall varies between 700 to 900 mm (Figure 9) indicating moderate hazard. In all the districts in both the regions the variability of rainfall is similar in characteristics, having a high inter-annual variability ranging between 18 to 30%. The mean annual temperature and relative humidity in all these districts vary FROM 23 to 300C, and 30±5% to 50±7%, pointing towards a community under moderate exposure to climate risk. All the districts are situated in the semi-arid region, therefore, moderate score has been given to all these districts.

Figure 8: Mean and Coefficient of variation of rainfall in the districts of Vidarbha region

Figure 9: Mean and Coefficient of variation of rainfall in the districts of Marathwada region

Surface and Groundwater resources of Marathwada and Vidarbha Regions, Maharashtra

Characteristics of the natural water resources vary between perennial and seasonal water sources in both the regions. Godavari, Krishna, Tapi, Narmada and West flowing river basins are the major ones of Maharashtra. The average annual water availability in the said river basins within Maharashtra territory is anticipated to be 163.82 BCM. About 89% of the geographical area of Maharashtra falls under the three major river basins of Godavari, Krishna and Tapi. While Krishna river basin is considered to be a water scarce basin, Godavari and Tapi are water rich (Government of Maharashtra, 2011). Thirteen districts (Akola, Amravati, Aurangabad, Bhandara, Buldhana, Chandrapur, Gadchiroli, Gondia, Hingoli, Nagpur, Wardha, Washim and Yavatmal) of the two study regions have normal water availability conditions (water availability in the range of 3,001-8,000 m3), four districts (Beed, Jalna, Nanded and Parbhani) have surplus water availability conditions (water availability in the range of 8,001-12,000 m3), and two districts (Latur and Osmanabad) of Marathwada have water deficit condition (water availability in the range of 1,500-3,000 m3). A low score has been given to the districts with water surplus condition; medium score has been given to the districts with normal water available condition, and a high score to those districts with water deficit conditions.

Maharashtra has a heterogeneous geology. About 75% of the State's geographical area is underlain by hard rock formations of Deccan trap origin. About 15% of Chandrapur, Bhandara, Gadchiroli and Nagpur districts of the Vidarbha region is underlain by crystalline formations. About ten per cent of Akola, Buldhana, Yavatmal and Amravati districts of Vidarbha region is underlain by alluvial formations. In the districts of Marathwada region underlain by alluvial formations, the groundwater level in the wells varies between 3 m and 15mts. Therefore, low to moderate exposure scores are given to all the districts here.

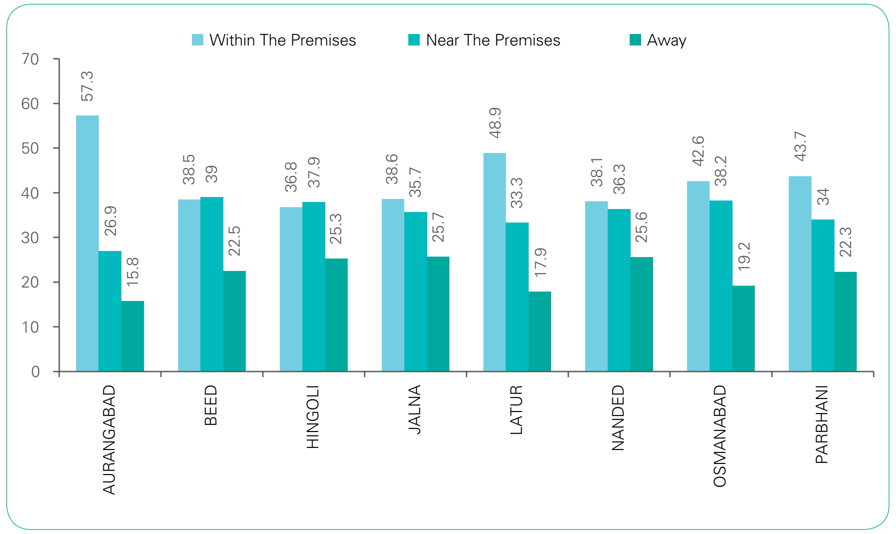
Socio-economic conditions in Marathwada and Vidarbha Regions of Maharashtra

According to Census of India (Government of India, 2011), Maharashtra has nearly23.83 million hHHs, with 13 million in rural areas and 10.8 million in urban areas. Marathwada and Vidarbha regions have about 11 million and 4 million HHs, respectively. About 24% of the HHs are covered with treated tap water supply, and 15% of HHs have access to improved latrines in both the study regions.

According to the Census data of Maharashtra, only Amravati district of Vidarbha region has a high proportion of HHs (about 55%) covered by treated drinking water supply and therefore a moderate exposure score is given. In other districts of both the regions coverage of treated water supply to rural HHs is very less; therefore a high exposure score has been given to all these districts.

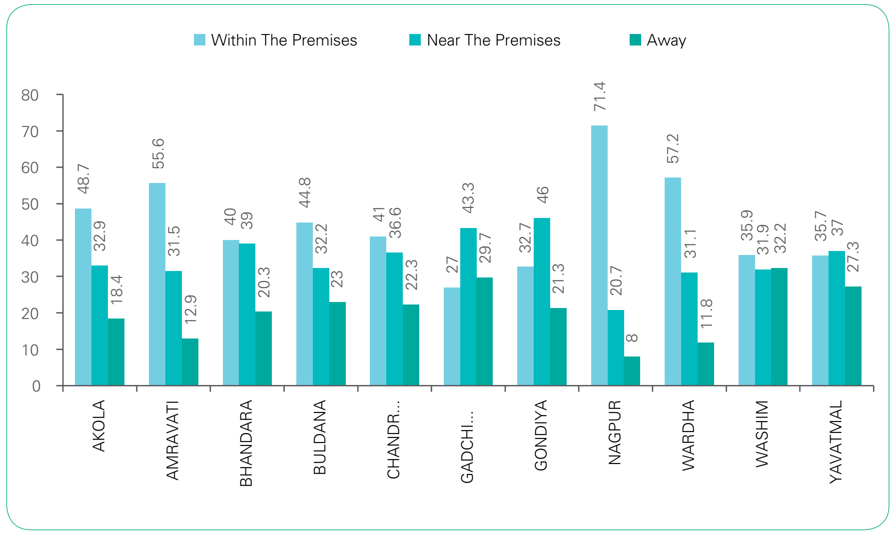
The analysis of access to drinking water sources within the premises shows that exposure to risk varies from moderate to high. Hingoli, Jalna and Nanded districts of Marathwada and Gadchiroli, Gondia, Washim and Yavatmal districts of Vidarbha have higher risk exposure due to HHs not having access to water sources within their premises (Figure 3 & 4).

Figure10: Location of Drinking water source in Districts of Marathwada



For computation of the risk index treated tap water supply has considered from Census data for both regions.

Figure 11: Location of Drinking water source in Districts of Vidarbha



From the census data of Maharashtra it is observed that very less proportion of people have access to modern toilets in both the regions, which exposes the region to higher climate induced risk. A high exposure score is given to all the districts, except Amravati and Nagpur in Vidarbha. According to the data from Department of Revenue and Forest, GoM, the exposure of people living in the low lying areas varies from low to high. As nearly one-third of population of Bhandara (36%) and Chandrapur (30%) districts in Vidarbha region are living in the low-lying areas, a moderate exposure score has been given to these districts. In Nanded and Parbhani districts of the Marathwada region 89% and 51% of population are living in the low-lying areas, therefore a high exposure score has been given to these districts.

Socio-economic conditions in Marathwada and Vidarbha Regions of Maharashtra

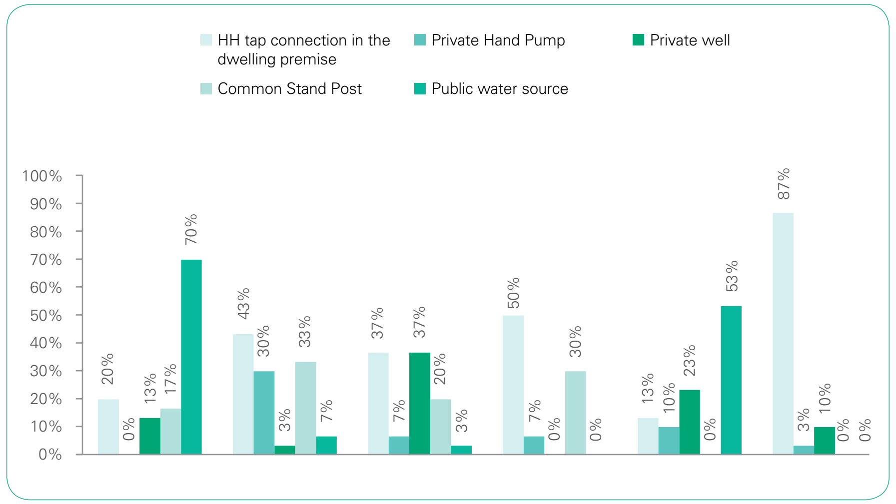
The access to primary health centres (PHC) data was analyzed for all the districts of both the regions studied and it is observed that the indicator varies from low to high. It is seen that in Nanded district of Marathwada and Wardha district of Vidarbha the proportion of access to the PHC is less than in other districts which indicates a high vulnerability during climate related risks. Therefore, a highest vulnerability score has been given to these districts. Three districts of Marathwada and two districts of Vidarbha have moderate vulnerability as per access to the PHCs, and the remaining districts have been given a lowest vulnerability score. The indicator for percentage of children under the age five with stunting (low-height for age ratio) is rated lowest to highest. Only Chandrapur district of Vidarbha is less vulnerable in terms of children with stunting. Therefore, a low vulnerability score has been given to the district, while six districts of Marathwada and two districts of Vidarbha have highly vulnerability in terms of children with stunting, therefore a highest vulnerability score has been given to these districts.

In terms of coverage of populations with sub-health centres in these districts, the vulnerability varies between lowest to moderate. From the MoHFW data it is observed that five districts of Vidarbha and all the districts of Marathwada are moderately vulnerable in terms of coverage of rural population with sub health centres.

Analysis of primary data from Field survey

A field survey was conducted in six districts namely Gadchiroli, Gondia and Wardha of Vidarbha region, and Latur, Jalna and Beed districts of Marathwada. It is observed that most of the HHs in rural areas are mostly dependent on household tap connection in their dwelling premises, as compared to other water supply sources. For rural HHs in Gadchiroli and Gondia of Vidarbha public water source is the main water supply channels (Figure 5).

Figure 12: Water Supply in the Rural Areas



Based on the analysis of primary data for the latrines constructed by the individual rural HHs, it seems that most of the HHs have constructed Pour flush latrines in Vidarbha district, while in the districts of Marathwada rural HHs have constructed pit latrines. The latrines are basically constructed using the grants obtained from the sanitation campaigns of the Government and NGOs.

The values of indicator on hand-washing were computed based on the primary data from field survey. It was observed that rural HHs in the districts are aware of good hygiene practices. Most HHs practice hand-washing before and after having food, and after toilet use with soap and water. Therefore, lowest exposure score has been given to all the districts in both Vidarbha and Marathwada regions.