World Health Organization and Department of Water Supply and Sewerage

Study on

Adaptation to impacts of climate change for the Climate Resilient Water Safety Plan

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December 2015

Contents

1 Acknowledgement

This research was supported by WHO under DfID funded project "Building adaptation to climate change in health in LDCs through resilient WASH". One of the outputs relates to climate resilient Water Safety Plans (WSP).

I would like to extend my gratitude to Mr. Raja Ram Pote Shrestha for technical inputs and contributions during study and report writing. We are thankful to our colleagues from WHO Country Office for Nepal: Mr Raja Ram Pote Shrestha and Dr Sudan Raj Panthi for providing guidance in the process to Ms Deepa Shrestha for providing administrative support.

We are also grateful toour DWSS colleagues: DDG Sunil Kumar Das, SDE Kiran Darnal and SDE Narayan Prasad Khanal for their valuable inputs.

We are also grateful to Mr. Chair Bhawani Paudel, Mr. Bishnu Kandel and other members of the WUSC of Amarapuri for their support during a visit, which made an effective contribution in this study.

We are also thankful to participants of sharing workshop organized on 27 December 2015 in DWSS for providing feedback and for improving this report and making more useful.

We have to express our appreciation to Mr Pravat KC who helped during field visit and prepared case study of Amarapuri.

2 Executive summary

WSP process requires a broader consideration of risks in view of climate change than direct impacts on water quality alone. IPCC defines that adaptive capacity is "*The ability of systems to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*".

The water resources on which potable water supplies depend are shared between multiple users and are subject to a wide range of quality, reliability and scarcity risks outside the control of the water sector. WSPs will benefit from a broader consideration of the risk factors at a catchment scale, related to water availability and reliability as well as the quality issues.

Effect of climate change may be seen in terms of intense precipitation, low precipitation or high/low temperature events which vary from place to place. Effect of climate change may impact on safe water supply system in terms of availability and quality of source water, ineffective water treatment plant for a short time, pollution in ground water sources and water distribution due to flooding and compelling people to use unsafe alternate source due to water scarcity and increased water demand and changes in treatment process due to extreme temperature.

There are various ways to adopt the impact of climate change on safe water system. Adaptation measures can be applied from catchment to consumer places. Various technologies and practices are available. Impact of climate change on water supply system depends on the location and type of the system, the hence selection of adaptation measures is system specific. WUSC need to predict climate changes and its impacts select appropriate adaptation for their situation and make a plan for the application. Adaptation covers augmentation of water and protection from pollution at the source, designing more resilient water treatment process in vies of high pollution in the extreme events, protecting distribution system with appropriate modeling, and educating consumers towards water conservation and protecting local alternate systems.

Study of Amarapuri indicated that the WSP team has tried to incorporate risk associated with the climate variations. This helped them ensure continued safety of water supply system considering wider view form climate change and variations. They have analyzed that they have already done and what they need to work in from catchment to consumer for more adaptation.

WSP approach can reduce the impact of climate change on water supply and health if the adaptation measures are applied and implemented over the lifetime. More case studies and design data generated after few pilot works help use various technologies national wide.

3 Background

WSP process requires a broader consideration of risks in view of climate change than direct impacts on water quality alone. IPCC defines that adaptive capacity is "*The ability of systems to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*". Main concepts in resilience are the **capacity to cope** during a disruptive event and the **ability to recover** after the event.

Nepal is one of the highly vulnerable countries to the adverse impacts of climate change. The change in climate has shown its impacts on Water Supply, Sanitation and Hygiene (WASH) sector. Climate Change has caused variation in water sources. Cases of depletion of surface water sources in the mountainous region and ground water source in Terai are affecting the sustainability of water supply systems including water safety plans.

Water Safety Plan (WSP) is the measures to reduce potential health impacts through the risk management process. It involves preventing of contamination in the source, if it is not possible to prevent at source, installing treatment units, re-preventing contamination in the distribution networks, and finally safe storage and use at households. The main principle of WSP is hazard analysis and control from catchment to consumers and monitors the control measures to ensure continued safety of the supplied water. Impact of climate change on water supply system exacerbates the level of risk hence, additional thinking in its process. This study is for exploring potential adaptation activities at various stages of water supply system, including source, treatment system, distribution system and consumer's area.

Here in the document adaptation interventions that address issues like resilience to extreme weather events, contamination of drinking water supplies, and water resource diversification and conservation benefits WSP in almost any imaginable climate scenario. The WSPs will benefit from a broader consideration of the risk factors at a catchment scale, related to water availability and reliability as well as the quality issues. Effect of climate change in terms of temperature and rainfall pattern varies from place to place and its impact on water supply system also varies with the type of source and overall system. Hence, the adaptation to climate change for a climate resilient WSP is system specific. Every WUSC needs to select the adaptation measure appropriate to them and make plans for application in the local situation and system context.

There are various technologies and practices for adaptation to climate change which can be broadly divided into five categories:

(1) Water source conservation and protection: Main impacts of climate change are seen in the sources and its catchment areas in terms of depletion of water qualities due to floods or depletion of safe water. Conservation and protection intend to control of hazards at catchment level in view of climate variations.

(2) Diversification of water supply: Diversification of water sources or water system minimizes risk of scarcity of safe water during extreme situation.

(3) Preparation for the extreme weather events: preparation for extreme weather events includes adapting the design and operation parameters for extreme rainfall and extreme temperatures and its variability within the system from catchments to consumers.

(4) Resilience to water quality variables: This includes designing system relating to water quality controls in view of changing incoming water qualities from the source in view of climate variations.

(5) Water conservation: This includes conservation in water use in view of potential scarcity of safe water during extreme situation including failure of water safety system.

The main objective of the study was to explore potential adaptation activities to address the effects of climate change in Water Safety Plans.

4 Review of documents

National water safety plan documents:

DWSS has developed ten step guideline and working manual for the systematic application of the water safety plan. It involves preventing of contamination in the source, if it is not possible to prevent at source installing treatment units, re-preventing contamination in the distribution networks and households. The main principle of WSP is hazard analysis and control from catchment to consumers and monitors the control measures to ensure continued safety of the supplied water. Ten steps of WSP process are: (1) Assembly of water safety team (2) System analysis (3) Hazard analysis (4) Control measures (5) Improvement plan (6) Monitoring plan (7) verification (8)Management process and support (9) Assessment of user satisfaction (10) Documentation and review of WSP.

WSP manual divides water supply system into four parts for the purpose of hazard analysis, control measures and making improvement plan and regular monitoring. DWSS is in the process of reviewing the WSP process in view of climate resilient WSP with respects to each step.

WHO Guideline for Climate Resilient Water Safety Plan, update July 2015:

This document is intended to help water suppliers and WSP teams who have already committed to using the WSP approach and are developing and implementing WSPs to gain greater understanding of climate change issues. The document presents briefly current knowledge on the impact of climate change on the water cycle, drawing on information in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report. The documents described how to integrate climate in the change WSP process. Document collected various examples of climate change impacts that may influence hazards and hazardous events and associated control measures. Some of them were useful as adaptation.

Climate Change and Water, IPCC technical paper VI, June 2008:

The documents described Impact of climate change on water resources and fresh water. The document also described the impact of climate change on water supply and sanitation system, vulnerability and adaptation measures. Some of them were useful for the current study.

Technologies for Climate Change Adaptation, Guide book for the Water Sector, UNEP, April 2011:

The document mentioned eleven adaptation technologies and practices and described them, including its contribution to climate change and barriers and opportunities for implementation. Document considered IWRM and WSP as broader approach for climate change adaptation. The document linked each adaptation technologies and practices into five areas: Diversification of Water Supply, Groundwater Recharge, and Preparation for Extreme Weather, Events, and Resilience to Water Quality Degradation, Storm water Control and Capture, and Water Conservation. These technologies and practices were useful for the present study.

5 Risk of climate change in safe water system

According to the Intergovernmental Panel on Climate Change (IPCC), many experts have concluded that "water availability and its quality, will be the main pressures for societies and the environment under climate change. Climate research provides compelling evidence that increases in global temperatures are influencing the global hydrological cycle. The average temperature is projected to increase by varying amounts over all major land masses and during all seasons.

Although temperature is projected to continue to increase globally, the effects of this increase in precipitation will vary from one area to another. The effect on precipitation may also vary seasonally; in some areas, precipitation is expected to increase in one season and decrease in another

In the context of Nepal the effects of climate change on water supply here separated into four categories: increased precipitation intensity, decreased water flows, greater precipitation variability, and temperature variability. All these effects will have ultimately impact on availability and quality of water supply leading water safety problem.

Impact of climate change on safe water systems and potential adaptation measures

Changes in precipitation, flow, and temperature associated with global warming will exacerbate water quality problems. For instance, longer dry seasons and the loss of snowpack will reduce instream summer base flows, resulting in the concentration and increased residence time of pollutants. Conversely, the increase in the frequency and intensity of rainfall events related to global warming will overload the capacity of sewer systems and wastewater treatment plants, resulting in more combined sewer overflows and storm water runoff, which increase water pollution from sediments, nutrients, pathogens, pesticides, and other pollutants. The following table will describe the complete scenario of impacts and potential adaptation measures at various stages of the water supply systems.

Impacts on safe water supply systems	**Adaptation measures**
Source areas:	
Stream source	
Increased release of pathogens, turbidity and chemicals and nutrient loads from a catchment area due to more intense precipitation and **floods** causing short term contamination in intake source water.	Prevention of flood: Increase vegetation and infiltration capacity over the catchment areas, stabilization of water paths and protection of catchment areas from the anthropogenic pollution and prevention of use of pesticides in agriculture within catchment area.
Increase turbidity due to landslides in the catchment areas caused by intense rainfalls and high runoff over weak soils causing short term, high turbidity in source water beyond the capacity of intake filters of diversion system.	Prevention of landslides or soil erosions: Identify area likely for soil erosion or landslides, divert water paths from the area for surface and subsurface. Create protection walls and increase forest and vegetations for natural protection.

Impacts on safe water supply systems	Adaptation measures
Increased turbidity and concentration of soil particles, sands and sediments at the intake point beyond its handling capacity caused by intense precipitation, high runoff combined with soil erosion and landslides.	Filtering capacity of Intake: Use one or more technology to handle high turbidity and sediments and water flow. Technologies like dynamic filter (auto stop), self cleaning arrangement or flow diversion can be used based on situation of intake in relation to normal flow and expected floods.
Spring sources	
Ingress of contaminants from a catchment area through subsurface flow and surface flow mainly nearby springs caused by intense precipitation, flooding or washing of contaminates in the catchment areas.	Catchment protection: Prevent pollution in the catchment area near by spring points and avoid direct flow of polluted water toward spring point from subsurface or surface water. Demarcate primary and secondary protection area with code of conduct.
Ingress of contaminants at spring points from subsurface flow and surface flow from nearby springs caused by intense precipitation, flooding or washing of contaminates.	Spring protection: Construct appropriate spring intake based on type of springs and protects upstream of spring point to avoid surface and subsurface flow from a nearby spring.
Ground water sources	
Contamination of groundwater due to infiltration of pollutants with large rainfall events or change in WQ parameters due to increased or decreased ground water level	Catchment protection and maintenance of water table: Avoid pollution in the catchment area mainly nearby well. Enhance infiltration in the potential infiltration areas. Protect well heads.
Contaminated surface water entering well heads after large runoff events	Wellhead protection: prevent pollution near well head, avoid seepage from well point and install deep-set tube well and avoid missing of contaminated water from upper layer to lower layer.
Water Treatment/storage area	
Short term inefficiency or ineffectiveness of water treatment units designed for normal situations during short term, high pollution caused by intense rainfall and floods.	Prevention: Prevent flow of water into treatment units for the short term. Treatment capacity: Design water treatment plant to accommodate a range of pollution expected during extreme situation or introduce additional treatment to handle increased pathogen and chemical challenge during peak events Management: Operate WTP by mainly by adjusting chemicals or cleaning periods during the extreme situations

Impacts on safe water supply systems	Adaptation measures
Heat-related impacts on water treatment chemicals such and doses of disinfectants like chlorine	Appropriate dosing for extreme temperatures: calculate appropriate dosing of chemicals and disinfectants for the range of temperatures in laboratories and in practice and prepare for the extreme situations and changing seasons.
Requirement of the large size of clear water reservoir due to short term failure of treatment system or intake during extreme situation or depletion of water during extreme dry periods.	Extra storage: design storage capacity in view of interruption of production time and quantity.
Distribution areas	
Cross contamination from surface water caused by floods and surface pollutions damaged sewage systems, surface drain and floods.	Prevention: Avoid pipe lines from drain line, wetlands and roads. Leakage control: Prevent through leakage control management Pressure: Maintain water pressure throughout the system based on hydraulic modeling and continuous flow. Maintain distance of pipelines from drain, wetlands and streets.
Fast decay of chlorine in the distribution system caused by temperature, detention time and ingress of pollution from leakages and flooding.	Chlorine modeling: determine appropriate doses of chlorine in view of detention time, potential contamination from leakages and pipe walls to maintain required FRC at the connection points over seasons. Establish system for flushing pipes, reducing detention times by zoning the distribution system or add buster chlorination.
Bursting of pipes and fittings due to freezing and melting of water at low temperatures or shrinkage and expansion mainly at the poor joints	Selection of pipe materials and fittings and jointing technologies: Avoid using rigid pipes in cold areas and make sure that joints are flexible to become temperature resilient. Control leakages at pipes, joints and valves.
Shortage of water in some part of service area due to unequal distribution of pressure and short term low flow	Hydraulic modeling: maintain pressure, flow and water age within an acceptable range over the distribution area through appropriate hydraulic modeling and zoning as required.
Consumer area	
Selection of less safe alternative sources due to decreased flow in the source or increased demand due to temperature.	Water conservation and protection of local sources: educate people for water conservation and traditional sources for use during extreme situations. Introduce technologies for reuse of wastewater for kitchen gardens.

6 Detail of technologies for adaptation

In the view of the impact of climate change in safety of water supply system from the catchment to consumers various adaptation measures can be practiced appropriately based on the climate situation of the location and type of the systems. Number of adaptation measures have been identified for the Nepalese contest and described below its relation to climate change and ways to apply.

6.1 Source and catchment areas

6.11Stream sources:

(1) Conservation of the catchment area for the stream source: The flow of water in the stream is the functions of rainfall and infiltration. Minimum flow in the stream is maintained based on water infiltrated and from the surface of catchment area and retained in the subsoil. The amount of rainfall and its pattern can be impacted by the climate change which ultimately impact on the flow in the stream. Availability of safe water can be augmented by increasing vegetation in the catchment area. Infiltration can be also enhanced by engineering interventions like a gully cutting, pond construction, construction of check dams, etc. This will maintain availability even the total rainfall decreased or pattern varied. Catchment area works like a balancing reservoir.

Process:

- Define catchment areas considering all areas from where rainfall is likely to come at the intake point through surface or subsurface flow.
- Increase the coverage of forest or vegetation areas in the catchment areas up to 100% as possible.
- Measure catchment areas (google map), annual rainfall in the area (data available on the DHM web site) and determine average water fall (lps), average flow in the stream during low flow (lps) and average water demand (lps). This will give idea of water availability.
- Create ponds, wetland areas, infiltration sites to increase chances of seepage and water retention in the catchment area if minimum water flow is close to water need.
- Establish a community forest group or a catchment conservation group to protect the catchment from illegal use, wildfire, etc.

Technologies involved: Gully cutting, Pond construction, check dam construction and plantation.

(2) Protection of catchment area and intake from pollution: Water qualities in the stream are a function of the nature of the catchment area and activities over the areas. Water qualities depend on the types of soils, natural minerals, and pollution from human activities and animals. High flood caused by the changing climate can change course of flow in the streams and can block infiltration areas. Floods can wash all the pollution in the stream and cause landslides bringing high turbid water in the intake beyond capacity of intake filter of treatment capacity. Community need to determine protection and zones and work for pollution control.

Figure 1 Bio-engineering for slope protection

Process:

- Define primary (near intake) and secondary (over catchment area) as protection area for pollution control
- Issue code of conduct for the protection area defining activities not allowed for doing. These include animal grazing, discharging waste water, fishing, bathing, using pesticides etc.
- Identify all existing and potential landslide points. Make the effort to avoid landslides by tree plantation, protection wall, diverting surface or subsurface from near the points.
- If there are unavoidable human settlement in the catchment area, ensures that pollution does not reach steam by surface or subsurface flow.
- Assign a caretaker for the protection of the protection zone and regular visits.
- Make people aware about protection zones, code of conduct and its links to the safety of the water.

Technologies involved: Landslide protection- Protection wall, slope protection, flood diversion and diversion of water flow towards erodible soils. Increase riparian area in the side of rivers. Barrier to pollution (waste water, septic tank and pit latrine) to water from surface and subsurface flow.

(3) Intake filters: Frequent flash flood caused by climate change can bring high turbidity, sand particles and faecal pollution at the intake points in a stream. Normal diversion allows turbid and polluted water pass to water treatment plant which make WTP ineffective. Intake filters are constructed near the intake for stream source as a first treatment unit which will check heavy pollution by controlling or by preventing

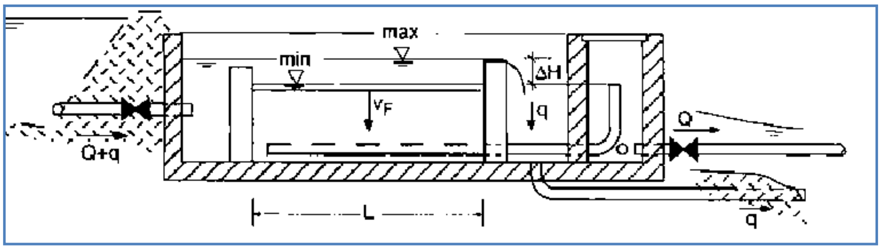

Figure 2 Dynamic Intake Filter

or by the self cleaning after a flash flood. Intake filter can be dynamic filter, self cleaning filter or flow preventing arrangement

Process

Figure 3 Perforated pipe arrangement for flood diversion

- Understand the nature of the intake and degree of problem caused by flash floods and pollution contents. Select the appropriate measure.
- Dynamic filter: Filter box is filled with two layers of gravel upper one for filter and lower one of support. Filter water can go up to 3m/Hr. Size of filter gravel 4-8 mm. If we replace filter gravel by 2-4 mm and increase filter rate of 5 m/hr it becomes a dynamic filter which automatically stops due to clogging during flash flood with high turbidity.
- Self cleaning: if there is more than sufficient water in the normal situation intake dam can be made such that portion of water continuously drains out from the bottom of the diversion wall. This will allow self cleaning of the deposited particle and sands.
- Flow preventing arrangement: Intake can be also designed in such a way that waterfall in the collection pipes (perforated) during normal flow and diverts away from the collection pipes during floods (high flow) and skip from collections. Collection pipes with perforation can be fitted in the down side walls of the diversion wall, in parallel, one below other such that in the normal condition water fall on them and collected.
- The community can come out with other options in the situation.

Technologies involved: Dynamic filter, self cleaning diversion works and flow diversion arrangement

6.12 Spring sources

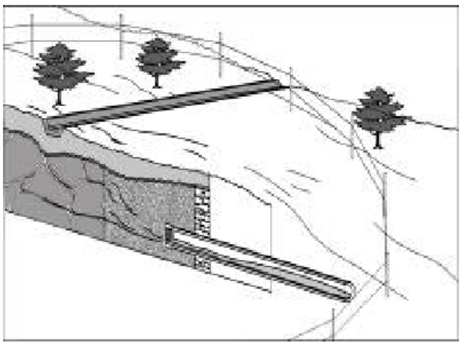

Figure 4 Spring Intake

(4) Spring protection: A spring is a place on the earth's surface where groundwater emerges naturally. The water source of most springs is rainfall that seeps into the ground uphill from the spring outlet. The amount, or yield, of available water from springs may vary with the time of year and rainfall. High flood caused by the changing climate can relocate eye points of the springs. Springs are susceptible to contamination by surface water, especially during rainstorms. Contamination sources include livestock, wildlife, crop fields, forestry activities, septic systems, and fuel tanks located upslope from the spring outlet. Changes in color, taste, odor, or flow rate indicate possible contamination by surface water. Spring can be conserved and protected by improving catchment area, pollution control in the catchment area and improving intake works.

Spring can be categorized as two types. Concentrated springs occur along hillsides at points where groundwater emerges naturally from openings in rock. These are the easiest springs to develop and protect from contamination. Proper development for concentrated springs consists of intercepting water underground in its natural flow path (eye point) before it reaches the land surface.

Seepage springs occur where groundwater "*seeps*" from the soil over large areas. The development process for seepage springs consists of intercepting flowing groundwater over a wide area underground and channeling it to a collection point. Because seepage springs collect water over large areas, they are more difficult to protect from surface water contamination than concentrated springs.

Process

- Springs protection involves following measures: Divert all surface water away from the spring as far as possible. Construct a U-shaped surface drainage diversion ditch or an earth berm at least 50 feet uphill from the spring to divert any surface runoff away from the spring. Be careful not to dig deep enough to uncover flowing groundwater. Fence an area at least 20 meters in the all directions around the spring box to prevent contamination by animals and people who are unaware of the spring's location. Avoid heavy vehicle traffic over the uphill water bearing layer to prevent compaction that may reduce water flow.
- To prevent depletion of or dryness of spring, it is important to improve infiltration in the catchment area and enhance artificial recharge by creating pond, dams, gully, wetlands and increasing vegetation
- Define conservation and the protection area, issue a code of conduct and ensure care taking by regular monitoring and make people aware of the importance of the spring protection.
- Divert surface water by construction of drain in the upstream.
- Monitor the variation of flow in the spring over the year and observe how the flow is changing over season and years and compare with rainfall patterns and conservation done.
- collect rainwater from ground surface, small reservoirs and micro-catchments to augment capacity of spring.

Technologies involved: Spring protection for point and scattered springs, catchment development, diversion of surface drain

6.13 Ground water sources

(5)a Tubewells as a Drought Intervention for Domestic Water Supply: A warmer climate is highly likely to result in more frequent drought. Shallow tubewells and hand dug wells are likely to be impacted by climate change in terms of water table depletion, flooding and surface pollution. Tubewells and dug wells can be protected prevented from pollution from the drought and flooding by appropriate measures.

Process

- Apply community wide WSP, considering all tubewells in the community
- Define whole community as conservation and protection area and issue codes of conduct for pollution control.
- Promote infiltration area, wetlands, ponds within the community and encourage the people to collect rain water from rooftops and use for ground water recharge.
- Minimize the impermeable area and promote plantation.
- Make plans for avoiding ingress of pollution from sanitary waste, toilets and solid waste management.
- If the bacterial control is not possible, regulate to use disinfectants.
- Seal the tubewell head by constructing platform and divert waste water away from the wells.
- Frequently clean the tubewell and dugwell by applying heavy dose chlorine.
- Clean the tube well and dug well after flooding.
- Coordinate with other users of ground water specially irrigation to make sure that over abstraction of water for irrigation do not cause depletion of ground water at a shallow level beyond the permissible limit.
- Replace shallow head, hand pump by deep set hand pump to collect water from the deeper aquifer, which is safe and stable over various seasons.

  Technologies involved: recharge from infiltration galleries, protection of well head, cleaning of well during emergencies.

(5)b Conservation and protection of the catchment area of ground water: Availability and safety of water in the ground are the function of rainfall and infiltration into the ground water reservoir which depends on the nature of the surface and soils in the ground. The amount of rainfall and its pattern can be impacted by the climate change. Ground water source can be conserved and ground water level maintained by maintaining water research and it can be protected by avoiding pollution to move from surface sources to ground water reservoir or borehole sites. Deep tubewells, usually defined by engineers as those that penetrate at least one impermeable layer, generally have much greater resilience to drought than traditional water supplies including springs, hand dug wells and surface water sources

Process

- Identify the sites from where the infiltration is high and ground water being recharged regularly. All areas around the bore site may not be the recharge area. Define recharge area and conservation and protection area.
- Improve infiltration area by improving infiltration capacity, creating artificial recharge creating dams, wetlands and ponds.
- Measure total rainfall, runoff and infiltration into the ground and water being drawn from the bore. This will give an idea of stability of ground water level. Water being infiltrated and water drawn should be balance. Water level can be maintained even in the extreme drought by the condition through balancing.
- Set water submersible pump well below the water table to incorporate water table delectation in the worst climate condition.
- Avoid flowing around the recharge area by plantation and avoiding landslides this will prevent clogging the recharge area and entering the heavy pollution into the ground reservoirs.
- Coordinate with other users of ground water limit for abstraction for other users on the basis of first right for drinking water.
- Seal the borehead for preventing pollution during flooding and prevent flow of the pollutant from upper layer to lower layer from where water has been drawn by sealing the aquifer.

Technologies involved: Infiltration galleries, sealing borehead and sealing the inter aquifer connections, recharge from rooftop water.

6.2 Water treatment system area

(6) **Resilient water treatment process and operations*:*** Water treatment plant consists of unit process and operations to remove or control the pollutants beyond the limit of acceptance. Water treatment units are normally designed for maximum expected pollution level over the year in normal situation. Climate change or variation is likely to bring a high level of turbidity or pollution during flash floods. Functions of treatment process also impacted by the change in temperature. Climate resilient treatment process takes care of extreme condition while designing or during operations.

Figure 5 Portable coagulation units

Process.

- Identify possible extent of pollution in terms of physical, chemical and biological parameters
- Identify possible extent of extreme temperature or temperature variations over the year and over multiyear.
- Add additional treatment or make provision for taking an additional load of pollution during extreme conditions.
- Design the special operation and chemical doses during extreme pollutions
- Prepare SoP of plant operation based on variation in pollution that is likely based on climate changes.
- Calculate chemical requirement and disinfectant doses for variable temperature and extreme situation.
- Design the system or make arrangement for diversion of flow during extreme pollution time and arrange for alarm system.
- Design treatment units to handle additional load during extreme situation like coagulation and flocculation unit.

Technologies involved: Diversion of flow during high contamination, Modification of units for excess contamination, addition of units for extra contamination, extra dosing of chemicals involved during extreme contamination, variation of chlorine dosing for seasons, schedule of cleaning as per variation of seasons and extreme situation of floods. Use of coagulation and flocculation units for high turbidity flow.

6.3 Distribution networks

(7) **Modeling distribution network system for flow, pressure and FRC in view of climate change*:*** Modeling of network involves analysis for flow, pressure and FRC in the various parts of the networks. Climate change causes drought, which may cause reduced flow. In addition, variations in temperature may impact on change in chemical reactions of disinfectant over pipe networks. Equitable distribution of flow with required pressure and FRC can be maintained even in the variable climate situation if the network is appropriately modeled. Modeling is applicable for both small and large distribution networks. Large networks needs more information over networks for calibrations to real situation.

Process

- Update the network data for pipe (length, size, material used) and junctions (elevation and positions) required for the hydraulic analysis.
- Update the current and future HH, pipe connections at various segments of the pipes and determine water demands.
- Analyze the network using appropriate software (eg Epanet), and determine the pressure for required flow in the various zones and improve the networks for achieving required pressure. Calibrate the model pressure by measuring actual pressure at various zones using portable pressure gauge.

- Determine the FRC at various zones for the given chlorine doses in normal and extreme temperature situation and calibrate the model by measuring actual FRC at various points of the networks.
- Reduce the loss of chlorine in the network by removing bio-films on the walls of the pipes (by flushing) and reducing water age mainly in the dead end.

Technologies involved: Modeling distribution system for flow, pressure and water age and maintaining equitable distribution for current and future needs, selection of appropriate materials for pipe and joints and process in view of climate variations over days and seasons, Re aligning pipes away from pollution area, Chlorine module in view of a distance, zones and temperature changes over the seasons.

(8) Leakage Management, Detection and Repair in Pipes joints and valves: leakages on pipes, joints and valves not only cause water loss, but also cause ingress of contaminants from the surroundings into the pipes. The situation becomes worse when the pipes are passing from water logged area, drain or floods. Intermittent system allows the ingress of pollution into the pipes when there is no flow or negative pressure. Leakage in pipes and joints depends on age of pipes and maintenance and repair system. Temperature variation over the day or extreme temperature caused breakage of pipes and joints due to contraction and expansion of the pipes. Freezing and melting of water causes bursting of pipes mainly in extreme cold climate. Leakages can be minimized to save valuable water and protected from pollution, mainly during extreme climate situations by appropriate consideration of the climate variables and its impact on the networks.

Process

- Monitor and keep the record of breakage of joints and pipes and analyze for the reason in view of pipe age, materials, activity around and above pipes and climate variations.
- Replace old pipes, correct week joints, use appropriate pipe and joint materials, relocate the pipe and align to the safe location away from roads, drains and wetlands.
- Avoid using metal pipes in the cold climate and using standard pipe joining process to avoid breakages in the joints.
- Keep records of break variation over the seasons and make plans for maintenance and repairs for expected changes.
- Plan for preventive maintenance in view of climate variations.
- Adjust chlorine dosing to maintain minimum FRC at far end points in view of pollution in the pipes, joints and valves caused by leakages.
- Detecting and preventing leakage in piped water systems can lead to large savings in the energy used to transport, treat and distribute water. Hence, flow standard process for detection and corrections using models and equipment approach simultaneously.

Technologies involved: Modeling for pressure, installation of pressure meters, aligning in safe locations, leakage detection and water loss control, pressure variation and leakage detection equipments (sounding, correlation, acoustic loggings).

6.4 Consumers area

(9) Water conservation and efficient use of water in households: water is required for drinking, cooking, bathing, sanitation, animal and kitchen gardening. It has been a general tradition to encourage use of water by fixing minimum tariff for minimum water required and control the excessive use of water by fixing a progressive tariff. Climate change may cause availability of water in the source during drought or cause increased demand due to temperature. Water conservation is an essential part of a comprehensive strategy to reduce pressure on existing water resources. Water can be conserved and by economic use, reuse.

Process

- Carryout an assessment of water use pattern by people in the various clusters.
- Prepare the ways to conserve water by efficient use of water for all purposes and educate the people.
- Encourage people for reuse of waste water from the kitchen and bathroom. This can be used in the kitchen garden, preferably using drip irrigation process.
- Encourage people to use urine as manure with water for saving both nutrients and water following the safety plan.

Technologies involved: water saving technologies, collection of used water and drip irrigation

(10) Household Water Treatment and Safe Storage (HWTS): general intent is to prevent the contamination at the source. If it is not possible, remove or control by treatment process and represent the contamination in the networks. Hence, safe water supplied from the taps is expected to be safely used in households by the people. Degradation of water quality is expected to be one of the key impacts of climate change on water resources and water supply. The effect of the climate change may impact the water supply system by causing extreme pollution beyond the treatment capacity. Residual chlorine may go below accepted limits due to the long residence time due to low flow or due to long water age in some dead ends due to intermittent flow or during emergencies caused by floods. In such situation people need to know methods for water treatment at HH levels.

Process:

- Make list of methods that people can store and use safely in the community context and educate them accordingly.
- Train community people for various methods of water treatment at households based on availability, affordability and easy to use.

- Train them on how to use a chlorine product when operators suggest to use them during the emergency or system failure in the extreme situation.
- Suggest users for using water directly from tap (before going to tank at HH) for the drinking purposes. Allow some time if there is excessive chlorine.
- If the water is safe in the normal situation and likely to deteriorate only during emergency suggest people to boil when asked than keeping costly products.

Technologies used: Chlorine products, filters, boiling, safe storage and protection at HH.

(11) Awareness of people about climate changes its impact on safe water system and their roles: Ultimately, users are the one who suffers from the impact of the climate change in the safe water system. People need to adopt and contribute to the adaptation plan prepared from the catchment, water supply system and at their household levels. Climate resilient adaptation will be effective if the diverse groups of users are identified and mobilized in the process. People need to know about the effect of climate change, its impact on safe water system and necessary adaptation during extreme situations.

Process

- Identified the diverse group of people in the community and assess their diverse needs and potentiality to contribute.
- Prepare list of tasks they can contribute in the various parts of the system form catchment to consumer for as per the adaptation plan prepared.
- Prepare list of adaptation measure that people can manage in their own at household level.
- Train all people at HH, community level in group covering all users in turn following standard courses including observation visits of the system and community.
- Intensify awareness level using multi channel like FM, school, health centers and community based organizations.
- Organize integration with community groups and organize mass meeting regularly.
- Carryout assessment survey and share the result regularly.
- Introduce mobile data collection technology for climate change information and water quality variations at HH and strategic locations of the system.
- Organize reward, recognition and prizes for the best contributors annually.

Technologies involved: Mobile data collection, portable kits, and mobile pressure gauge.

(12) Conserve and protect local traditional sources for use during water sacristy and emergencies: When there is a problem in the availability or quality of water in the system caused as a result of climate variations or extreme situations people are forced to use local sources which are likely to be unsafe. Conservation and protection of local traditional sources like wells, springs, hand-pumps can be alternate source and adopt the impact of climate change on the regular system.

Process

- Identify the all sources like springs, wells and handpumps .
- Prepare plan for conservation and protection gradually so that it can be used as alternate during emergency after applying chlorine.
- Also protect traditional ponds for using water for other purposes to reduce competition for using water from system for other non domestic purposes and determine an efficient way of using them.
- Monitor the availability and quality of water from those traditional sources regularly.

Technologies involved: Spring and well protection, Hand pumps, Rainwater harvesting

7 Steps for planning adaptation

Effect of climate change varies from place to place and its impact depends on nature of water supply systems. Hence, adaptation to climate change is specific to the water supply system. Following are the steps for planning adaptation to climate change towards climate resilient water safety plan. Mainly the adaptation planning involves climate prediction, its implications in water sources, the implication in the water safety systems and selecting resilient technologies and practices in the situation.

- Climate predictions: Discuss on observed changes in climate in the past 30 or 50 years. Climate change can be measured in terms of high precipitation, low precipitation, variation in pattern and low temperature and drought. Discuss on potential changes on climate factors in the long future in the same trend continued.
- Implications on the safe water system: Discuss on the potential impact of climate change in the water supply system from source to consumers in terms of source depletion, flow variations, floods, potential peak loads in water treatment plants, potential damage in water supply system or increased demands.
- Adaptation practices: Discuss appropriate adaptation practices suitable at source, WTP, distribution system and consumer area.
- Plan of action: Make plans for practicing selected adaptation measures various areas of the water supply systems.
- Monitoring plan: Make a plan for monitoring effect and impact of climate in the different seasons and over different years and generate data. Make records of extreme events and impacts in the water supply system and its operations.
- Coordination: Coordinate other communities who need to cooperate in the adaptation process, for example: source area lies in a different community. Coordinate with different agencies who need to cooperate in the adaptation process like forest, agriculture, tourism education,etc.
- Climate data: Make link with government agencies that can provide data relating to climate change in the local situation.
- Modeling: Make plans for monitoring as part of technical and management function for generating data on change in consumption pattern, population growth, source flow, change in water qualities. Understand water supply system for how it works under different flow and water quality situation.
- Plan for emergencies: Make plans for preserving alternate sources during emergencies within communities
- Public awareness: Identify the diverse group of users and stakeholders assess their needs and potential contribution and plan for an awareness program.

8 Recommendation for further works

Followings has been recommended for further works for developing national capacity and experience

- Prepare more case study covering source types: Spring and stream in the Himalaya ; spring and small stream in the hills; ground water system in the Terai (or inner Terai); Community hand pumps; community wide protected springs.
- Train a group of engineers in the sector as resource person for facilitating WUSC for preparing an adaptation to the impact of climate change in CRWSP. It is three days training with field visits or two days without field visits.
- Prepare working guideline based on the outcomes of this study and prepare design with sketch for each technology.
- Organize a pilot adaptation plan in selected WSPs to generate design parameters and lessons learned about various technologies.
- Explore innovative technologies used in the various parts of the country.
- Prepare hydrological map indicating increasing and decreasing trend of rainfall and temperatures based on projections and models for the various parts of the country.
- Incorporate adaptation measure explored in this document in to CRWSP guideline as list of control measure at various parts of the water supply system as appropriate
- Incorporate adaptation technologies and concepts in the design guideline of DWSS (12 volumes). Mainly it applies to design process, WTP design, O&M and drawings.
- Prepare hydraulic and chlorine modeling of a water supply system in view of climate variations preferably Amarapuri and calibrate for the real data.

9 References

WHO Guideline for Climate Resilient Water Safety Plan, update July 2015

Climate Change and Water, IPCC technical paper VI, June 2008

Technologies for Climate Change Adaptation, Guide book for the Water Sector, UNEP, April 2011

Climate Change and Water Resource Management: Adaptation Strategies for Protecting People and the Environment, Fact sheet, NRDC April 2010

Handbook on Community –Wide Water Safety Planning, DoLIDAR 2013

Handbook on Recharge Ponds for WASH program, DoLIDAR 2013

Annex A: Lesson learned from visit of Amarapuri (Nawalparasi)

The Amarapuri water supply system was first constructed in 1971 by DWSS and expanded with water treatment plant with the support of the FINNADA project in 2001 and currently being extended under project 'co-financing' of DWSS. The current capacity of the WTP is 20 lps and new WTP will add 12 lps. Distribution network can supply up to 47 lps and improved network has been designed to supply peak demand (55 lps). WSP applied in 2010 as a result, people are benefiting continuous safety of supplied water. It is also developing as a resource center for WSP. People think that water supplied from the system very safe and they know how to use it safely.

The source of Amarapuri WSS is JharaheKhola which is a stream source. After passing through a grit chamber and PST near the source, water is conveyed to WTP one kilometer away from the source. The WTP consists of RF, SSF and Chlorination unit. The water is then collected in two RVT each of capacity $200m^3$. The water from one SSF is collected in one RVT and that from other two is collected in second RVT. Then water is distributed from two RVT in two different areas be collected in $400m^3$ RVT and distributed. After addition of new system network has been divided into three zones supplied from three tanks.

Catchment area which extends up to 6 Km away from intake points and covers 20km2 lies in the another VDC but the forest over the area is used by the people of Amarapuri as Sundari Community Forest Users group. The catchment area is about 90% forest and highly conserved. Pollution in the intake, river and catchment area has been protected by issuing a code of conduct, caretaker assigned and people made aware. Minimum flow in the river is 70lps. Water used for the system is only 31 percent of the minimum flow and 0ne percent of the total rainfall. Hence, availability of the water is not a problem. Water become very turbid during rainy season frequently due to landslides. WUSC has a plan to construct a new intake with self cleaning approach and make a plan to protect landslide areas by construction of wall, plantation and diversion of flow from potential landslide areas.

Normally flow with turbidity up to 1000 is allowed in the WTP then after during flash flood it is stopped before RF. After each flash flood RF is backwashed and its whole media is washed once in a year. The slow sand filter is scraped at an interval of three months during winder and one month during summer. Turbidity in the effluent of SSF is almost zero and bacteria nil irrespective of incoming pollution in the RF. This is good management of WTP. During scraping E- Coli may appear up to 5 for a week. They test every day and apply chlorine until it disappear. But after WSP they apply chlorine continuously for further safety in the networks. They have not noticed a variation in efficiency of WSP except the need for cleaning. There is no other pollution than turbidity and E-Coli.

The distribution network is very old. It breaks frequently (one per day in winder and two per week in the summer). During cold season it breaks frequently due to contraction and expansion of joints. They have already realigned pipes in safe route avoiding drain, roads and wetlands. Currently water leakage is about 25%, but in the new system, it is expected to minimum acceptable.

Chlorine is applied at a rate of 1ppm after SSF by drop from 1% solution tank. About 3.5 kg Bleaching Power (30% chlorine) is consumed. FRC is maintained at a level of 0.5 ppm at the outlet of the tank and 0.1-0.3 in the community. People can feel the presence and level of chlorine by smell. They collect water for drinking purpose from tap directly before going to HH tank for safety.

The WSP team organizes training for the users by inviting 10 persons from each of three wards in a group and cover up to 100 HH in a year. They have provided training to all HH once. It is three days training including one day observation visit of system and community covering WSP and total sanitation. Community is first declared Total Sanitation of Nepal.

In a work organized during visit WUSC and WSP team discussed on current level of adaptation to impact of climate variation and they have identified new adaptation in the all parts of the system: catchment, WSP, networks and consumer's area. In over all community already have done 60% adaptation and need to improve for the 100 %.