Appendix B

Model water safety plans

The following represent 'model' water safety plans for a range of technologies including community-managed point sources (boreholes, springs, dug wells and rainwater) and piped water supplies as well as mechanised boreholes connected to distribution systems and utility distribution systems. These are laid out in tables that provide the basis of the information required. This format, however, does not imply that this is how water safety plans must be developed.

For some of the hazard events, the risk will vary with season. However, the same categories are used as in other water safety plans for consistency. The risk should be interpreted as an overall relative frequency of occurrence. It should also be noted that for some hazards (e.g. priming water) the risk refers to the probability of the hazard occurring if the practice is followed and should not be taken as an overall assessment of probability of using priming water of all handpumps.

Model plans are presented, in table form, and are followed by information on verification for:

- boreholes fitted with handpumps;
- protected springs not connected to piped water supplies;
- dug wells;
- mechanised boreholes;
- rainwater collection no disinfection as standard;
- a utility distribution system; and
- a community managed distribution system.

B1 BOREHOLES FITTED WITH HANDPUMPS

Table B.1: Model water safety plan for boreholes fitted with handpumps.

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Ingress of contaminated surface water directly into borehole	Poor wellhead completion	Unlikely/ Major	Proper wellhead completion measures	1m concrete apron around wellhead; lining extends 30cm above the apron; drainage ditches in place	Lining stops at ground level. Apron damaged or cracked. Ditches full, faulty or absent	Sanitary inspection	Monthly	Community operator	Extend lining Repair apron Clean and repair drainage ditches
Ingress of contaminants due to poor construction or damage to the lining	Poorly maintained welllhead completion	Moderate/ Major	Proper wellhead completion	Top 5 metres of the annulus sealed Rising main in good condition	Annulus sealed for less than 3 metres. Colour changes Increased pumping required to raise water	Sanitary inspection Water clarity	Annual/as need arises	Community operator	Insert seal around annulus. Replace worn and corroded rising mains. Use materials less likely to corrode (e.g. plastics)
Borehole area is inundated with contaminated surface water	Lack of diversion ditches	Unlikely/ Major	Good drainage around wellhead	Diversion ditches of adequate size, in good condition and clear of rubbish	Ditch has rubbish or shows signs of wear	Sanitary inspection	Monthly	Community operator	Repair and clean ditch Increase size of ditch using

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Contamination introduced as handpump requires priming	Priming water contaminated	Almost certain/ Minor	Use direct handpump or clean water for priming	Water for priming stored in secure container	Priming water comes from contaminated source or is stored poorly	Inspection	Weekly	Community operator	Select handump that does not require pumping.
Contaminated shallow water drawn into aquifer	Hydraulic connection exists between shallow and deeper aquifers allowing draw-down into deeper aquifer	Almost certain/ Minor	Pumping regimes do not induce leaching	No evidence of drawdown of shallow groundwater	Evidence of shallow water drawdown (e.g. shallow wells start to dry up)	Colour Taste Odour Inspection	Annual/as need arises	Community operator	Set intake deeper (microbes) Water treatment (microbiol) blending (chemicals)
Leaching of microbial contaminants into aquifer	Leaching of faecal material from sanitation, solid waste, drains	Moderate/ Moderate	Provide adequate set-back distances defined on travel time	No sources of faecal material within set-back distance	Latrines/sewers built or solid waste dumps within separation distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve sanitation design, reduce sewer leakage
Groundwater contains naturally occurring chemicals	Geological setting means chemicals present at toxic levels	Moderate/ Moderate	Select groundwater with acceptable levels of natural chemicals	Water quality assessments indicate water quality is acceptable	Evidence of natural contaminants	Risk assessment of geological setting Water quality assessment	Before construction Periodic evaluation	Water development agency	Use alternative source Treatment of water

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Leaching of chemicals into groundwater	Leaching of chemicals from landfills, waste dumps, discharges to ground	Moderate/ Minor	Provide adequate set-back distances defined on travel time	No sources of chemicals within set-back distance	Pollutant discharges within set-back distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve pollution containment

B1.1 Verification plan

The majority of boreholes or tubewells fitted with handpumps are managed by communities. As a result, verification is likely to be undertaken by the surveillance agency rather than the supply managers. In this situation, verification is primarily geared towards ensuring that the water safety plan for boreholes/tubewells as a whole is effective rather than verifying the performance of an individual supply on a regular basis. In some urban areas, it may be possible to initiate relatively frequent monitoring with boreholes visited once or twice per year, with at least one sample taken in the wet season. In rural areas, verification is likely to be undertaken through a rolling programme of visits, with each supply visited every 2-5 years.

B1.2 Parameters for verification

Routine verification for microbial safety would primarily focus on testing for *E.coli*, with sanitary inspections also performed. If the handpump must be primed, the water used for priming should be tested in addition to the water in the borehole or tubewell.

A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification may not include routine testing of chemicals, although in some case regular testing of chemicals known to be prone to temporal variation (for instance arsenic in shallow groundwater) may be warranted. In addition, verification should also include testing of physio-chemical parameters such as turbidity and electric conductivity.

Validation of control measures may include testing of other microbes, for instance faecal streptococci, as these are useful for groundwater known to be at risk of faecal contamination because they are more persistent than *E.coli*. Bacteriophages (for instance F-specific RNA phages) may be used to validate the control measures with respect to viral pathogens. It would not be expected that protozoa would represent a significant risk and if validation shows effective control for bacterial and viral pathogens, it is reasonable to assume that control would also be assured for protozoa.

Validation may also include analysis of nitrate, chloride and redox potential to validate control measures for draw-down of contaminated shallow groundwater into deeper groundwater and leaching of microbial or chemical contaminants into the aquifer. Tracer studies and hydrogeological models may be of value to validate control measures against draw-down or leaching of contaminants into the aquifer. If measures put in place to prevent or remove chemical contaminants, the chemical parameters should be included in the validation plan.

B2 PROTECTED SPRINGS NOT CONNECTED TO PIPED WATER SUPPLIES

Table B2: Model water safety plan for protected springs not connected to piped water supplies

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Contamination able to recharge spring in backfill area	Backfilled area becomes eroded	Moderate/ Major	Effective spring protection measures maintained	Area has grass cover; fence and diversion ditch in good condition No surface water uphill	Fence is broken Diversion ditch is damaged Surface water pools develop	Sanitary inspection	Monthly	Community operator	Repair fencing and ditches; drain surface water. Re-lay grass. Rehabilitate protective measures
Contamination in spring box or outlet	Spring box or retaining wall in poor condition, inundation from wastewater	Moderate/ Major to moderate	Maintenance of protection and drainage works	Masonry in good condition, wastewater ditch clear and in good condition	Masonry deteriorated; wastewater ditch blocked	Sanitary inspection	Monthly	Community operator	Repair masonry and covers; clear ditch

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Contaminated surface water causes rapid recharge	Surface water is allowed to form pools uphill and leads to rapid recharge of contaminants and limited attenuation	Moderate to Unlikely/ Major	Establish set-back distance based on travel time; drainage	No surface water, solid waste dumps uphill Faecal disposal methods available	Surface water close to springs Low sanitation coverage Poor solid waste removal Springs show rapid response in flow and quality to rainfall	Sanitary inspection Colour change response to rainfall	Monthly/ seasonally	Community operator	Drain surface water pools uphill of springs, promote improved sanitation and solid waste disposal
Contaminated shallow water drawn into aquifer	Hydraulic connection exists between shallow + deeper aquifers allowing draw-down into deeper aquifer	Almost certain/ Minor	Pumping regimes do not induce leaching	No evidence of drawdown of shallow groundwater	Evidence of shallow water drawdown (e.g. shallow wells start to dry up)	Colour Taste Odour Inspection	Annual/as need arises	Community operator	Set intake deeper (microbes) Water treatment (microbiol) blending (chemicals)

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Ingress of animal faeces	Animal husbandry uphill and close to the spring Animal damage to backfill area	Moderate/ Moderate	Set-back distance to Control animal husbandry; good fencing	No kraals or sheds in set-back distance; fence in good condition	Animal husbandry found within controlled area Fencing damaged or absent	Sanitary inspection	Monthly	Community operator	Remove animal sheds or kraals from uphill of spring or move to safe distance Repair or erect fences
Leaching of microbial contaminants into aquifer	Leaching of faecal material from sanitation, solid waste, drains	Moderate/ Moderate	Provide adequate set-back distances defined on travel time	No sources of faecal material within set-back distance	Latrines/sewers built or solid waste dumps within separation distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve sanitation design, reduce sewer leakage
Groundwater contains naturally occurring chemicals	Geological setting means chemicals present at toxic levels	Moderate/ Moderate	Select groundwater with acceptable levels of natural chems	Water quality assessments indicate water quality is acceptable	Evidence of natural contaminants	Risk assessment of geological setting Water quality assessment	Before construction Periodic evaluation	Water development agency	Use alternative source Treatment of water

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Leaching of chemicals into groundwater	Leaching of chemicals from landfills, waste dumps, discharges to ground	Moderate/ Minor	Provide adequate set-back distances defined on travel time	No sources of chemicals within set-back distance	Pollutant discharges within set-back distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve pollution containment

B2.1 Verification plan

The majority of protected springs not connected to a distribution system are managed by communities. As a result, verification is likely to be undertaken by the surveillance agency rather than the supply managers. In this situation, verification is primarily geared towards ensuring that the water safety plan for protected springs as a whole is effective rather than verifying the performance of an individual supply on a regular basis. In some urban areas, it may be possible to initiate relatively frequent monitoring with protected springs visited once or twice per year, with at least one sample taken in the wet season. In rural areas, verification is likely to be undertaken through a rolling programme of visits, with each supply visited every 2-5 years.

B2.2 Parameters for verification

Routine verification for microbial safety would primarily focus on testing for *E.coli*, with sanitary inspections also performed. A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification may not include routine testing of chemicals, although in some case regular testing of chemicals known to be prone to temporal variation (for instance arsenic in shallow groundwater) may be warranted. In addition, verification should also include testing of physio-chemical parameters such as turbidity and electric conductivity.

Validation of control measures may include testing of other microbes, for instance faecal streptococci, as these are useful for groundwater known to be at risk of faecal contamination because they are more persistent than *E.coli*. Bacteriophages (for instance F-specific RNA phages) may be used to validate the control measures with respect to viral pathogens. It would not be expected that protozoa would represent a significant risk and if validation shows effective control for bacterial and viral pathogens, it is reasonable to assume that control would also be assured for protozoa.

Validation may also include analysis of nitrate, chloride and redox potential to validate control measures for draw-down of contaminated shallow groundwater into deeper groundwater and leaching of microbial or chemical contaminants into the aquifer. Tracer studies and hydrogeological models may be of value to validate control measures against draw-down or leaching of contaminants into the aquifer. If measures put in place to prevent or remove chemical contaminants, the chemical parameters should be included in the validation plan.

B3 DUG WELLS

Table B.3: Model water safety plan for dug wells

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Ingress of contaminated surface water directly into well	Well does not have a cover; lining stops at ground level; faulty or absent apron; drainage ditches faulty or absent	Moderate/ Major	Proper wellhead completion with raised wellhead, cover and apron. Good drainage	Well covered Lining extends 30cm above the apron. Apron with radius of 1.5m around well. Drainage ditches in good condition	Lack of cover on well; lining stops at ground level; apron damaged or cracked; ditches full, faulty or absent	Sanitary inspection	During construction Monthly	Water development agency Community operator	Provide cover on well Extend lining. Repair apron. Clean and repair drainage ditches.
Ingress of contaminants due to poor construction or damage to the lining	Entry of contamination in top few metres of dug well because of cracks in lining or poor sealing of lining	Moderate/ Minor	Proper construction and use of a mortar seal on lining	Lining in good condition; no signs of weep holes in lining during rainfall	Well lining is pitted, evidence of seepage into well during rainfall	Sanitary inspection	Seasonal	Community operator	Improve well lining

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Animal damage allows contamination routes to develop	Animals not excluded from immediate wellhead	Likely/ Moderate	Fencing	Fence in good condition	Lack of fence or faults in fence	Sanitary inspection	Monthly	Community operator	Repair or install fence
Contamination introduced by buckets	Handpump or other sanitary means of abstraction not installed or non-functioning	Almost certain/ Major	Install and maintain handpump or other sanitary means of abstraction	Abstraction by handpump or other sanitary method in good working order	Lack of handpump or other sanitary means of withdrawal	Sanitary inspection	Monthly	Community operator	Install or repair handpump or other sanitary means of withdrawal
Wellhead area is inundated with contaminated surface water	Lack of diversion ditches mean that source is not protected against flood events	Unlikely/ Major	Diversion ditches surround the dug well, designed	Diversion ditch clear of rubbish and in good condition	Ditch has rubbish or shows signs of wear	Sanitary inspection	Monthly	Community operator	Repair and clear ditches
Leaching of microbiol contaminants into aquifer	Leaching of faecal material from sanitation, solid waste, drains	Moderate/ Moderate	Provide adequate set-back distances defined on travel time	No sources of faecal material within set-back distance	Latrines/sewers built or solid waste dumps within separation distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve sanitation design, reduce sewer leakage

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Groundwater contains naturally occurring chemicals	Geological setting means chemicals present at toxic levels	Moderate/ Moderate	Select groundwater with acceptable levels of natural chemicals	Water quality assessments indicate water quality is acceptable	Evidence of natural contaminants	Risk assessment of geological setting Water quality assessment	Before construction Periodic evaluation	Water development agency	Use alternative source Treatment of water
Leaching of chemicals into groundwater	Leaching of chemicals from landfills, waste dumps, discharges to ground	Moderate/ Minor	Provide adequate set-back distances defined on travel time	No sources of chemicals within set-back distance	Pollutant discharges within set-back distance	Inspection by community	Monthly	Community operator	Move pollutant sources, improve pollution containment

B3.1 Verification plan

The majority of protected dug wells are managed by communities. As a result, verification is likely to be undertaken by the surveillance agency rather than the supply managers. In this situation, verification is primarily geared towards ensuring that the water safety plan for dug wells as a whole is effective rather than verifying the performance of an individual supply on a regular basis. In some urban areas, it may be possible to initiate relatively frequent monitoring with dug wells visited once or twice per year, with at least one sample taken in the wet season. In rural areas, verification is likely to be undertaken through a rolling programme of visits, with each supply visited every 2-5 years.

B3.2 Parameters for verification

Routine verification for microbial safety would primarily focus on testing for *E.coli*, with sanitary inspections also performed. If a handpump is used that must be primed, the water used for priming should be tested in addition to the water in the dug well.

A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification may not include routine testing of chemicals, although in some case regular testing of chemicals known to be prone to temporal variation (for instance arsenic in shallow groundwater) may be warranted. In addition, verification should also include testing of physio-chemical parameters such as turbidity and electric conductivity.

Validation of control measures may include testing of other microbes, for instance faecal streptococci, as these are useful for groundwater known to be at risk of faecal contamination because they are more persistent than *E.coli*. Bacteriophages (for instance F-specific RNA phages) may be used to validate the control measures with respect to viral pathogens. It would not be expected that protozoa would represent a significant risk and if validation shows effective control for bacterial and viral pathogens, it is reasonable to assume that control would also be assured for protozoa.

Validation may also include analysis of nitrate, chloride and redox potential to validate control measures for draw-down of contaminated shallow groundwater into deeper groundwater and leaching of microbial or chemical contaminants into the aquifer. Tracer studies and hydrogeological models may be of value to validate control measures against draw-down or leaching of contaminants into the aquifer. If measures put in place to prevent or remove chemical contaminants, the chemical parameters should be included in the validation plan.

B4 MECHANISED BOREHOLES

Table B4: Model water safety plan for mechanised boreholes

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Ingress of contaminated surface water directly into borehole	Poor wellhead completion	Unlikely/ Major	Proper wellhead completion measures	1m concrete apron around wellhead; lining extends 30cm above the apron; drainage ditches in place	Lining stops at ground level. Apron damaged or cracked. Ditches full, faulty or absent	Sanitary inspection	Monthly	Operator	Extend lining Repair apron Clean and repair drainage ditches
Ingress of contaminants due to poor construction or damage to the lining	Poorly maintained welllhead completion	Moderate/ Major	Proper wellhead completion	Top 5 metres of the annulus sealed Rising main in good condition	Annulus sealed for less than 3 metres. Colour changes Increased pumping required to raise water	Sanitary inspection Water clarity CCTV	Monthly	Operator	Insert seal around annulus. Replace worn and corroded rising mains. Use materials less likely to corrode (e.g. plastics)
Borehole area is inundated with contaminated surface water	Lack of diversion ditches	Unlikely/ Major	Good drainage around wellhead	Diversion ditches of adequate size, in good condition and clear of rubbish	Ditch has rubbish or shows signs of wear	Sanitary inspection	Weekly	Operator	Repair and clean ditch Increase size of ditch using

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Contaminated shallow water drawn into aquifer	Hydraulic connection exists between shallow and deeper aquifers allowing draw-down into deeper aquifer	Almost certain/ Moderate	Control pumping regimes Set intake at depth	No evidence on induced leakage	Evidence of shallow water drawdown (e.g. shallow wells start to dry up)	Colour (appearance) Taste Odour Electric conductivity	Weekly	Operator	Set intake deeper (microbes) Water treatment (microbiol) or blending (chemicals)
Rapid recharge by rivers, streams and ponds	Hydraulic connection exists between surface water and aquifers	Unlikely/ Major to Catastrophic	Set intake at greater depth	Rapid recharge does not occur or cannot reach intake	Evidence of rapid recharge from surface water bodies	Surface water levels Colour Electric conductivity	Daily	Operator	Set intakes at greater depth or modify pumping regimes
Pumping leads to increased leaching of contaminants	Pumping induces increased leaching of chemicals	Unlikely/ Moderate	Pumping regime	Leaching of contaminants is within predicted range	Evidence of increased leaching of contaminants	Monitoring of key contaminants of concern Hydro-chemical models	Monthly	Operator	Modify pumping regime Treatment

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Pumping increases safe distances beyond current protection zone boundaries	Pumping increases cone of depression extends minimum travel time distance beyond protection zone	Unlikely/ Moderate	Protection zones	Protection zones include influence of drawdown on groundwater flow	Drawdown increases distance equivalent to travel time set	Water table levels surrounding borehole when pumping	Annual	Operator	Extend groundwater protection zone to account of the change in distance
Back-siphonage from pipe into borehole	No backflow preventer installed	Likely/ Minor	Backflow preventer on mains	Backflow preventer installed	Lack of backflow preventer	Inspect pumping works	Installations Periodic checks	Constructor Operator	Backflow preventer installed
Failure in disinfection process	Disinfection process fails	Unlikely/ Major catastrophic	Effective chlorination with contact time	Ct value adequate and residual produced	Lack of residual	Monitoring chlorine dosing and residual	Daily/hourly	Operator	Take pump off-line and repair disinfection unit

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Mobilisation of toxic chemicals and elution of viruses	Changes in land-use and increased recharge through irrigation leads to mobilisation and elution	Rare/ Minor to moderate	Land-use control, in particular managing irrigation	Little artificial recharge through irrigation, pH and Eh of water stable	Significant changes in land-use Increased use of irrigation	Land-use; pH of groundwater Redox (Eh)	Weekly	Operator	Reduce artificial recharge
Leaching of microbiol contaminants into aquifer	Leaching of faecal material from sanitation, solid waste, drains	Moderate/ Moderate	Protection zones and set-back distances	Lateral separation defined on basis of travel times and hydrogeology	Latrines/sewers built or solid waste dumps within separation distance	Sanitary inspection; inspection of protection zone, electric conductivity, sewer leakage	Monthly	Operator	Remove pollutant sources, improve sanitation design, reduce sewer leakage, insert cut-off walls around sewers
Groundwater contains naturally occurring chemicals	Geological setting means chemicals present at toxic levels	Moderate/ Moderate	Source selection	Use of groundwater with no natural chemical at harmful levels	Evidence of natural contaminants	Risk assessment of geological setting Initial assessment of water quality	Before installation	Constructor	Use alternative source Treatment

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Agricultural pollution: nitrate	Use of inorganic or organic fertilisers, stock density	Unlikely/ Minor	Protection zone	Nitrate vulnerable zones defined for aquifer prevent excessive leaching	Evidence of increasing nitrate levels	Monitoring of nitrate in groundwater Monitor fertiliser applications Monitor stock densities	Monthly	Supplier Environment agency	Control of fertiliser applications Blending of drinking water
Agricultural pollution: pesticides	Pesticides leached into the groundwater	Unlikely/ Minor	Protection zone	Pesticide applications controlled in recharge area	Evidence of increasing pesticides in water Evidence of pesticide application at high-risk locations and times	Monitor pesticide applications	Monthly	Supplier Environment agency	Control of pesticide applications
Leaching of chemicals from landfill sites into groundwater	Leaching of chemicals from landfills, waste dumps, industrial discharges to ground	Moderate/ Minor	Protection zone	Landfills are sanitary and properly sealed Landfill presence controlled on basis of travel times and hydrogeology	Monitoring around pollutant sources indicate increasing pollution migration	Monitor for key contaminants around pollutant sources Monitoring bills of lading	Weekly/daily	Waste Managers Environment agency Supplier	Move pollutant sources, improve pollution containment, monitoring network around pollutant sources

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Pathogens from hospital wastes contaminate groundwater	Poor disposal of hospital wastes allows direct ingress of leaching into groundwater	Unlikely/ Catastrophic	Proper hospital waste disposal	Hospital wastes with pathogenic material incinerated	Hospital waste disposal in dumps or ground containers	Monitor hospital waste disposal methods	Daily	Water supplier Health authorities	Ensure all pathogenic material incinerated or sterilised
Pollution from urban areas contaminates groundwater	Poorly sealed drains cause recharge of groundwater	Moderate/ Minor	Protection zones	Drainage water unable to recharge groundwater	Poorly constructed drains increase potential for recharge	Inspection	Operator	Weekly	Ensure all drains properly sealed in recharge or vulnerable areas
Industrial discharges contaminated groundwater	Poorly disposed of industrial waste can inundate groundwater source or leach into aquifer	Moderate/ Minor	Waste containment and treatment	Effective disposal methods prevent spills and leaching	Waste disposal methods do not provide security against inundation and leaching	Monitor containment methods at industrial sites	Supplier Environment agency	Monthly	Ensure all industrial waste is properly contained and treated at the site

B4.1 Verification plan

Mechanised boreholes are usually connected to distribution systems and may be managed by a utility or local Government water supplier, a water user association or water user group or by communities. Where boreholes are operated by a water supplier, it would be expected that they would undertake much of the routine verification, although they may seek assistance in validation. Verification should be carried out on a regular basis and in particular the potential for seasonal deterioration in water quality taken into account when designing a verification programme. Verification data should be reviewed in the audits undertaken by the surveillance agency.

In supplies managed by the community or where water user association or water user groups then verification may be undertaken by the surveillance agency. In this situation, verification is primarily geared towards ensuring that the water safety plan for mechanised boreholes as a whole is effective rather than verifying the performance of an individual supply on a regular basis. In some urban areas, it may be possible to initiate more regular monitoring and for boreholes to be visited once or twice per year, with at least one sample taken in the wettest season. In rural areas, verification is likely to be undertaken through a rolling programme of visits, with each supply visited every 2-5 years.

B4.2 Parameters for verification

Routine verification of microbial safety would primarily focus on testing for *E.coli* and turbidity, with sanitary inspections also performed. If the pump must be primed., the water used for priming should be tested in addition to the water in the borehole. Close-circuit television (CCTV) should also be included in verification as a means of undertaking an inspection of the integrity of the casing of the borehole. Audits of maintenance records of the borehole, as well as other key functions such as drainage, should be carried out during verification. Audits may also be undertaken of any industries discharging into the environment within a distance identified as being of concern.

A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification should include routine testing of chemicals known to be present and that are known to be prone to temporal variation. In addition, verification should also include testing of physio-chemical parameters such as electric conductivity and redox potential.

For boreholes operated by utilities, pathogen assessments should be considered as a key component of validation. This should include assessing risks from key reference pathogens and also undertaken studies to assess whether these are present. Validation may also include testing of other indicator organisms, such as bacteriophages (for instance F-specific RNA phages) to validate the control measures with respect to viral pathogens. Suitable organisms (for instance *Clostridium perfringens*) should be identified for protozoan pathogens.

Validation may also include analysis of a range of chemicals for which control measures are identified and in areas where there is potential for leaching of microbial or chemical contaminants into the aquifer. Tracer studies and hydrogeological models may be of value to validate control measures for draw-down and leaching of contaminants into the aquifer.

B5 RAINWATER COLLECTION, WITH NO DISINFECTION AS STANDARD

Table B5: Model water safety plan for rainwater collection no disinfection as standard

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Bird and animal droppings found on roof or in guttering	Roof is not cleaned properly or regularly allows build-up of faecal material	Likely/ Minor	Cleaning of roof and gutters	Roof is clean before rainfall	Roof dirty as rainfall collection starts	Sanitary inspection	Before rains	Owner/ Operator	Clean roof regularly
Trees overhang the collection tank	Overhanging branches allow birds and animals to gain access to roof	Likely/ Minor	Tree surgery	Trees branches do not overhand roof	Branches encroach on roof	Sanitary inspection	Annual	Owner/ Operator	Trim branches

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Animals and birds can enter the tank	Inspection covers and vents open or improperly sealed	Likely/ Major	Ensure all openings on tank are bird and animal proof	Inspection covers fitted and locked, vents have mesh	Inspection cover damaged, not in place, mesh damaged or not in place	Sanitary inspection	Annual	Owner/ Operator	Install or repair inspection covers and vents mesh
Tank dirty or sediment accumulates	Poor cleaning of tank	Unlikely/ Moderate	Cleaning of tank	Tank cleaned regularly and disinfected annually	Dirt seen inside tank Water appears turbid	Sanitary inspection Appearance	Annual	Owner/ Operator	Cleaning of tank, removal of sediment, disinfection
First flush of water can enter tank	First flush of water from roof is not diverted and so enters tank	Moderate/ Major	Foul-flush diversion unit	Foul-flush system in place and used correctly	Lack of foul-flush system Poor operation of foul-flush system	Sanitary inspection Colour Odour	On installation, then annual	Owner/ Operator	Install foul-flush system and train users
Unhygienic withdrawal of water allows contamination to enter	Water withdrawn using buckets which introduce contamination	Almost certain/ Minor	Install tap or other sanitary means of withdrawal	Tap in place to allow easy withdrawal of water	Lack of tap	Sanitary inspection	On installation	Owner/ Operator	Install tap with intake at least 5cm from base of tank

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Tank is damaged or allows contaminated surface water or groundwater to enter	Tank has cracks and other damage	Likely/ Minor	Structural integrity of tank	Tank set above ground and in good condition	Cracks in tank structure	Sanitary inspection	Annual	Owner/ Operator	Effect repairs
Roof material introduced into tank	Collection surface is soft and allows material to be leached into the tank	Likely/ Minor	Only use hard surfaces for rainwater collection	Collection from impermeable surfaces	Collection from thatch and other soft surfaces	Sanitary inspection	At installation	Owner/ Operator	Replace roof material
Water is not filtered	Water enters into tank with no filtration	Likely/ Minor	Filter installed and maintained	Tanks have working filter installed to remove debris	Lack of filter, increased turbidity	Sanitary inspection Turbidity Colour	Annual	Owner/ Operator	Install filter Clean filter
Leaching of chemical from roof material into water	Roof material contains lead or other harmful chemicals	Unlikely/ Minor	Materials for rainwater collection approved	Roof material should not contain lead or other harmful substances	Roof material known to contain lead or other harmful chemicals	Inspection of materials	At installation	Owner/ Operator	Use lead-free roofing material

B5.1 Verification plan

The majority of rainwater collection systems are operated by households or communities. As a result, verification is likely to be undertaken by the surveillance agency. In this situation, verification is primarily geared towards ensuring that the water safety plan for rainwater collection as a whole is effective rather than verifying the performance of an individual supply. Verification is likely to be undertaken through a rolling programme of visits, although not every individual supply may be visited.

B5.2 Parameters for verification

Routine verification would primarily focus on sanitary inspection with some testing of *E.coli* and turbidity. If not previously carried out prior to commissioning, during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical.

Validation of control measures may include testing of other microbes, for instance faecal streptococci and bacteriophage. Validation may also include analysis of lead from some roofs which use tanalised timber. Other chemicals may be included if it is considered they are likely to be present and may vary over time.

B6 UTILITY DISTRIBUTION SYSTEM

Table B6:Model water safety plan for a utility distribution system

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Water entering distribution is contaminated	Treatment failure	Moderate/ Catastrophic	Treatment is effective	Optimised treatment	Treatment plant moves out of compliance	Ct value Residual disinfectant) Particle count Turbidity Inspection	Hourly/daily	Operations staff	Take treatment unit off-line and apply appropriate corrective action
Microbial contamination of service reservoir	Birds/ animal contamination of service reservoirs	Unlikely/ Catastrophic	Ensure service reservoirs are bird and animal proof	All vents covered, inspection covers in place and locked No tree branches overhang reservoir. Fence around tank	Vent or inspection covers not in place or damaged; fence damaged, tree branch encroach on tank	Sanitary inspection	Daily	Operations staff	Repair and replace damaged vents and inspection covers. Cut back tree branches.

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Microbial contamination derived biofilm and/or sediment in service reservoir	Biofilm and sediment may slough or be disturbed.	Likely/Minor	Manage biofiml and sediment	Interior of reservoir is clean and sediment is minimised and undisturbed	Biofilm develops, increase in chlorine consumption	Sanitary inspection, chlorine residuals, turbidity Biofilm coupons	Daily	Operations staff	Take tank off-line during cleaning and flushing. Flush mains after completion with chlorinated water
Ingress of contaminated water into service reservoir	Leaks in tanks below ground or where stagnant water collects around base	Unlikely/ Minor	Structural integrity and drainage	Tank structure sound with no cracks and drainage channels in good condition	Drainage channels blocked, cracks develop in tank structure	Sanitary inspection	Daily	Operations staff	Clear drainage channels. Take tanks off-line for repairs. Flush tank and distribution before re-commissioning
Contamination enters distribution system at valves at service reservoir	Valve boxes become inundated by contaminated surface water	Moderate/ Major (depends on location and population served)	Structural integrity and drainage	Valve box with permeable base and adequate drainage	Water build up within valve box; drainage damaged or requires cleaning	Sanitary inspection	Daily	Operations staff	Repair leaks drains and valve box. Repair valve if showing signs of wear

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Contamination enters distribution system at major sluice valves in distribution	Major sluice valves are inundated by contaminated water	Moderate/ Major (depends on location and population served)	Structural integrity and maintenance of valve boxes	Valve box with permeable base and adequate drainage	Water build up within valve box, damage to drains or drains in need of cleaning	Sanitary inspection, chlorine residual, turbidity	Daily	Operations staff	Repair leaks drains and valve box. Repair valve if showing signs of wear.
Contamination enters distribution system from major institutions	Intermittence or pressure fluctuations lead to back-siphonage from large institutions into mains.	Likely/ Moderate	Ensure backflow preventers (one-way valves) installed Institutional WSP developed	Backflow preventers function correctly and water quality management plan developed and followed	Backflow preventer absent/faulty Absence of a water quality management plan	Sanitary inspection of backflow preventers	Weekly/ monthly	Operations staff	Utility to provide advice to institution on water quality management plan. Repair to backflow preventers
Contamination results from cross-connections to sewer system	Leaking sewer lie to close to mains and allows pathogens to directly enter the supply	Likely/ Catastrophic (depends on location and population served)	Good design and sewer and mains leakage control programmes	Systems designed to prevent cross-connection under all circumstance	Sudden chlorine loss, risk assessment indicates elevated risk	Chlorine residual, turbidity, sanitary inspection/ risk model	Monthly	Operations (both water and sewerage	Leaks in water supply and sewer should be repaired rapidly; rehabilitation to improve hydrostatic pressure; cut-off walls in high-risk areas

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Back-siphonage of contaminated water	Leaks in pipe combined with drops in pressure (either intermittence or transient pressure waves) allow ingress of water containing pathogens from faecally-contaminated soils	Likely/ Moderate (depends on location and population served)	Reduce intermittence and limit potential for transient pressure waves by limiting direct connections on pumping mains	Piped water supply with leakage control programme and positive hydrostatic pressure Cut-off walls Limited water hammer	Sudden loss of chlorine, increase in turbidity, risk assessment indicates high risk	Chlorine residuals, turbidity, sanitary inspection/ risk model	Daily	Operations staff	Reduce intermittence. Leakage control programme. Where intermittence unavoidable, disinfection strategy developed. Cut-off walls constructed in high risk areas Reduce transient pressure waves
Contamination introduced during repairs on distribution system	Poor hygiene in repair work allows contamination to enter into the system	Moderate/ Catastrophic	Hygienic codes of practice for work on distribution mains	Hygiene code developed, available to all staff and followed	Evidence that hygiene code not followed	Turbidity Chlorine residuals Site inspection	Daily	Management/operations	Ensure that hygiene code is prepared and made available to all staff. Training in good hygiene for mains repair teams.

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Biofilm sloughing into drinking water	Biofilm develops because of high AOC content and lack of control strategy. Hydraulic changes (surges/water hammer) lead to sloughing	Moderate/ minor	Minimise biofilm formation (chlorination or use biologically stable water)	Little biofilm developed and limited risk of sloughing	Increases in turbidity, chlorine loss, changes in colour	Chlorine residual, colour, turbidity, odour, customer complaints, corrosion coupons	Daily	Operations	Replacement of high adherence pipe material, improve biological stability through optimised treatment, improve steady state flow

B6.1 Verification plan

Verification of utility supplies would usually be the responsibility of the utility that operates the system. Surveillance agencies should undertake regular audits of the supplier records and may undertake some independent testing of water quality. Verification should be ongoing and include regular testing, as well as periodically performing more extensive assessments and internal audits. The latter would typically be carried out on an annual basis.

Sampling should be spread throughout the system and standard operating procedures defined. This should include use of accepted sampling methods (for instance those defined by ISO). Sample numbers for microbial safety should be calculated on the basis of population served as shown in the table below.

Table B7: Recommended minimum sample numbers for faecal indicator testing in distribution systems

Population	Total number of samples/year
<5 000	12
5000 to 100 000	12 per 5000 head of population
>100 000-5000K	12 per 10 000 head of population plus an additional 120 samples
>500,000	12 per 100,000 head of population + an additional 180 samples

B6.2 Parameters for verification

Routine verification would primarily focus on testing for E.coli and turbidity, with sanitary inspections also performed. Other parameters may be identified as appropriate, for instance routine analysis of Clostridium perfingens of treatment performance. There should be regular verification of the chemical quality of source and final waters, with the parameters selected based upon an initial risk assessment. In the distribution system, testing of chemicals for verification may be less frequent and should be determined on the basis of a risk assessment.

Validation of control measures will, by preference, be based upon pathogen assessments using selected reference pathogens (e.g. *Cryptosporidium*, *E.coli* O157:H7 and rotavirus) and risk assessments performed to evaluate performance in relation to health-based targets. Validation may also use index organisms such as bacteriophages (for instance F-specific RNA phages) as surrogates for validate the control measures with respect to viral pathogens.

A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification should include routine testing of chemicals known to be present and that are known to be prone to temporal variation. In addition, verification should also include testing of physio-chemical parameters such as electric conductivity and redox potential.

Validation may also include analysis of chemicals for which control measures have been defined, Tracer studies, hydrochemical and flow models may be of value to validate control measures in treatment works and to predict likely impact of contamination events within distribution systems. The measurement of AOC may also be considered if control measures are in place to reduce re-growth.

B7 COMMUNITY MANAGED DISTRIBUTION SYSTEM

Table B8: Model water safety plan for community managed distribution system

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Water entering distribution is contaminated	Failure at source (see spring, borehole WSP)	Moderate/ Catastrophic	Ensure source WSP adhered to	Optimised source protection (see spring/borehole WSP)	Source WSP indicates non-compliance	Sanitary inspection Turbidity Chlorine residual (if chlorinated)	Weekly/daily	Community operator	Take source off-line and apply appropriate corrective action (see appropriate WSP)
Microbial contamination of storage tank	Birds/ animal contamination of storage tanks	Unlikely/ Major	Make sure tank is animal and bird-proof	Vents covered, inspection covers in place and locked No tree branches overhang reservoir. Fence around tank	Vent or inspection covers not in place or damaged; fence damaged, tree branch encroach on tank	Sanitary inspection	Weekly/ Monthly	Community operator	Vents should be designed so as to prevent direct access and covered to prevent access from small birds and rodents. Tree branches should be cut-back and the site made secure.

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Ingress of contaminated water into storage tank	Leaks in tanks may lead to contamination. This may occur when tanks are either below ground or allow stagnant water to collect around base	Unlikely/ Minor	Structural integrity and drainage	Tank structure sound with no cracks and drainage channels in good condition	Drainage channels blocked, cracks develop in tank structure	Sanitary inspection	Monthly	Community operator	Clear and repair drainage channels. Take tank off-line to make repairs. Flush tank and distribution before re-commissioning
Contamination enters distribution system at major valves in distribution or storage tank	Major sluice valves are inundated by contaminated water	Moderate/ Major	Valve maintenance and drainage	Valve box with permeable base and adequate drainage	Water build up within valve box, damage to drains or drains in need of cleaning	Sanitary inspection, turbidity	Monthly	Community operator	Repair leaks drains and valve box. Repair valve if showing signs of wear Disinfect supply

Hazard event	Cause	Risk	Control measure	Critical limits		Monitoring			Corrective action
				Target	Action	What	When	Who	
Back-siphonage of contaminated water	Leaks in pipe combined with drops in pressure (either intermittence or transient pressure waves) allow ingress of water containing pathogens from faecally-contaminated soils	Likely/ Moderate (depends on location and population served)	Ensure that supply has sufficient water to meet demand and ensure all connections downstream of tanks	All connections on lines served by tank, leakage is low	Intermittence increases, leakage increases	Sanitary inspection, turbidity, chlorine residuals (if chlorinated	Daily/weekly	Community operator	Reduce intermittence. Leakage control programme.
Contamination introduced during repairs on distribution system	Poor hygiene in repair work allows contamination to enter into the system	Moderate/ Catastrophic	Hygienic codes of practice followed	Hygiene code developed and training provided to all people working on system	Evidence that hygiene code not followed	Turbidity Site inspection	As required	Community operator	

B7.1 Verification plan

Verification for community-managed piped distribution systems will depend on local resources. In developed countries, verification may be undertaken by some communities. However, in developing countries and in smaller community-managed supplies in developed countries, verification is likely to be undertaken by the surveillance agency. In this situation, verification is primarily geared towards ensuring that the water safety plan for community-managed distribution systems as a whole is effective rather than verifying the performance of an individual supply on a regular basis. In rural areas, verification is likely to be undertaken through a rolling programme of visits, with each supply visited every 2-5 years.

Within the system, sampling should be spread throughout the system and standard operating procedures defined. This should include use of accepted sampling methods (for instance those defined by ISO). Sample numbers for microbial safety should be calculated on the basis of population served as shown in the table below.

Table 9: Recommended minimum sample numbers for faecal indicator testing in distribution systems

Population	Total number of samples/year
<5 000	12
5000 to 100 000	12 per 5000 head of population

B7.1 Parameters for verification

Routine verification for microbial safety would primarily focus on testing for *E.coli*, with sanitary inspections also performed. A comprehensive analysis of the chemical quality of water should have been undertaken prior to commissioning of the supply. If this was not performed, then during the first verification visit the water should be tested for a range of chemical parameters. The specific parameters should be determined on the basis of an assessment of the likely presence of the chemical. These should always include consideration of arsenic, fluoride, nitrate and selenium. Subsequent verification may not include routine testing of chemicals, although in some case regular testing of chemicals known to be prone to temporal variation (for instance arsenic in shallow groundwater) may be warranted. In addition, verification should also include testing of physio-chemical parameters such as turbidity and electric conductivity.

Validation of control measures may include testing of other microbes, for instance faecal streptococci, as these are useful for groundwater known to be at risk of faecal contamination because they are more persistent than *E.coli*. Bacteriophages (for instance F-specific RNA phages) may be used to validate the control measures with respect to viral pathogens. Where the supply includes treatment of surface water, *Clostridium perfringens* should be included within validation to assess treatment performance in relation to risks from protozoan pathogens. Validation should also include analysis of relevant chemicals where control measures have been identified for chemical contaminants.