Executive Summary

Key Risks at the Global Scale

Freshwater-related risks of climate change increase significantly with increasing greenhouse gas (GHG) concentrations (*robust evidence*, *high agreement*). {3.4, 3.5} Modeling studies since AR4, with large but better quantified uncertainties, have demonstrated clear differences between global futures with higher emissions, which have stronger adverse impacts, and those with lower emissions, which cause less damage and cost less to adapt to. {Table 3-2} For each degree of global warming, approximately 7% of the global population is projected to be exposed to a decrease of renewable water resources of at least 20% (multi-model mean). By the end of the 21st century, the number of people exposed annually to the equivalent of a 20th-century 100-year river flood is projected to be three times greater for very high emissions (Representative Concentration Pathway 8.5 (RCP8.5)) than for very low emissions (RCP2.6) (multi-model mean) for the fixed population distribution at the level in the year 2005. {Table 3-2, 3.4.8}

Climate change is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions (*robust evidence*, *high agreement*). {3.4, 3.5} This will intensify competition for water among agriculture, ecosystems, settlements, industry, and energy production, affecting regional water, energy, and food security (*limited evidence*, *medium* to *high agreement*). {3.5.1, 3.5.2, Box CC-WE} In contrast, water resources are projected to increase at high latitudes. Proportional changes are typically one to three times greater for runoff than for precipitation. The effects on water resources and irrigation requirements of changes in vegetation due to increasing GHG concentrations and climate change remain uncertain. {Box CC-VW}

So far there are no widespread observations of changes in flood magnitude and frequency due to anthropogenic climate change, but projections imply variations in the frequency of floods (*limited evidence*, *medium agreement*). Flood hazards are projected to increase in parts of South, Southeast, and Northeast Asia; tropical Africa; and South America (*limited evidence*, *medium agreement*). Since the mid-20th century, socioeconomic losses from flooding have increased mainly due to greater exposure and vulnerability (*high confidence*). Global flood risk will increase in the future partly due to climate change (*limited evidence*, *medium agreement*). {3.2.7, 3.4.8}

Climate change is *likely* to increase the frequency of meteorological droughts (less rainfall) and agricultural droughts (less soil moisture) in presently dry regions by the end of the 21st century under the RCP8.5 scenario (*medium confidence*). {WGI AR5 Chapter 12} This is *likely* to increase the frequency of short hydrological droughts (less surface water and groundwater) in these regions (*medium evidence*, *medium agreement*). {3.4.8} Projected changes in the frequency of droughts longer than 12 months are more uncertain, because these depend on accumulated precipitation over long periods. There is no evidence that surface water and groundwater drought frequency has changed over the last few decades, although impacts of drought have increased mostly due to increased water demand. {3.5.1}

Climate change negatively impacts freshwater ecosystems by changing streamflow and water quality (*medium evidence*, *high agreement*). Quantitative responses are known in only a few cases. Except in areas with intensive irrigation, the streamflow-mediated ecological impacts of climate change are expected to be stronger than historical impacts owing to anthropogenic alteration of flow regimes by water withdrawals and the construction of reservoirs. {Box CC-RF, 3.5.2.4}

Climate change is projected to reduce raw water quality, posing risks to drinking water quality even with conventional treatment (*medium evidence*, *high agreement*). The sources of the risks are increased temperature, increases in sediment, nutrient and pollutant loadings due to heavy rainfall, reduced dilution of pollutants during droughts, and disruption of treatment facilities during floods. {3.2.5, Figure 3-2, 3.4.6, 3.5.2.3}

In regions with snowfall, climate change has altered observed streamflow seasonality, and increasing alterations due to climate change are projected (*robust evidence*, *high agreement*). {Table 3-1, 3.2.3, 3.2.7, 3.4.5, 3.4.6, 26.2.2} Except in very cold regions, warming in the last decades has reduced the spring maximum snow depth and brought forward the spring maximum of snowmelt discharge; smaller snowmelt floods, increased winter flows, and reduced summer low flows have all been observed. River ice in Arctic rivers has been observed to break up earlier. {3.2.3, 28.2.1.1}

Because nearly all glaciers are too large for equilibrium with the present climate, there is a committed water resources change during much of the 21st century, and changes beyond the committed change are expected due to continued warming; in glacier-fed rivers, total meltwater yields from stored glacier ice will increase in many regions during the next decades but decrease thereafter (*robust evidence*, *high agreement*). Continued loss of glacier ice implies a shift of peak discharge from summer to spring, except in monsoonal catchments, and possibly a reduction of summer flows in the downstream parts of glacierized catchments. {3.4.3}

There is little or no observational evidence yet that soil erosion and sediment loads have been altered significantly due to changing climate (*limited evidence*, *medium agreement*). However, increases in heavy rainfall and temperature are projected to change soil erosion and sediment yield, although the extent of these changes is highly uncertain and depends on rainfall seasonality, land cover, and soil management practices. {3.2.6, 3.4.7}

Adaptation, Mitigation, and Sustainable Development

Of the global cost of water sector adaptation, most is necessary in developing countries where there are many opportunities for anticipatory adaptation (*medium evidence*, *high agreement*). There is limited published information on the water sector costs of adaptation at the local level. {3.6.1, 3.6.3}

An adaptive approach to water management can address uncertainty due to climate change (*limited evidence*, *high agreement*). Adaptive techniques include scenario planning, experimental approaches that involve learning from experience, and the development of flexible and low-regret solutions that are resilient to uncertainty. Barriers to progress include lack of human and institutional capacity, financial resources, awareness, and communication. {3.6.1, 3.6.2, 3.6.4}

Reliability of water supply, which is expected to suffer from increased variability of surface water availability, may be enhanced by increased groundwater abstractions (*limited evidence*, *high agreement*). This adaptation to climate change is limited in regions where renewable groundwater resources decrease due to climate change. {3.4.5, 3.4.8, 3.5.1}

Some measures to reduce GHG emissions imply risks for freshwater systems (*medium evidence*, *high agreement*). If irrigated, bioenergy crops make water demands that other mitigation measures do not. Hydropower has negative impacts on freshwater ecosystems, which can be reduced by appropriate management. Carbon capture and storage can decrease groundwater quality. In some regions, afforestation can reduce renewable water resources but also flood risk and soil erosion. {3.7.2.1, Box CC-WE}