The impact of climate change on

WATER SCARCITY

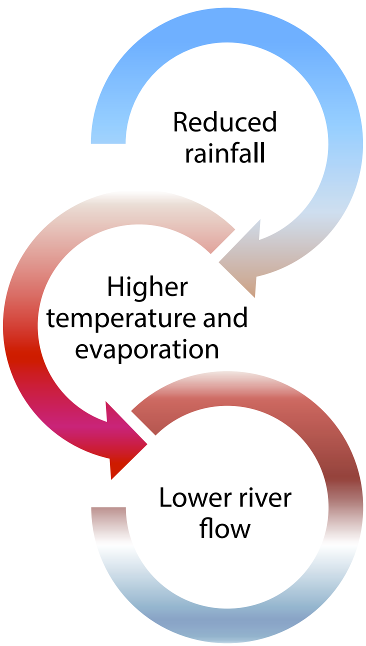
1 Climate change may more than double the frequency of extreme summer low flow events by 2050.

2 Climate change will likely lead to increases in summer temperatures, resulting in an increased demand for water resources, such as for crop irrigation.

3 More frequent extreme low flows will impact on our water supply, water quality and the ecological health of our rivers.

Why are low flow events important for Scotland?

The water available from Scottish rivers and lochs is vital for a range of industries and public water supply. In addition, it is a key condition for supporting a healthy aquatic ecosystem. In periods of sustained low flows, this resource is put under pressure leading to impacts on the environment, economy and health.



How does climate change affect water scarcity in Scottish waters?

Long-term water scarcity lasting more than a few months, such as that experienced in parts of Tayside during 2003-2004 is extremely rare in Scotland. Typically, water scarcity is a short-term issue occurring mostly in summer.

During the summer, the combination of lower rainfall and higher evaporation, and the take-up of water by plants lead to lower river and loch levels.

Climate projections indicate a reduction of summer rainfall and an increase in temperature across much of Scotland by 2050s. Greater plant productivity and evaporation in agricultural areas is likely to lead to a higher demand for irrigation.

These effects are likely to result in a lower natural supply of water combined with a greater demand for water from rivers, lochs and groundwater in the summer and autumn months.

SEPA
Scottish Environment Protection Agency

The maps below show the reductions in summer rainfall and the change in severity of low flow events across Scotland since 1961.

Change since 1961

An analysis of rainfall records by the UK Met Office has shown a mixed pattern of changes in rainfall since 1961. In terms of summer rainfall, there is some evidence of a decrease in parts of the north of Scotland by as much as 20%.

As for the number of days in a row with no rainfall, the pattern of change reflects a geographic split with fewer days in the west and more in the east.

Source: Scotland's Climate Trends Handbook, Sniffer 2014

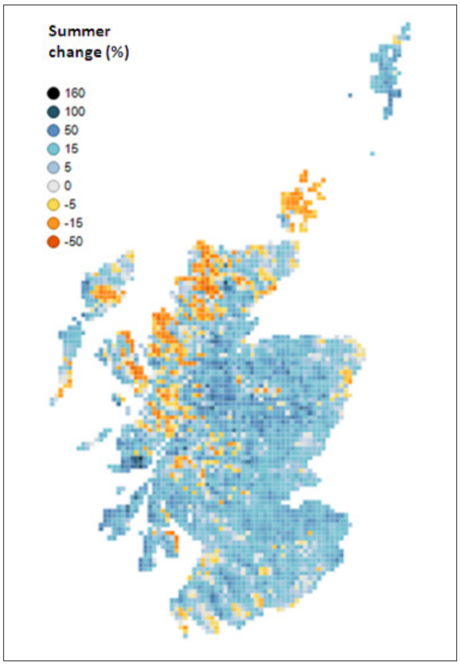


Figure 1. Percentage change in total summer rainfall between 1961 and 2011.

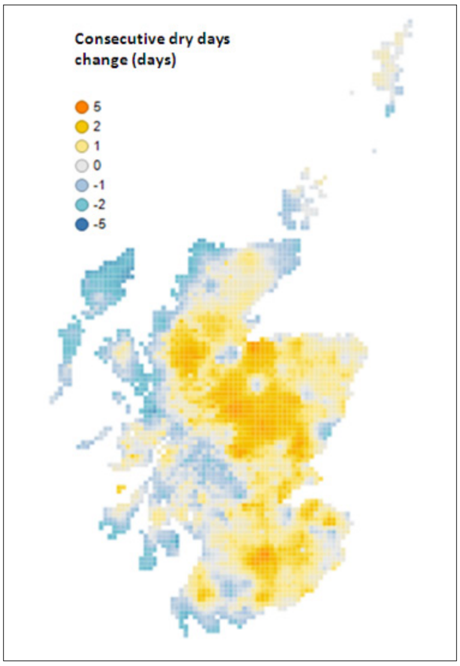


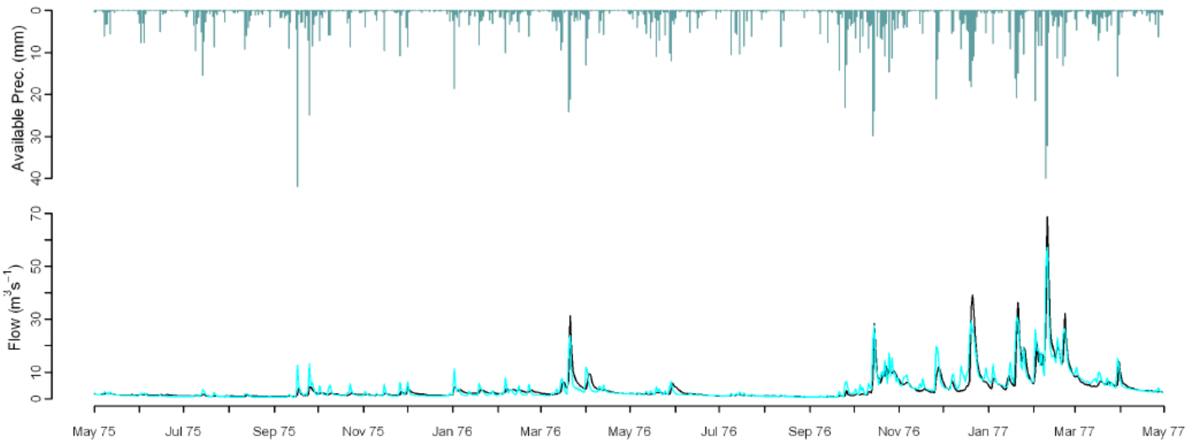
Figure 2. Change in maximum number of consecutive dry days each year between 1961 and 2004.

How has the severity of low flow events changed so far?

A useful measure of a low flow event can be one which quantifies how much the flow over a month deviates from the long-term average. This is measured using the Normalised Flow Index (Zaidman *et al.* 2012). An analysis of the change in severity of summer low flow events since 1961 at 31 sites across Scotland has shown that, for all but one site, there has been no clear change. We conclude that any changes in summer rainfall have so far not resulted in measurable trends in summer water scarcity.

Area	Increased severity	Decreased severity	No change
Argyll	0	0	4
Forth	0	1	5
North Highland	0	0	2
Northeast Highland	0	0	11
Solway	0	0	2
Tay	0	0	1
Tweed	0	0	5
Total	**0**	**1**	**30**

Figure 3. Change in the severity of one month low flow events at 31 SEPA gauging stations since 1961.



Source: Catchment fact sheet 14001. NRFA (2014)

Figure 4. Gauged (black) and simulated (cyan) flows from observed climate – the river Eden at Kemback (14001). The available precipitation shown in the top graph was used to generate the simulated flows.

Confidence in modelling flows

In order to understand how changes in climate will affect river flows in the future, we need to be able to model river flows resulting from a given set of weather conditions. These models are tested against measured river flows over the full length of the measured record and across a full range of flows.

The graph of flow in the River Eden in Fife (Figure 4) illustrates a snap-shot of the results of a river flow model during the particularly dry period of the mid-1970s and shows that, even under these extreme conditions, the models can perform well when compared to the measured flows. With a given set of rainfall, wind and temperature values, it is possible to confidently estimate river flows.

These demonstrate that with known climate components such as rainfall, wind and temperature, it is possible to estimate river flows with a high degree of accuracy, demonstrated here during the exceptionally dry mid-1970s.

Unlikely to be drier than this | Central projection | Likely to be drier than this

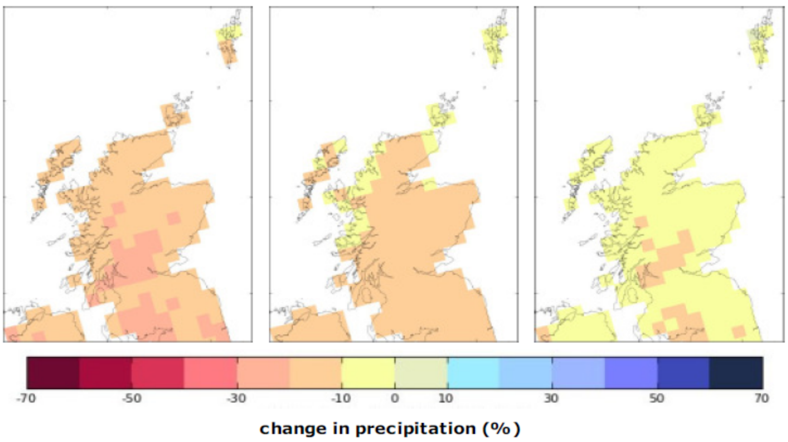


Figure 5. Projected change in summer precipitation by the 2050s (medium emissions scenario).

Note: the three projections relate to the 33, 50 and 67% probability levels from UKCP09 http://ukclimateprojections.defra.gov.uk

This shows that where existing monitoring is in place, the link between rainfall, evaporation and flow are well understood. For a given set of climate projections such as UKCP09 produced by the Met Office (see Figure 5) we can be confident of understanding the associated impacts on river flows.

Projected flows in 2050

Assuming a medium greenhouse gas emissions trajectory up to 2050, the UK climate projections indicate a strong likelihood of lower summer rainfall and higher summer temperatures across Scotland. The climate scenarios of temperature and rainfall have been fed through well established river models to examine how these changes would affect river flows.

In climate modeling, uncertainty is expressed by producing many possible future scenarios and from these we get the range in which the future climate is likely to lie. The range of uncertainty is a key consideration when planning how to adapt, and in terms of indicating the direction of travel, the middle of the range, or median value, can be a useful guide. Applying the future flow modeling across Scottish rivers, it can be seen that the median value of a typical annual low flow event* reduces across nearly all of Scotland by 2050 (Figure 6). In some rivers, this reduction from current flows may be more than 25%.

Looking at more extreme events we can analyse the change in frequency of a low flow event that currently occurs, on average, once every 40 years. This is an extreme low flow which could cause the drying up of smaller rivers and lead to a high risk of interruptions in domestic, industrial and agricultural water supply.

This analysis shows that reduced rainfall and higher temperatures may lead to more than a doubling in the frequency of extreme low flow events by 2050 (Figure 7) from once every 40 years to once every 20 years.

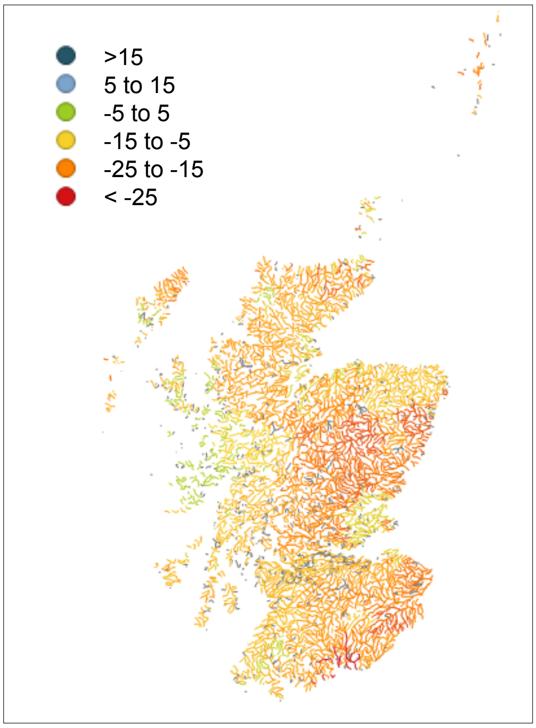


Figure 6. Median percentage change in low flow* by 2050.

*the flow exceeded 95% of the time

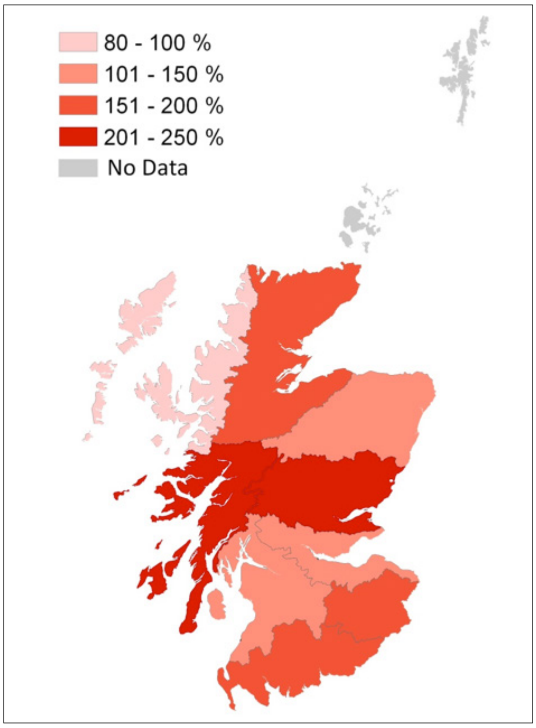


Figure 7. Median increase in frequency of extreme low flow events by 2050.

Note: an increase of 100% equates to a doubling of frequency

So, how will this affect us?

By 2050, reduced summer flows are projected across most of Scotland's rivers as a result of higher temperatures and lower rainfall.

In terms of land use change and the demand for water, some assumptions can be made about how changes in climate may feed through to impacts on these factors. The James Hutton Institute has used climate change projections to estimate the potential change in demand for irrigation by 2050. Based upon the currently irrigated area, the total volume of water required for irrigation may increase by around 30%. Important spatial variations are identified in this increased demand which identify hot spots where higher demand for irrigation combines with lower supply from rainfall (see Figure 8).

Less flow means less dilution of the pollutants that make their way into rivers and, combined with the higher temperature, could likely result in a reduction of water quality. This will impact on the river environment and water users. This may mean a higher frequency of incidences where water quality is unsuitable for recreational use and more intensive treatment may be required for raw water supply to business.

Extreme low flow events are projected to more than double in frequency in some parts of the country. These events are likely to lead to risks to water supply and major reductions in wetted habitat for river plants and animals.

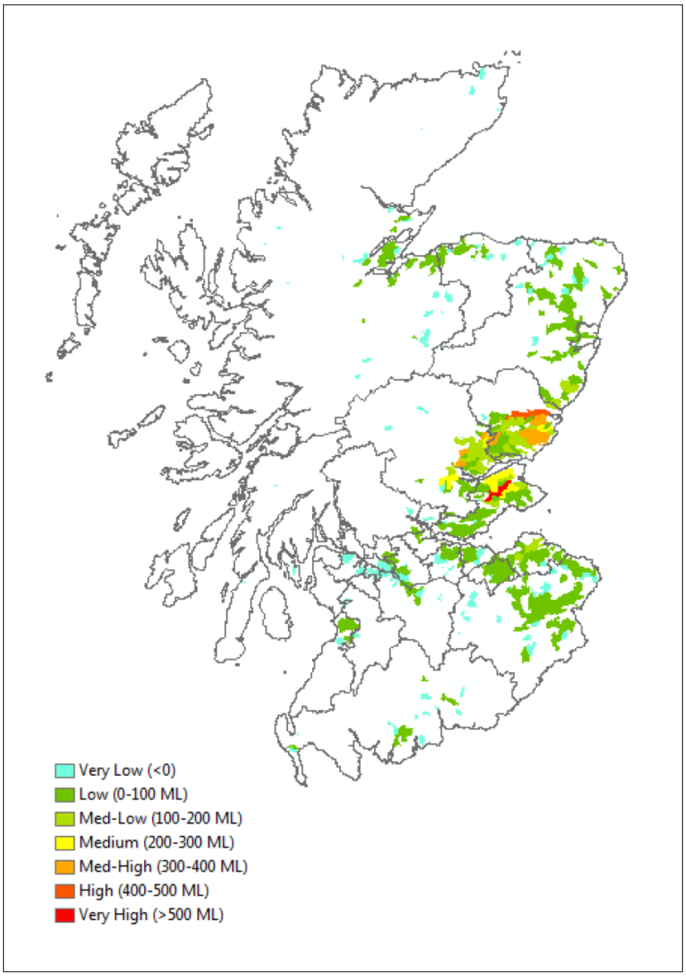
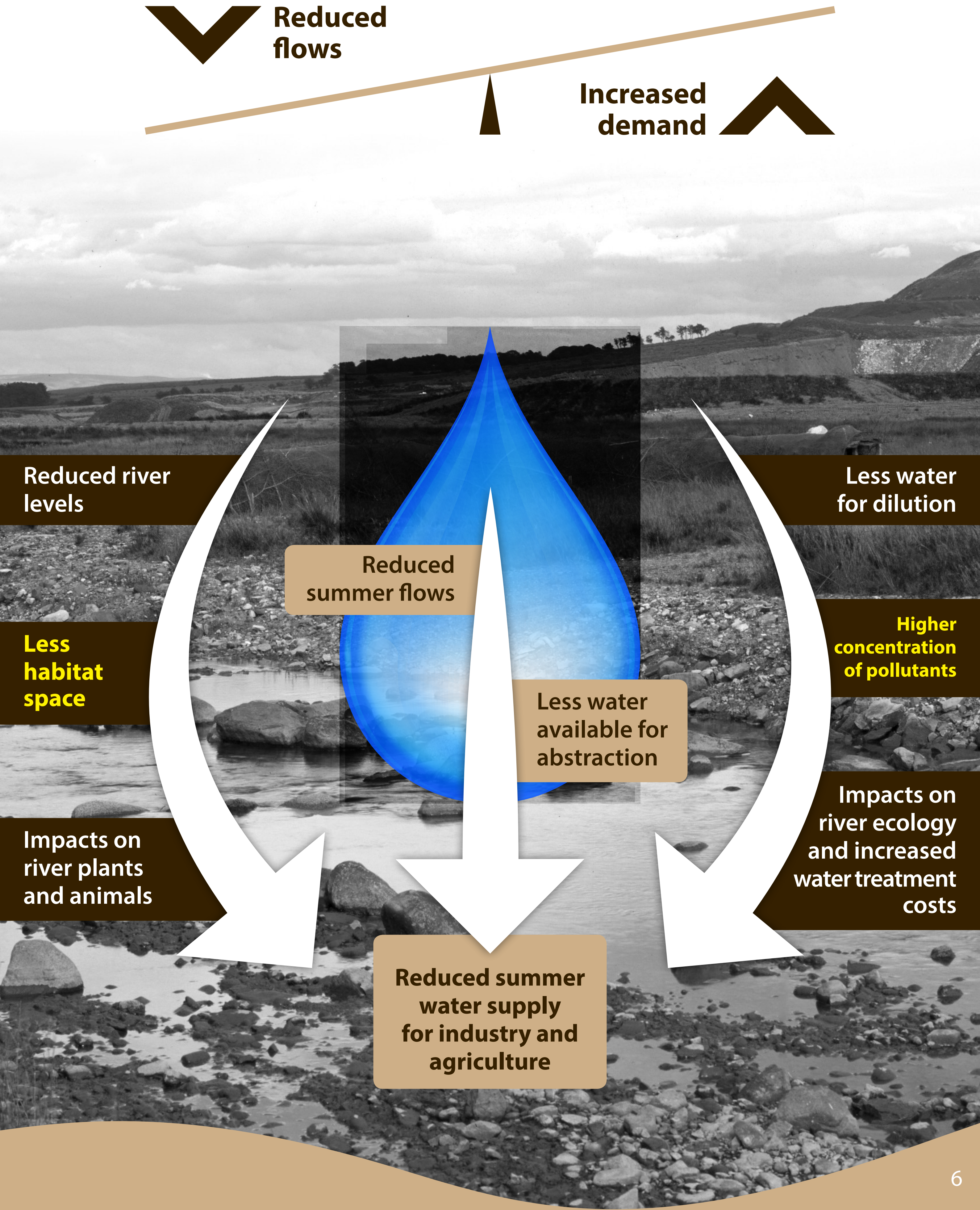


Figure 8. Change in projected irrigation demand.
Source: Brown *et al.* 2012


Reduced flows
Increased demand
Reduced river levels
Less habitat space
Impacts on river plants and animals
Reduced summer flows
Less water available for abstraction
Reduced summer water supply for industry and agriculture
Less water for dilution
Higher concentration of pollutants
Impacts on river ecology and increased water treatment costs

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