Indicators and trends

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Indicator name				Version
NB27 Summer low flow events in Scottish rivers (Normalised Flow Index)				**15/04/16**

Indicator type:	**Risk/opportunity**	**Impact**	**Action**
	X		

SCCAP Theme	SCCAP Objective	CCRA risk/opportunity
Natural Environment	N2: Support a healthy and diverse natural environment with capacity to adapt. N3: Sustain and enhance the benefits, goods and services that the natural environment provides	• BD14 Ecosystem risks due to low flows and increased water demand • WA2 Lower summer river flows

At a glance

- Periods of unusually low flow in rivers can have detrimental impacts on aquatic ecology and threaten public water supply
- Climate change projections indicate hotter, drier summers for much of Scotland by the 2050s, potentially leading to an increase in periods of water scarcity
- The summer of 2014 resulted in moderate water deficit conditions in the Clyde region
- There is currently no observable trend in summer low flows

Latest Figure

	No. of Area Advisory Group regions per condition class		
Low flow index	**Alert**	**Mod. deficit**	**Signif. deficit**
Summer 30 day*	5	1	0
Summer 90 day**	1	0	0

*1st August 2014
** 1st September 2014

Trend

No observable trend

Why is this indicator important?

Despite generally being considered a wet country, Scotland can be vulnerable to prolonged periods of dry weather, which can result in pressure upon the environment and water users in some areas

(SEPA, 2014). In some regions of the country, particularly in the North and West Highlands, water supply sources have relatively little storage capacity in comparison to the larger supply sources of the Central Belt. This makes the task of maintaining the public water supply without resorting to special measures more vulnerable to the types of dry summer episodes highlighted by this indicator.

Whilst the ecology of rivers can generally adapt to a natural range of conditions and water levels, prolonged dry periods can lead to detrimental impacts on the environment. Aquatic ecology can be vulnerable to low flows in summer when water temperature is at its highest and wetted habitat space and dissolved oxygen are at their lowest. During low flow events, there is reduced dilution capacity in rivers and, as a consequence, the concentrations of pollutants can increase markedly. As river levels drop, changes in flow may fragment the river and reduce suitable habitat space. A low flow in a river may also prevent migratory fish from moving upstream and disrupt food supplies by impacting on aquatic invertebrates (SEPA, 2014).

Climate change projections indicate hotter, drier summers for much of Scotland by the 2050s, potentially leading to an increase in periods of water scarcity.

Analysis of historical drought impacts in Scotland indicates that it is departure from normal rather than changes in absolute water supply that determines whether water scarcity impacts occur (Gosling, 2014). Water scarcity indices provide a measure of how exceptional a period is in comparison to a long term average. In order to improve their ability to plan for and respond to water scarcity events, SEPA utilise a number of measures to monitor conditions across Scotland (SEPA, 2014). This indicator draws upon analysis of low flow events in Scotland's rivers as defined by the Normalised Flow Index (NFI). This measures how much the flow over a 30 or 90 day period deviates from the long term average.

The two time periods are presented in order to assess the different drought types that can impact water resources in Scotland (both acute and chronic). In regions with little storage capacity, risk of water supply and environmental impacts may best be indicated by one month duration, whereas regions with significant storage are likely to be more vulnerable to anomalies of a longer duration (Gosling, 2014).

Related indicators:
NA13 Abstraction of water for irrigation
NB33 Progress towards the environmental objectives of the River Basin Management Plans
BW7 Customers and zones vulnerable to supply deficit

What is happening now?

Figures 1 and 2, and Table 1, show the low flow situation during summer 2014. The summer 30-day NFI showed that there were mild low flow conditions across much of the country with the largest deficit occurring in the Clyde region. The 90-day index illustrates the longer term situation across June, July and August. Again, although not particularly severe, the Clyde experienced the lowest flows relative to the long-term average.

Table 1 Condition classes for 30-day (1st August 2014) and 90-day (1st September 2014) low flow indices (NFI) for SEPA Area Advisory Group regions

	NFI condition class (low flow severity level)									
	No deficit		Early Warning		Alert		Moderate deficit		Significant deficit	
Area Advisory Group region	**30-day**	**90-day**	**30-day**	**90-day**	**30-day**	**90-day**	**30-day**	**90-day**	**30-day**	**90-day**
Argyll										
Clyde										
Forth										
N -Highland										
N-E Highland										
Solway Tweed										
Tay										
W - Highland										
Orkney and Shetland										

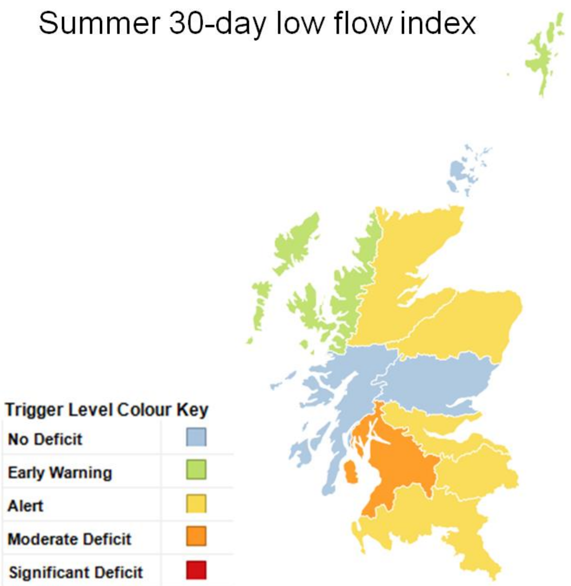

Figure 1 The 30-day low flow index (NFI) for SEPA Area Advisory Groups on 1st August 2014

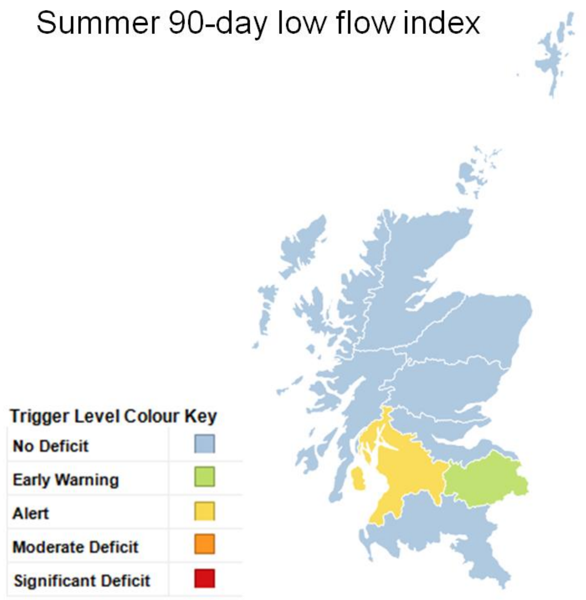

Figure 2 The 90-day low flow index (NFI) for SEPA Area Advisory Groups on 1st September 2014

What has happened in the past?

Over the period 1981 to 2014, there has been very little evidence of any trends in the severity of summer low flow events (Tables 2 and 3). Only one gauging station (in Argyll) has shown a significant increase in the severity of 30-day summer low flow events. As for the 90-day index, nine stations have shown a trend of decreasing severity of these longer duration summer low flows but the majority indicate no trend.

Table 2 Changes in severity of summer 30 day low flow events by SEPA Area Advisory Group between 1981 and 2014. Numbers refer to number of gauging stations in each category.

Area	No trend	More severe	Less severe
Argyll	32	1	0
Clyde	3	0	0
Forth	24	0	0
N -Highland	13	0	0
N-E Highland	24	0	0
Solway Tweed	40	0	0
Tay	7	0	0
W - Highland	3	0	0
Orkney and Shetland	No data	No data	No data
Grand total	**146**	**1**	**0**

Table 3 Changes in severity of summer 90 day low flow events by SEPA Area Advisory Group between 1981 and 2014. Numbers refer to number of gauging stations in each category.

Area	No trend	More severe	Less severe
Argyll	31	0	2
Clyde	3	0	0
Forth	18	0	6
N -Highland	13	0	0
N-E Highland	24	0	0
Solway	40	0	0
Tay	6	0	1
W - Highland	3	0	0
Orkney and Shetland	No data	No data	No data
Grand total	**138**	**0**	**9**

What is projected to happen in the future?

Using the UKCP09 climate model outputs as inputs to rainfall-runoff models it has been shown that reductions in summer flows are projected across many of Scotland's rivers by 2050 (Haxton et al., 2012). These flows have been used to project changes in the indices of low flow events presented here i.e. the 30 and 90-day normalised flow indices (Gosling 2014). These results indicate a projected increase in severity and frequency of summer and autumn low flow events. Exceptional summer low flow events with a return period of 1 in 40 years for the current baseline period (1961-90) are projected to have median return periods as low as 1 in 9 years by the 2050s.

Patterns of change

Regional patterns are presented in Figures 1 and 2 and Tables 2 and 3. Over the summer of 2014, the Clyde region experienced the lowest flows relative to the long-term average.

Interpretation of indicator trends

The lack of observable trend in historical records of summer low flows may not contradict the projected changes in flows implied by UKCP09. Several studies have recently shown that, given the rate at which climate is expected to change and given the high natural variability of the maritime climate of the UK, it may not be possible to detect climate change in river flows for some time to come (Fowler et al., 2010; Radziejewski & Kundzewicz, 2004).

Limitations

The indices are only calculable at gauging stations measuring near natural flows and which have a long period of record. There are 147 such stations covering the period 1981 to present day. In some areas such as the North West Highlands there are few gauging stations which fit these criteria and there are none in Orkney and Shetland. For assessing trends over a longer period, fewer records are available. Shorter record lengths inhibit the ability to detect statistically significant trends in the flow data which have high year on year variability. Having said this, 147 gauging stations with records longer than 30 years provides a good base for detecting trends in the future.

References

Fowler, H. J., Wilby, R. L., Cooley, D., Sain, S. R. & Thurston, M. (2010) Detecting changes in UK precipitation extremes using climate model projections: Implications for managing

fluvial flood risk. *Proceedings of the Third BHS International Symposium,* Newcastle University, UK, July 2010.

Gosling, R. (2014) Assessing the impact of projected climate change on drought vulnerability in Scotland. *Hydrology Research* **45** (6), 806-815

Haxton, T., Crooks, S., Jackson, C. R., Barkwith, A. K. A. P., Kelvin, J., Williamson, J., Mackay, J. D., Wang, L., Davies, H., Young, A. & Prudhomme, C. (2012) *Future Flows Hydrology.* Available at http://dx.doi.org/10.5285/f3723162-4fed-4d9d-92c6-dd17412fa37b.

Radziejewski, M. & Kundzewicz, Z. W. (2004) Detectability of changes in hydrological records. *Hydrological Sciences Journal* 49 (1), 39–51.

SEPA (2014) *Scotland's National Water Scarcity Plan* (Consultation document Dec 2014). Available online at: *https://consultation.sepa.org.uk/water-unit/water-scarcity-plan/supporting_documents/Consultation%20Scotlands%20National%20Water%20Scarcity%20Plan.pdf*

Further information

Scotland's National Water Scarcity Plan (consultation document)
https://consultation.sepa.org.uk/water-unit/water-scarcity-plan/supporting_documents/Consultation%20Scotlands%20National%20Water%20Scarcity%20Plan.pdf

Acknowledgements

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Appendix One: Indicator metadata and methodology

Table 1: Indicator metadata

	Metadata
Title of the indicator	NB27 Summer low flow events in Scottish rivers (Normalised Flow Index)
Indicator contact: Organisation or individual/s responsible for the indicator	Anna Moss (CXC, University of Dundee)
Indicator data source	SEPA flow gauging station data. The indicators are based upon daily mean flow times series for 147 sites across Scotland
Data link: URL for retrieving the indicator primary indicator data.	The flow and indices data are not currently available online

Table 2: Indicator data

	Indicator data
Temporal coverage: Start and end dates, identifying any significant data gaps.	The indices presented here run from 1981 to 2014
Frequency of updates: Planned or potential updates	Annually during October
Spatial coverage: Maximum area for which data is available	The data cover all areas of Scotland with the exception of Orkney and Shetland
Uncertainties: Uncertainty issues arising from e.g. data collection, aggregation of data, data gaps	Values for the regions (Area Advisory Group areas) are derived from a selection of gauging stations measuring near natural flows. Some areas have few of these sites, notably West Highland and Clyde regions and the level of uncertainty may be assumed to be highest in these regions as a result.
Spatial resolution: Scale/unit for which data is collected	SEPA Area Advisory Groups
Categorical resolution: Potential for disaggregation of data into categories	For each gauging station flow time series, indices are calculated as a numerical value. These have been catergorised into severity classes at the regional level
Data accessibility: Restrictions on usage, relevant terms & conditions	See SEPA general terms and conditions of use of data

Table 3 Contributing data sources

Contributing data sources Data sets used to create the indicator data, the organisation responsible for them and any URLs which provide access to the data.
None other than the SEPA flow gauging station daily mean flow data.

Table 4 Indicator methodology

Indicator methodology

The methodology used to create the indicator data

The NFI is a particular version of standardised anomaly where the flow data are transformed assuming they fit a Log-normal distribution, As such the anomaly or Z score becomes:

Z score = (Average of logged values- ln(X)) / Standard deviation of logged sample

The values being the daily mean flows for a gauging station record over either a 30 or 90 day duration.

For example, a 90-day NFI reported on the first day of July would be calculated by first evaluating the anomaly between the logged mean flow from the recent 90 day period from April to June and the logged mean flow of all the periods from April to June averaged over the long-term record. This anomaly is then normalised by the standard deviation of the logged mean April to June mean flows over the long-term record.

This approach has been previously applied by Zaidman et al. (2002) and Shukla and Wood (2008) amongst others.

The index values have been categorised into 6 classes as shown in the table below

Condition	NFI
No deficit	<0.25
Early warning	0.25
Alert	0.5
Moderate deficit	1.0
Significant deficit	2.0
Extreme deficit	2.5

A set of criteria are used to determine the appropriate category for a particular region. These criteria stipulate that the relevant class is the one in which at least 50% of gauging stations are in that class and, of the remainder, at least 50% are in the preceding class.