A proposal for amending the Poor and Bad status environmental river flow standards at medium and high flows.

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1 Background

1.1 The environmental standards for river flows were developed from work undertaken by SNIFFER profect WFD48 . The environmental standards were developed in order to assess the risk to ecological status posed by alterations in flows across the flow regime. The study was not remitted to consider Heavily Modified Water Bodies where flow was regulated. As a consequence the standards produced did address impacts where the scale of the flow regime was altered i.e. from abstractions, but did not explicitly address situations where the pattern of the flow regime was altered through flow regulation. The project did highlight however that it would not make sense to define different sets of standards for abstractions and releases from impoundments. This point was recognised during the development of the condition limits for managed flows (UKTAG 2007) which aimed to supplement and not conflict with the environmental flow standards. It may be concluded that, in the development of the river flow standards, greater consideration was given to their application in situations where abstractions impact across the entire flow regime or at low flows, than in situations where abstractions only occur at high flows.

1.2 Environmental standards for flows have been defined for all five ecological status classes although, under the Water Framework Directive (European Commission 2000), hydrology is stipulated as a determinant of ecological status only at High status. For other status classes, hydrology can be used as supporting evidence. Nevertheless, in order for this evidence to be of use, the flow environmental standards should best reflect ecological status as defined in Annex V or the Water Framework Directive.

2 The basis for reviewing the hydrology river flow standards.

2.1 The existing environmental standards for river flows were published in 2007 and subsequently have been used by the UK environment agencies for water body classification and regulation of activities for a number of years. There now exists an opportunity to review the operation of the flow standards in comparison with other environmental standards as well as from practitioner's experience.

2.2 As will be shown in section 3, both anecdotal evidence from practitioners using the flow standards and evidence from a comparison between status classes resulting from hydrology and biological quality elements assessments have indicated that the mid and high flow hydrology environmental standards appear to require some revision.

2.3 It is also possible to review the evidence base upon which an understanding of the relationship between flow and aquatic ecology stands. For both the literature preceeding and succeeding the phase 2 development of the environmental standards for hydrology, the importance of a maintainence of low flows for supporting aquatic ecosystems has been highlighted (Mainstone 2010) . For example, in Dried Up 3 (Dunbar *et al* 2010), a significant relationship between summer Q95 and autumn LIFE (Lotic invertebrate Index for Flow Evaluation)

score has been identified (Figure 1). It is shown that reductions in the mean summer Q95 of between 10 and 30% are correlated with reductions in rheophilic (thriving on flow variability) taxa in the subsequent autumn.

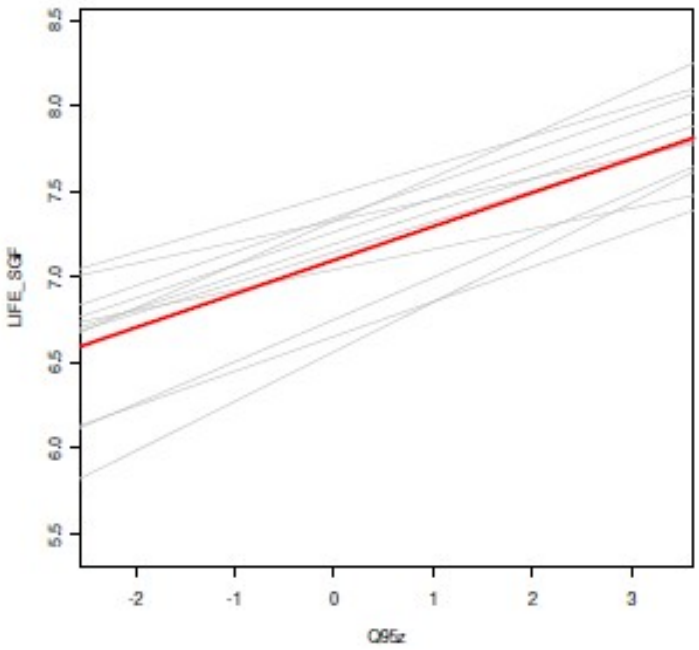

Figure 1 Mean relationship (red line) and predicted relationships for individual sites (grey lines) for multilevel model with Q95 as predictor of autumn LIFE score (from DRIED-UP 2 Dunbar et al 2009 p.21)

2.4 It is felt that the findings of the Dried Up project do not contradict the expert judgement in WFD48 which developed the existing flow standards at low flows and as such there is no proposal to revise these standards

3 An examination of the evidence base for impacted high flows resulting in Poor and Bad status.

3.1 In Annex V of the Water Framework Directive the following definitions are given for Poor and Bad ecological status

Waters showing evidence of major alterations to the values of the biological quality elements for the surface water body type and in which the relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions, shall be classified as poor.

Waters showing evidence of severe alterations to the values of the biological quality elements for the surface water body type and in which large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent, shall be classified as bad.

(European Commission 2000, p38)

3.2 It is clear from these definitions that if a hydrological impact results in Poor or Bad status, there should be some ecological evidence of at least a major alteration in

biological quality elements and, in the case of bad status, evidence of missing portions of biological communities e.g. the absence of expected species.

3.3 In a review of Environmental Flow Indicators (EFIs) undertaken for the Environment Agency of England and Wales (Atkins 2010), a view expressed by practitioners using the EFIs (based upon flow standards thresholds) was that the thresholds were unnecessarily constraining at high flows, that is, the flow standards seemed to indicate a greater impact at high flows than were apparent from the ecological indicators. Similar feedback has been received from SEPA practitioners.

3.4 As well as anecdotal evidence it has been possible to examine the 2009 classification results from each of the UK environment agencies to see if any evidence exists that breaches of the hydrology environmental standards at high flows are reflected in impacts on the biological quality elements.

3.5 To carry out this analysis the following rules have been applied:

3.5.1 Waterbodies which have been classified as less than Good status for physico-chemical quality elements have been excluded to ensure that flow impacts alone are considered.

3.5.2 Since the aim was to identifiy the possible occurrence of Poor or Bad status, the lowest ecological status of all biological quality elements has been used, rather than those judged to be most sensitive to flow. This represents a conservative estimate of status due to flow impacts.

3.5.3 In order to attempt a verification of the higher flow environmental standards, the comparison of biology and hydrology classification was undertaken on those waterbodies which only failed Good hydrology status at flows greater than Q95 (tables 1, 2 and 3).

3.5.4 Since the Environment Agency do not classify hydrology status below Good, The environmental flow indicator compliance bands 1, 2 and 3 have been used instead of Moderate, Poor and Bad. The results presented here have been derived from the national river waterbody classification database for England and Wales, however it is unlikely that all relevant waterbodies have been captured in this table. Further analysis may be possible if local data become available.

Numbers of waterbodies		Hydrology Classification		
		EFI Band 1	EFI Band 2	EFI Band 3
Biology Classification	High			
	Good			
	Moderate	1	3	1
	Poor			
	Bad			

Table 1. Environment Agency waterbody classification. A comparison of hydrology and biology classifications for flows impacted only above Q95

Numbers of waterbodies		Hydrology Classification		
		Moderate	Poor	Bad
Biology Classification	High	1		
	Good	1		1
	Moderate			
	Poor			
	Bad			

Table 2. Northern Ireland Environment Agency waterbody classification. A comparison of hydrology and biology classifications for flows impacted only above Q95

Numbers of waterbodies		Hydrology Classification		
		Moderate	Poor	Bad
Biology Classification	High	20	19	9
	Good	10	6	3
	Moderate	14	7	1
	Poor		1	
	Bad			

Table 3. Scottish Environment Protection Agency waterbody classification. A comparison of hydrology and biology classifications for flows impacted only above Q95

3.6 It is clear from these tables that relatively few waterbodies exist where hydrology classification indicates a failure of the flow standards at higher flows but not low flows. However, where these situations do occur, there is evidence of only 1 waterbody where the biological quality elements indicate less than Moderate status.

3.7 In comparison, a total of 36 waterbodies have been classified as Poor (or Band 2 non-compliant) and 15 waterbodies as Bad (or Band 3 non-compliant) for Hydrology.

3.8 Three possible conclusions can be drawn from this analysis:

3.8.1 It could be concluded that the hydrology classification is incorrect and an impact at high flows is classified where it does not occur. This conclusion is unlikely to explain the mismatch since the waterbodies addressed in this analysis are almost exclusively Heavily Modified Waterbodies for flow regulation. As such, the nature of their operation makes impacts at high flows almost inevitable.

3.8.2 It could be concluded that the combined classification of biological quality elements does not reflect real ecological impacts due to changes in flow. The difficulty in employing a biological index which is truly sensitive to flow alterations is well known. In particular it is realised that the biological indices used do not directly take account of loss of habitat space, rather the changes in expected species composition. Arguably the most sensitive index is the LIFE score used by the Environment Agency yet none of the 4 waterbodies which are less than Band 1 compliant is less than Moderate status for LIFE score. Furthermore, it should be expected that, since the definition of Bad

status requires such a major impact on biological communities, some evidence of major ecological impact should be evident.

3.8.3 It could be concluded that the hydrology environmental standards at high flows overestimate the biological impact. In order to understand whether this satisfactorily explains this mismatch it is necessary to consider the ecological responses that may be expected from impacts at higher flows and consider these alongside the definitions of Poor and Bad status.

4 Ecological responses to impacts at mid and high flows

4.1 There is a wide range of literature which addresses the ecological repsonses to flow alterations. In the DRIED-UP project (Environment Agency 2009) which examined LIFE score responses to variations in Q10 and Q95 it was shown that an effect on the biological indicators could be discerned in response to changes in both low and high flows.

4.2 The ecological impacts caused by reductions in mid flows can be expected to be a loss in habitiat space and a prolonging of low flows. The impact of a reduction in mid flows on the average duration of the low flow period can be demonstrated using flow data collected at hydrology gauging stations (figure 2)

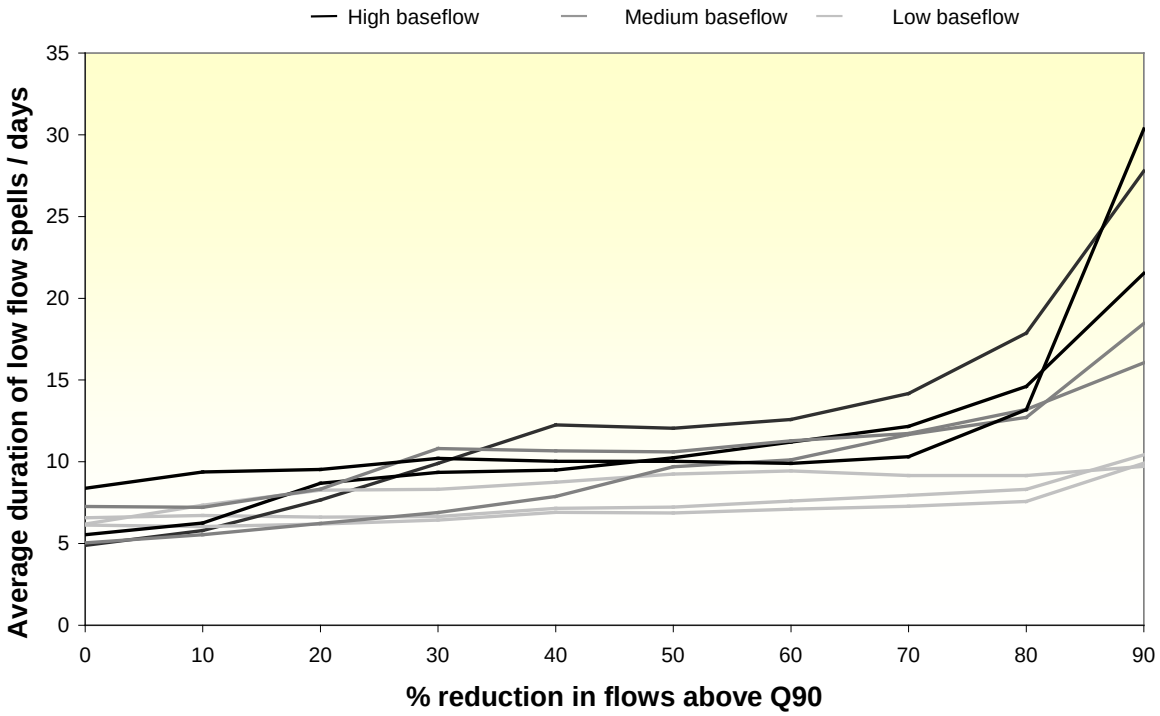

Figure 2. The increase in mean duration of low flow spells (flows < Q90) with percentage reduction in flows above Q90 for 8 SEPA gauging station records. Stations are grouped by baseflow index (BFI) where low is <0.35, medium is 0.35 to 0.45 and high is > 0.45

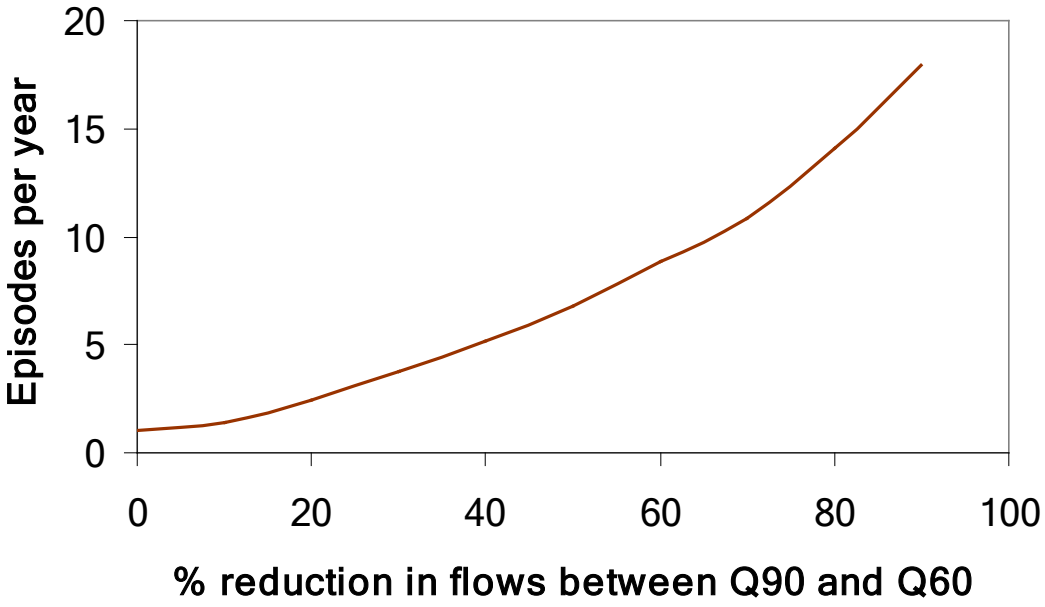

Figure 3 The impact of a reduction in mid range flows upon the number of low flow episodes. The curve represents the mean of 8 sites. A low flow episode is taken as an event where the duration equals or exceeds the duration of a natural low flow event with a 1 year return period.

4.3 It may also be helpful to examine the increased frequency of a natural low flow event caused by a reduction in mid range flows. Figure 3 shows that a low flow episode which, in an unimpacted stream, has a return period of 1 year could become 10 times more frequent as mid-range flows reduce by 60%.

4.4 In a review of the evidence base for setting flow targets to protect river habitats undertaken by Natural England, it has been shown that the prolonging of low flow periods can lead to the reduction of plant species diversity, a concentration of aquatic species, a desertification of riparian species composition and reduced plant growth and increased mortality due to stress (Mainstone 2011).

4.5 In figures 2 and 3, a low flow has been defined as Q90 although the definition of what constitutes a low flow period is somewhat subjective. There is evidence to suggest that, when considering the sensitivity of hydraulic properties such as wetted width, flows below Q95 are typically more sensitive to flow change than higher flows (e.g. RAPHSA, Rapid Assessment of Physical Habitat Sensitivity to Abstraction, Booker and Acreman 2007) and provides a reasonable distinction between low and high flows. However, beyond habitiat space as measured by wetted width there are minimum habitat requirements for some species which would indicate a higher low flow definition. Using weighted useable area as a measure of habitat suitability for salmonids it can be shown that the rate of change of habitat value with increasing flow may not begin to tail off until flows somewhat higher than Q95 (Figure 4)

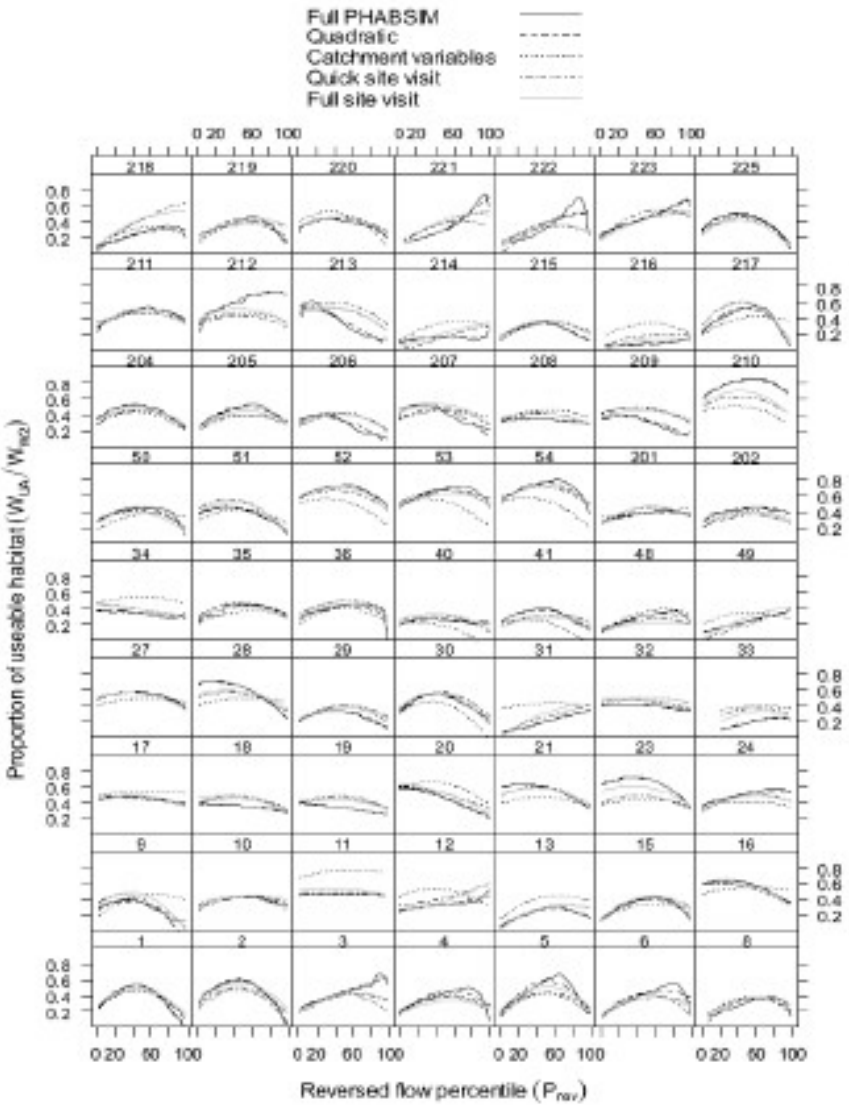

Figure 4 Habitat-discharge relationships for juvenile Atlantic salmon in a range of UK sites, using different levels of catchment and site information (from Booker and Acreman 2007)

4.6 The ecological processes impacted by reductions in high flows typically revolve around loss of stream energy and, in turn, reduced bed load mobility and increased sediment deposition. Added to this, reduced high flows can impact on river-floodplain connectivity affecting marginal habitats. Reductions in the frequency and timing of high flow events will also impact migratory fish, with disrupted migration cues along with impacts on spawning habitats.

4.7 The response to a loss of mid and high flows will be a shift from lotic (flow) to lentic (stillwater) species within macroinvertebrate communities and it is this shift which the LIFE score is designed to pick up. From the evidence presented here, along with evidence emerging from studies being undertaken downstream of impounded rivers in Scotland it seems that, although a shift from lotic to lentic composition is evident, there is little evidence of a significant absence of portions of biological communities where low flows are sustained.

4.8 In the waterbodies analysed here, where impacts only occur at flows above Q95, there is one waterbody in the UK which is classified as less than Moderate status using the biological quality elements. On further analysis, this waterbody reaches the Poor hydrology standard at Q70 and, as such, there is no biological evidence of any waterbodies in the UK falling below Moderate status when flows are only impacted above Q70

5 Recommendations for the revision of mid and high flow environmental standards

5.1 The purpose of the hydrology environmental strandards, with the exception of High ecological status, is to provide supporting evidence to the biological quality elements for the determination of ecological status.

5.2 Evidence has been presented here which suggests that, at mid to high flows there is little verification that the existing hydrology environmental standards support the ecological classification of Poor and Bad status.

5.3 It is clear that a reduction in high flows alone will have some impact upon biological communities with an exanding niche favouring lentic species at the expense of lotic species. However, it is not clear that such an impact, where low and mid flows (below Q60) are maintained, will lead to a major alteration in biological quality elements and a substantial deviation in expected biological communities.

5.4 **It is recommended that, for flows above Q60, the flow environmental standards are not used to support the indication of ecological status below Moderate status.**

5.5 There is a little more evidence, both empirically and conceptually that, where both high and mid flows are impacted, a substantial deviation in expected biological communities may occur. It has been shown that where flows above Q70 are impacted there is one case of Poor ecological status as determined by the biological quality elements. In addition, it can be shown that a reduction in flows above Q90, if great enough, can lead to a substantial elongation of low flow periods, which is associated with a number of ecological impacts.

5.6 **It is recommended that, for flows between Q90 and Q60, the flow environmental standards are not used to support the indication of ecological status below Poor status.**

5.7 The analysis of the impact upon the mean duration of low flow period caused by a reduction in flows above Q90 has indicated that there is a gradual increase up to around 60% reduction beyond which the rate of increase in low flow duration rises rapidly (figure 2). In the absence of generic relationships between physical habitat and flow for broad river typologies, the impact on low flow duration may serve as a method for characterising some element of ecological impact. Reductions of flow greater than 60% appear to indicate a major alteration to the length of low flow periods and, as a consequence, the ecological impacts associated with prolonged low flows. Figure 3 expresses this impact in a different way, showing that the frequency of an event to which species have adapted on the basis of an expected annual occurance may increase by an order of magnitude with flow reductions of 60%.

5.8 The sensitivity of length of low flow period to reduction in mid range flows is dependent upon the gradient of the flow duration curve, with flatter, higher baseflow river types being more sensitive to flow reductions than flashier, lower baseflow types. However, the existing river typologies generally assume greater sensitivity to flow reduction in flashier rivers as those communities with a greater rheophillic character are assumed to more sensitive to flow changes (Mainstone 2011). However Dunbar *et al.* 2010 noted a difference in the response of macroinvertebrate LIFE score to flow between upland and lowland rivers, with scores from routine monitoring being more affected by low flow conditions in lowland rivers. Generalising the sensitivity of ecology in different river types to flow changes is a challenge and it is quite possible that different orders of sensitivity can be found across river types at different parts of the flow regime.

5.9 **It is recommended that, for flows between Q90 and Q60, the Moderate/Poor threshold is set at 60%**

6 The impact of the proposed changes on waterbody classification

6.1 The proposed revisions to the river hydrology environmental standards do not affect the High and Good status thresholds. Since both the Environment Agency and the NIEA do not use the hydrology standards to classify the ecological status of waterbodies below Good status, these proposals would not impact upon the ecological status classifications in England, Wales and Northern Ireland.

6.2 Having said this, the standards are used in some form or other in all agencies to support the regulation of new activities, in particular, for balancing environmental risk against socio-economic benefit. The revisions will have some impact on the assessment of new schemes with low flow provisions e.g. flow regulation with compensation flow and run of river hydropower schemes with hands off flows. For such schemes, the impact of the revisions will be, in some cases, a reduction in the assessed risk they pose to the water environment.

6.3 In Scotland, the Hydrology classification is used to support the ecological status classification where water resource pressures exists since the ecological classification tools are currently insufficiently sensitive to flow pressures. As a result, these changes will potentially alter the assessment of ecological status class below Good status in Scotland.

6.4 The proposed revisions to the flow standards take effect at flows above Q90. Consequently the revisons will affect the classification of those waterbodies which have a protected low flow and impacted medium and high flows e.g. rivers downstream of flow regulation or hands-off flow conditions.

6.5 Figure 5 indicates the changes to the 2009 Hydrology classification in Scotland (2394 waterbodies). As pointed out above, the changes do not affect those waterbodies classified as High or Good status and consequently these are not presented in figure 5.

6.6 Unsurprisingly the revisions results in a direction of travel from lower to higher status classes. Broadly speaking, the revisions result in a raised status for 30% of Poor and 20% of Bad status waterbodies.

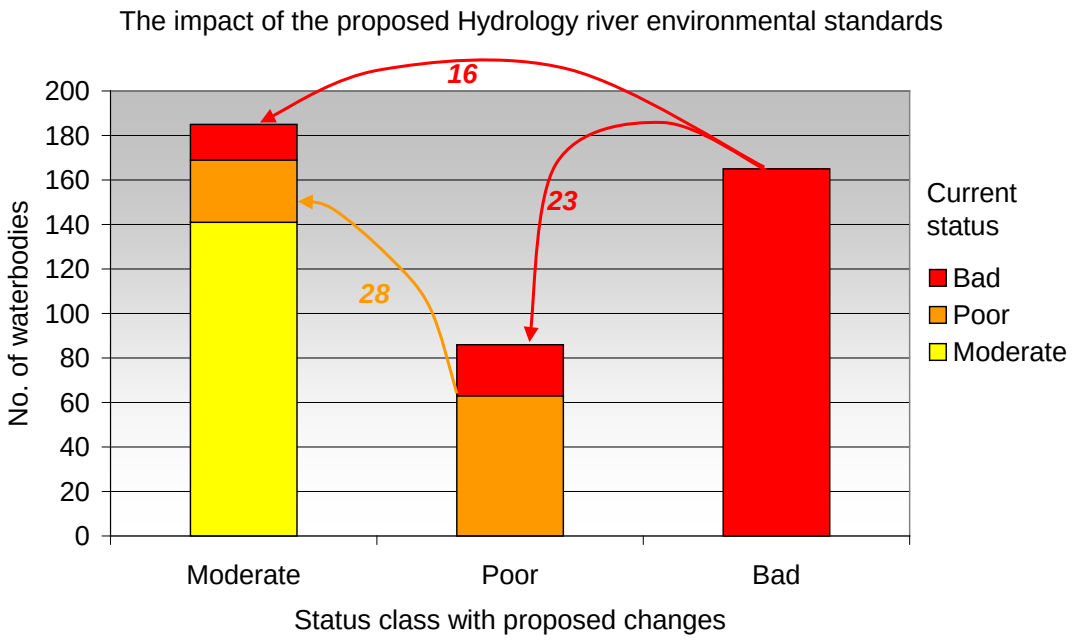

Figure 5. The impact of the proposed changes to high/medium flow hydrology environmental standards to Scotland's 2009 hydrology classification. Note: there are no changes on waterbodies currently classified as High or Good

6.7 A judgement of the consequences of these proposed changes will, ulitimately, be based upon whether they better account for the impacts on aquatic ecology caused by flow alteration. A relaxation of the environmental standards such as is proposed may result in a lower level of environmental protection if the standards do not improve the assessment of ecological status. Equally, standards which over-estimate ecological damage may also be to the detriment of environmental protection in that they do not facilitate a risk-based approach to environmental improvement.

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