Army Basing Programme – Groundwater Model Update:
Briefing note on Groundwater Model Scenario Output

1. Background

Amec Foster Wheeler has received a request from the DIO to run the Wessex Basin Groundwater Model (WBM) for a number of scenarios relating to the differing options for abstraction and discharge from the Larkhill, Upavon and Bulford Camps as part of the Army Basing Programme (ABP). These runs are summarised in **Section 2** and were agreed in consultation with the Environment Agency *(35647d077_DIO Model Runs_Agreed Rates_for GWABS_Leakage_STW SWDIS.xlsx)* on 1 December 2015.

This Briefing note is the third issued for groundwater modelling work related to ABP. The first two being:

- Wessex Basin Groundwater Model – Scenario Runs for the Defence Infrastructure Organisation (DIO) – September 2014 (35647tn025i2) which formed Technical Appendix 9A of the Masterplan EIA; and
- Wessex Basin Groundwater Model – Larkhill and Bulford Discharge Options – March 2015 (35647g058) which included initial thoughts on the Water Resources implications of differing sewage treatment discharge locations and rates as part of the ABP.

This Briefing note (35647tn025i1 – January 2016) provides details on a further set of runs which include up to date information on abstraction and discharge rates at MoD sites across the Hampshire Avon CAMS area and further optioneering around ABP abstraction and discharge rates and locations. The base model run also includes the latest agreements on the Sustainability Reductions undertaken by Wessex Water.

Section 2 outlines the model updates undertaken and the scenarios that have been run.

Section 3 discusses the scenario results and **Section 4** provides a brief summary.

At the end of this note, a series of draft figures are presented and the following text makes reference to these figures. This Briefing note is designed to support ongoing planning applications and the Water Management Strategy for the MoD sites across Salisbury Plain that is being produced by Kelda Water and WSP.

It is therefore assumed that the reader is aware of the overarching work and the ABP as well as being familiar with the concepts behind the Water Framework Directive (WFD) Review of Consents (RoC) and associated Environmental Flow Indicators (EFIs).

Throughout this document the term '**Full Licence**' should be read to include MoD abstractions even though they are not yet licensed.

2. Model Setup

Figures 1-3 contain the locations of the features mentioned throughout this note, in particular the water resources arrangements at Upavon, Larkhill and Bulford Camps.

The following work has been undertaken on the Groundwater Model as part of this most recent update:

- Made small amendments to existing artificial influences e.g. inserted Tilshead STW (previously omitted in error) and correctly located the Knook Camp discharge point;
- Introduced small 'farm' abstractions across SPTA;
- Included in the Full Licence runs the latest agreements on the Wessex Water Sustainability Reductions;
- Updated Tidworth abstraction rates, leakage rates & discharge rates based on information provided by the Environment Agency; and
- Updated MoD discharge rates, leakage rates and abstraction rates as supplied by Kelda. **Note that this included increasing discharges with the move from Recent Actual to Full Licence** (previous modelling had taken the conservative approach of increasing abstractions but not discharges). Leakage was not increased with abstraction as this is perceived to be a function of fully saturated pipe pressure (which would not change with increased consumption).

Details of the abstraction and discharge arrangements at Upavon, Larkhill and Bulford are provided in **Table 1**. The other changes made to abstraction and discharges as part of this work are as agreed by the DIO, Kelda Water, Wessex Water and the Environment Agency (email reference '35647d081_Wessex Basin Groundwater Model Runs - Update on Artificial Influences' – dated 1 December 2015).

The following runs were undertaken as part of this update:

- **(Run 251 remains the Natural Run against which other runs are compared)**
- Run 295 – updated Recent Actual (RA). **Note that the RA has not been altered to take account of Wessex Sustainability Reductions and so it is possible that abstraction in the RA is greater than in the FL at certain locations/times. This is not important for the ABP analysis, but care should be taking in using this run for other 'non MoD-ABP' analysis.**
- Run 296 – updated Full Licence (FL)
- Run 297 – updated Full Licence + Army Basing*
- Run 298 – as per Run 297 but with Bulford abstraction turned off
- Run 299 – as per Run 297 but with Larkhill abstraction turned off and Round O turned down
- Run 300 – as per Run 297 but with Bulford and Larkhill abstraction turned off and Round O turned down
- Run 301 – as per Run 297 but with Bulford and Larkhill abstractions turned down by 50% and Round O turned down by half as much as it was in Run 300

(* - As Tidworth is licensed and has available headroom between RA and FL, there is no further requirement to increase Tidworth between FL and FL+ABP even though there are Army Basing developments that will utilise abstraction from Tidworth)

Table 2 – Abstraction and Discharge Rates at ABP Locations on Salisbury Plain

Artificial Influence (values in m3/d)	Run 295	Run 296	Run 297	Run 298	Run 299	Run 300	Run 301
Upavon Abstraction (Hill and East)	251	308	326	326	326	326	326
Upavon Discharge	106	130	147	147	147	147	147
Upavon Leakage	140	140	140	140	140	140	140
Bulford Abstraction (BH1)	630	1398	1375	0	1375	0	688
Bulford Abstraction (BH2)	477	0	0	0	0	0	0
Bulford Discharge (contribution to Ratfyn above Recent Actual)	0	182	226	226	226	226	226
Bulford Leakage	376	376	376	376	376	376	376
Larkhill Abstraction	1016	1357	1357	1357	0	0	678
Round O Abstraction	652	977	1071	1071	846	846	958
Larkhill Discharge	665	934	0	0	0	0	0
Larkhill Discharge (contribution to Ratfyn)	0	0	1154	1154	1154	1154	1154
Larkhill Leakage	462	462	462	462	462	462	462
Round O Transfer Leakage	312	312	312	312	312	312	312

3. Model Output and Discussion

Figure 4 shows the in-combination modelled impact of all artificial influences compared to modelled Natural flows at Q95. Note that with the exception of a number of cells in the ephemeral reach, that the Bourne is now less than 10% impact as a result of the sustainability reductions. No further consideration of the Bourne is required at this stage. Note that the Natural flow in the Nine Mile is restricted to the last 2 model cells (a 500 m reach) and is significantly impacted by abstractions (EFI is 15% less than Natural Q95). The Till is also significantly impacted by abstraction (locally agreed RoC EFI is 10% less than Natural Q95). The impact on the Middle Avon is in parts above the locally agreed EFI (10% less than Natural Q95) but not above nationally agreed EFI (15% less than Natural Q95). **Figure 5** provides the same information but as absolute values on Ml/d.

Figure 6 provides the same detail but following the completion of the ABP. Note that at Upavon there is decrease in groundwater level at the abstraction point and an increase in groundwater level at the discharge point as would be expected. ABP impacts at Bulford are neutral as would be expected (Kelda supplied figures show abstraction at Bulford goes down from 1398 m3/d before ABP to 1375 m3/d after ABP)

The main impact of the ABP is not the increase in abstraction at Round O (977 m3/d before ABP and 1071 m3/d after ABP) or Larkhill (which remains at 1357 m3/d) but the removal of the 934 m3/d **groundwater** discharge from Larkhill STW and relocation to Ratfyn as a **surface water** discharge. The water level difference contours cover both the top of the Till and a reach of the Avon both upstream and downstream of Ratfyn STW. Therefore by comparing between Figures 4 and 6, it can be seen that flows are lower upstream of Ratfyn after ABP and higher downstream. Whilst downstream of Ratfyn the removal of Larkhill will still be 'reducing' baseflow inputs, this is counteracted and surpassed by the increased surface water discharge from the Ratfyn STW after ABP implementation. Comparison of Figures 5 and 7 show the influence of the increased discharge at Ratfyn on the modelled impact downstream of the discharge point.

Figure 8 provides the same information in accretion profile format at Q95. This clearly shows the impact of ABP switches from negative to positive (as far as flows on Avon are concerned) either side of Ratfyn STW as

would be expected. Results from Run 300 show how the in-combination impact of all abstractions at **Full Licence** would be reduced to within the national EFI for all but a short reach, were all Bulford and Larkhill supplies to be switched to Wessex Water.

Figure 9 is a set of modelled Flow Duration Curves (FDCs) upstream of the Ratfyn STW. This shows that at this point in the Avon, the removal of the Larkhill discharge has an impact of about -400m 3/d. This compares with an impact of +900 m3/d were Larkhill abstraction to be turned off. These are important considerations when contemplating any 'mitigation measures' as a result of relocation the Larkhill STW. In terms of Water Resources (though not necessarily Water Quality) the movement of discharges further downstream is likely to increase upstream abstraction impacts.

Figure 10 is a set of FDCs for Bulford on the Nine Mile. This illustrates that even turning off Bulford all together would not return flows to within 10% of the natural flows (i.e. above the green EFI line on the graph) at flows <~Q90. This is not surprising given the nearby Durrington PWS which operates at ~5 Ml/d at Full Licence and ~2.25 Ml/d at Recent Actual. This again is an important point when considering the use of water from Wessex Water (as a replacement to MoD abstraction) and how this would impact Recent Actual flow. Little would be achieved at Recent Actual if the turning off of Bulford was replaced by Durrington being increased (albeit within licence agreements) from Recent Actual towards Full Licence levels.

Figure 11 shows the same information in accretion format. Whilst Bulford has a clear impact on low flows, it is also clear that other abstractions also have an impact (e.g. Durrington). It should also be noted that the flowing section here is very short and the flows (even natural) are low.

Figure 12 looks at the number of days in which there is 'some' flow in the Nine Mile each under different scenarios. Comparison of the 2 plots on this figure highlights that there is no clear impact of ABP (compared to Full Licence)

Figure 13 illustrates that whilst Bulford has an impact on flows (in particular at the bottom of the Nine Mile) the impact, in terms of wetted stream bed does not stretch that far upstream. It is important to remember that these plots indicate the number of days in which there is some flow and not the magnitude of that flow. Nevertheless they are insightful with regard to the **modelled** conditions at the upstream ponds.

Figures 14 and **15** re-iterate previous model findings with regard to the modelled groundwater levels underneath the pond nearest to the abstraction (OMR Marsh Pond). These show that there is an impact of abstraction, but one that is focussed at the bottom of the hydrograph and hence the abstraction makes the lowest levels lower rather than significantly impacting on the duration of time (or timing) at which the groundwater levels are above the base of pond. These findings need to be considered in light of the ongoing fieldwork at the ponds. The groundwater model analysis assumes totally hydraulic connection between groundwater levels in the Chalk Aquifer and water levels in the pond. The fieldwork will highlight whether the water level in the ponds can remain perched above receding groundwater levels (e.g. due to a low permeability substrate). The investigations will additionally help determine whether the ponds fill up due to rising groundwater levels alone, or are also influenced by local surface and near surface drainage and its reaction to rainfall events.

Figure 16 shows that the model predicts that the influence of abstraction only changes the pass/fail criteria (water level >10cm above pond bottom for March-Sept) in 3 years (1989, 2000 and 2010) and that instead the impact of abstraction is for the ponds to 'fail' for slightly longer (though even that is limited to only one or two ~10 day stress periods in a given year).

Figure 17 shows the impact of abstractions and discharges on the low flows at Bury Bridge on the Till. This shows (comparison between Runs 297 and 296) that although the Larkhill discharge is nearer the Avon, and impacts the Avon more (see Figure 6), there is also an impact on the Till of relocating the Larkhill discharge. By comparing with Run 301, it can be seen that by reducing the Larkhill and Round O abstractions it is possible to 'neutralise' the impact of the relocation the sewage treatment work discharges to Ratfyn. If a mitigation measure such as this is required, the groundwater model could be used to inform/refine the decision making around proposed abstraction rates. It seems likely that reducing the Round O abstraction (which is more firmly in the Till catchment) will result in a proportionately higher flow return to the Till than will be the case with equal reductions at Larkhill (which more clearly impacts on both the Till **and** the Avon). With all these type of solutions it is important to remember that:

- the flow impact on the Till of relocating Larkhill is relatively modest at ~200 m3/d; and

- any changes need to be considered in terms of the other influences in the catchment (e.g. ~1 Ml/d ongoing abstraction at Round O and the ~2.2 Ml/d Wessex Water Abstraction at Shrewton).

Figures 18-21 illustrate the impacts of turning off (or down) the abstractions at Round O, Bulford and Larkhill on groundwater levels and hence flows in the baseflow dominated rivers.

4. Summary

The main impact of ABP is the relocation of the Larkhill sewage discharge point rather than the modest increases in abstraction that are required. The degree to which this relocation (in water quantity terms, rather than water quality) can be mitigated depends on the level to which Wessex Water supply is used to replace/supplement abstraction from the MoD boreholes.

There is nothing that surprising in any of these results and it follows that the more the MoD sites rely on existing licence volumes from Wessex Water (and the less they ask for in their own forthcoming licence discussion) the better the flows will be at **modelled** full licence conditions. However it should be remembered that this generic statement is heavily hypothetical when it comes to the more immediate impacts of ABP (and ongoing MoD abstractions) on current flows in the Avon, Till and Nine Mile. By switching to Wessex Water supplies, **recent actual flow improvements** will only be potentially achievable if the replacement water is abstracted by Wessex Water from outside the catchments of concern and moved across the Wessex Water Supply Network (i.e. the new 'Grid') to supply the camps. If the replacement water is actually sourced, albeit within existing Wessex Water licence conditions, from within the catchments (e.g. from the Shrewton or Durrington sources) at times of low flow, then **actual** flow improvements might not be readily realised.

It is therefore important that any mitigation measures and/or planning conditions in this regard remain pragmatic and achievable and do not confuse future protection of the environment under full licence conditions with nearer term improvements in ecology ('future recent actual conditions'). Clearly the move to catchment based solutions and regulation (which to date has not been enforceable due to Crown Exemption) is a step forward, though year to year ecological status will continue to be (more) strongly influenced by other external factors such as climate, river management and water quality.

Author	Reviewer
Tim Power	DRAFT – NOT FORMALLY REVIEWED

Figure 1 – Key Abstractions and Discharges

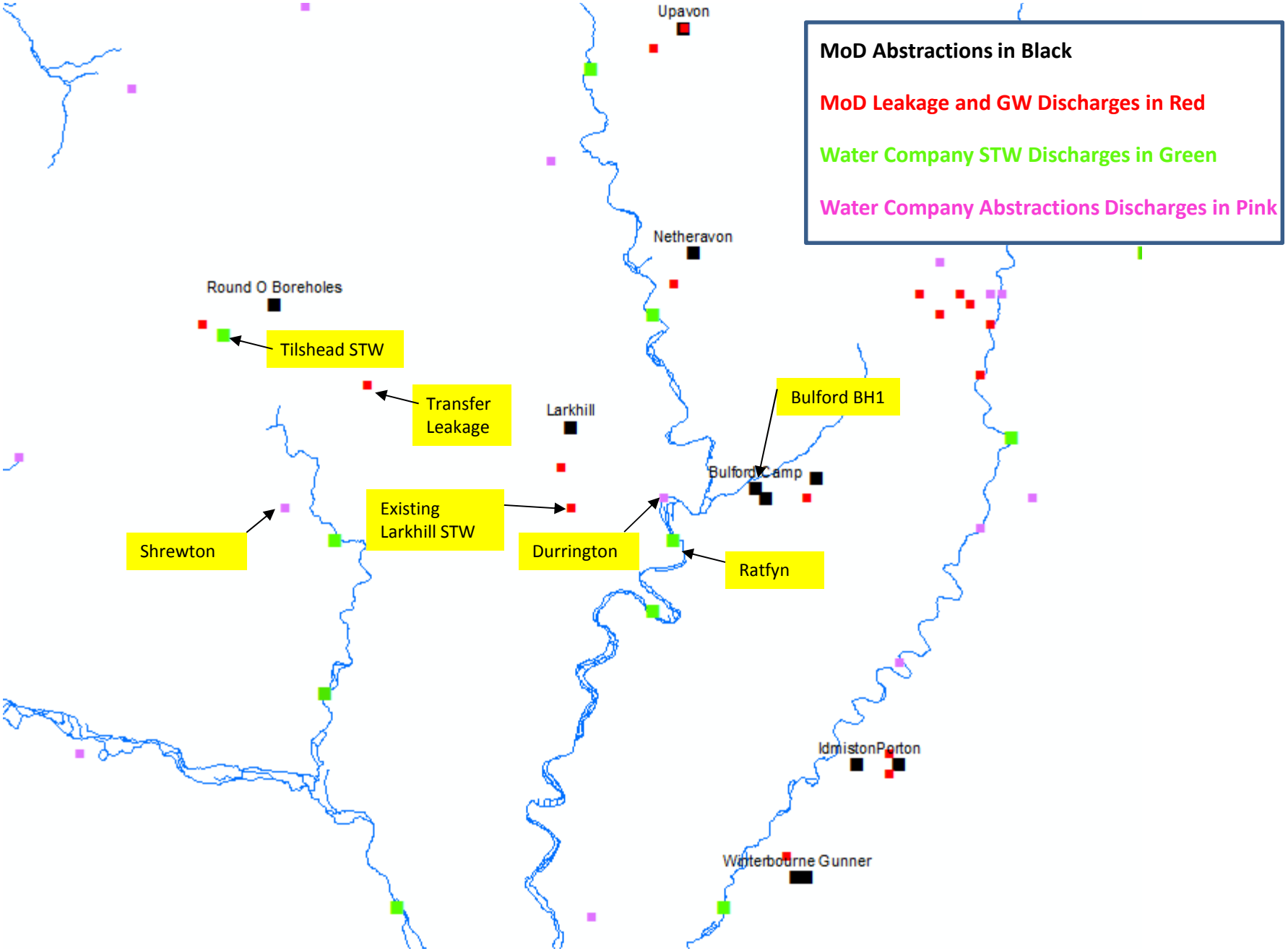


Figure 2 – Flow Comparison Locations (selected sites labelled)

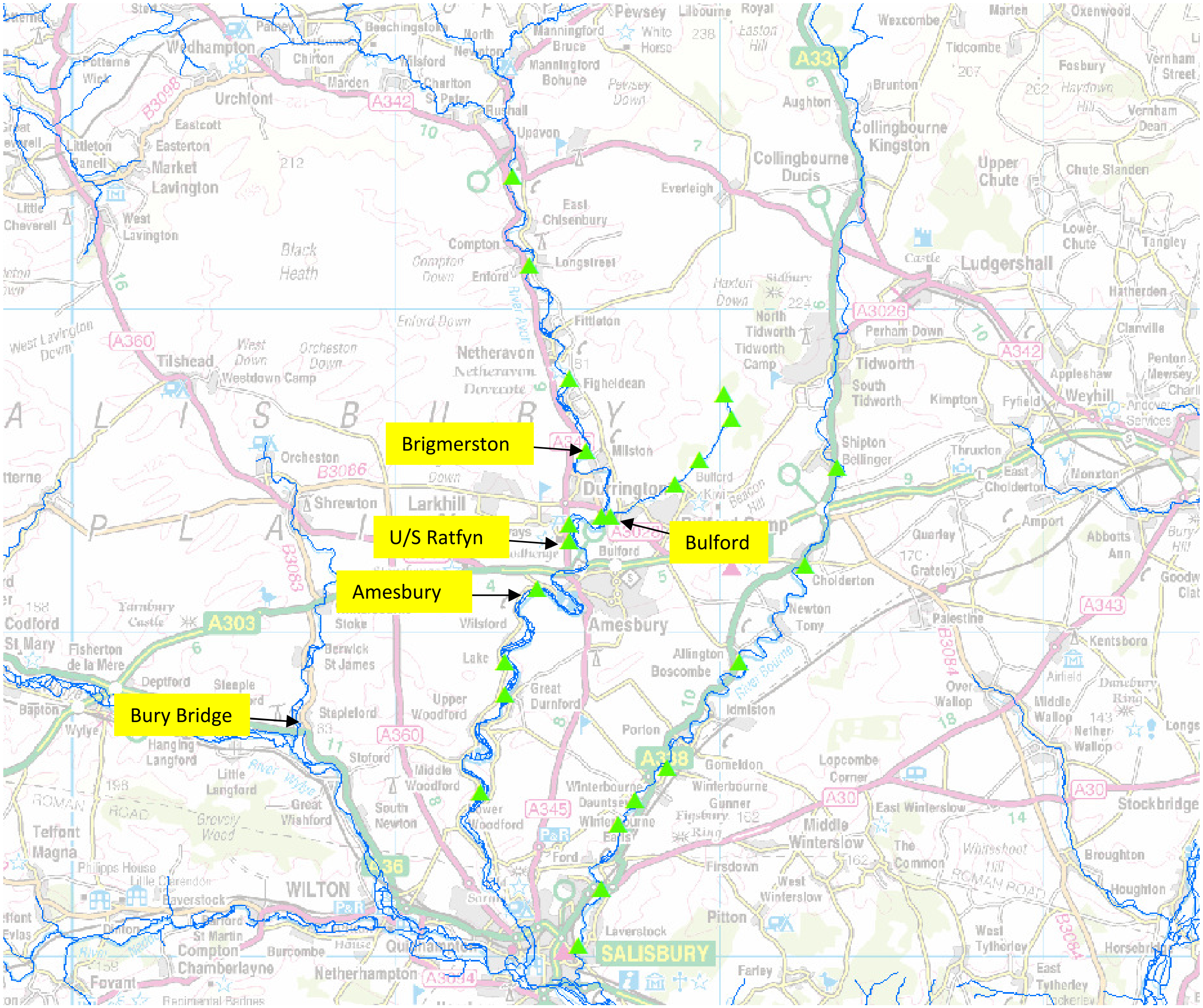


Figure 3 – Locations of ponds of ecological interest

Figure 4 – Full Licence (Run 296) Impact of abstraction as a % of Natural Flow (Run 251) at Q95

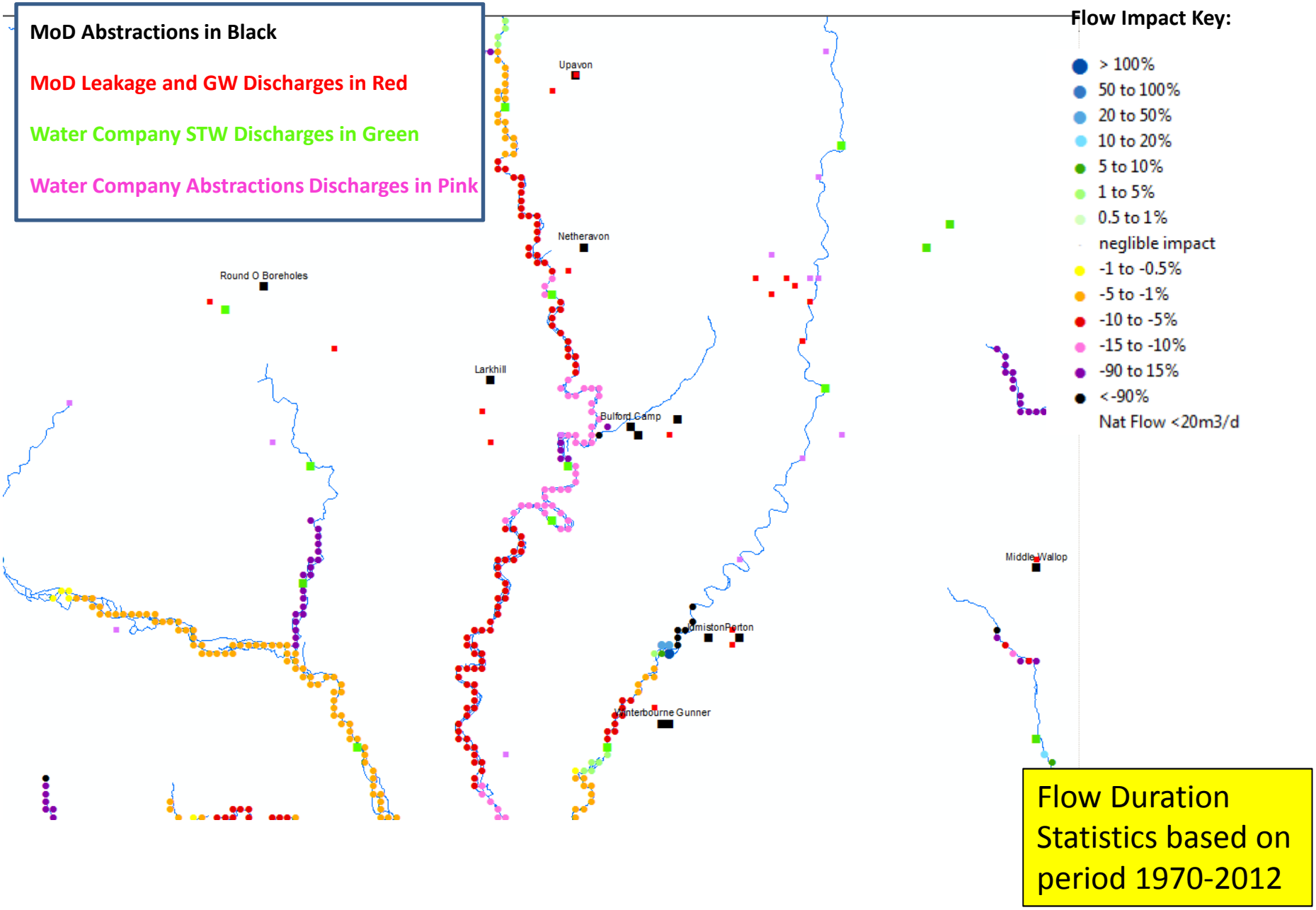


Figure 5 – Full Licence (Run 296) Impact of abstraction in Ml/d compared to Natural Flow (Run 251) at Q95

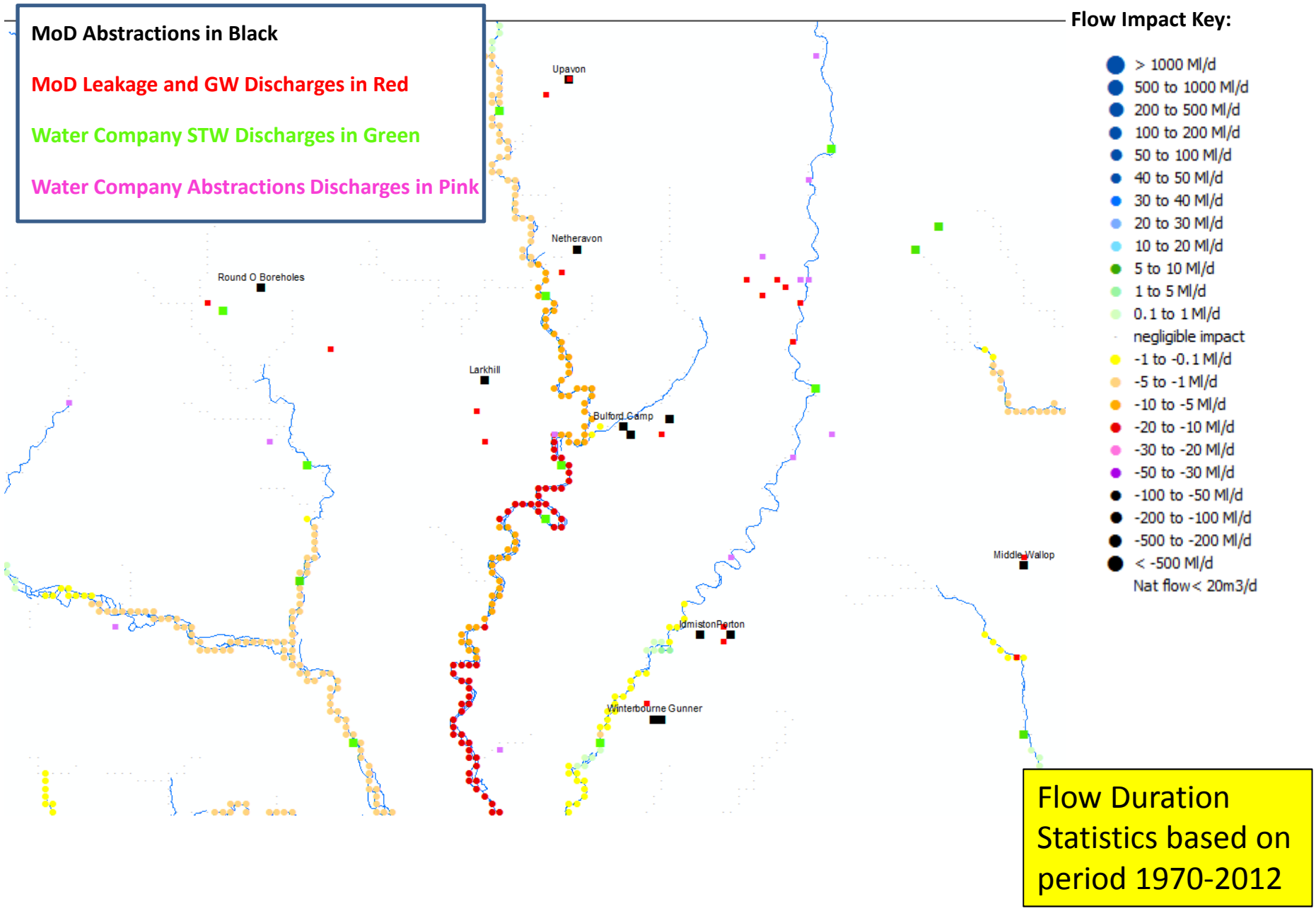
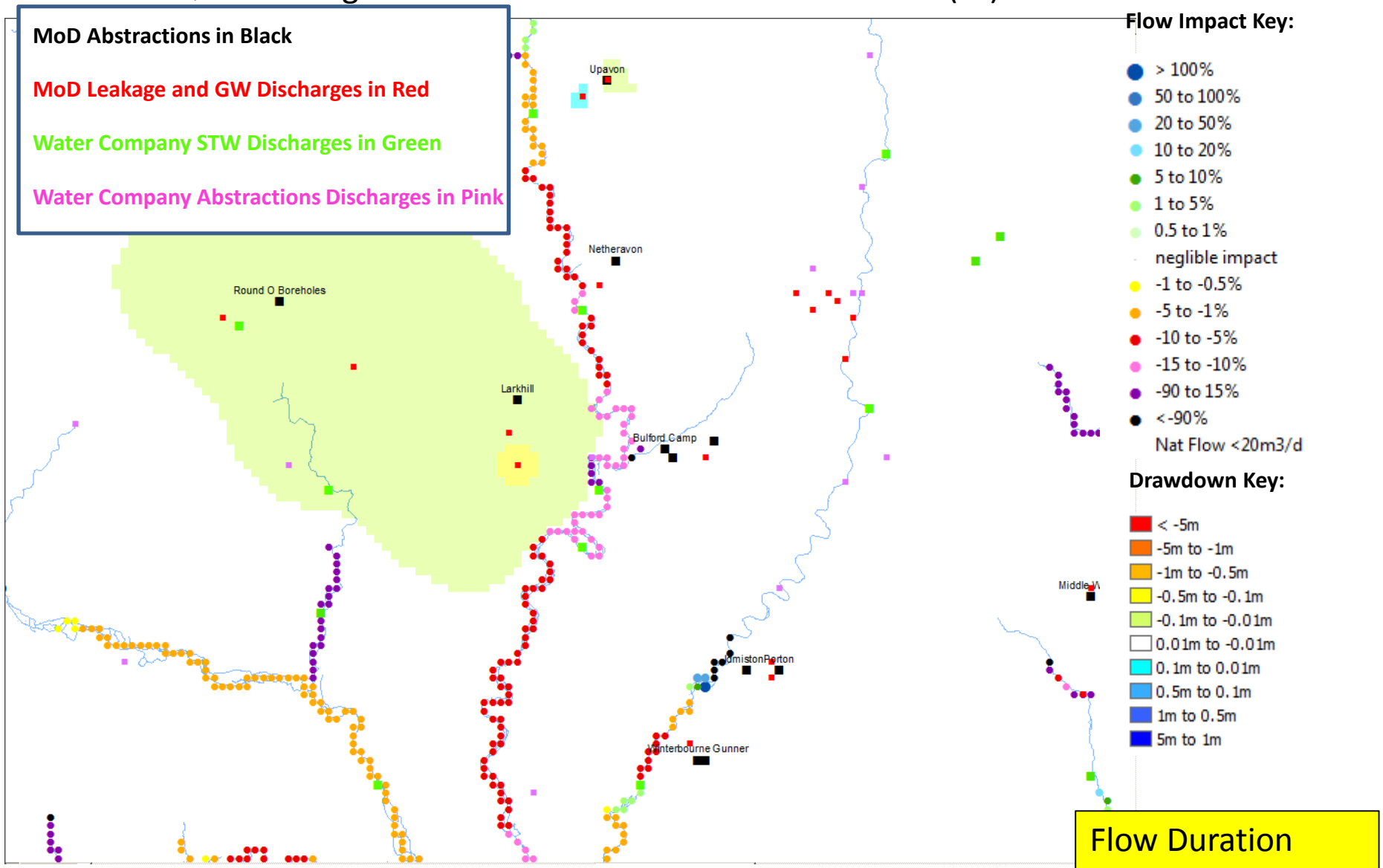


Figure 6 – Full Licence +ABP (Run 297) Impact of abstraction as a % of Natural Flow (Run 251) at Q95 and Aug 2003 GWL Difference between Run 296 (FL) and Run 297



Flow Duration Statistics based on period 1970-2012

Figure 7 – Full Licence (Run 297) Impact of abstraction in Ml/d compared to Natural Flow (Run 251) at Q95

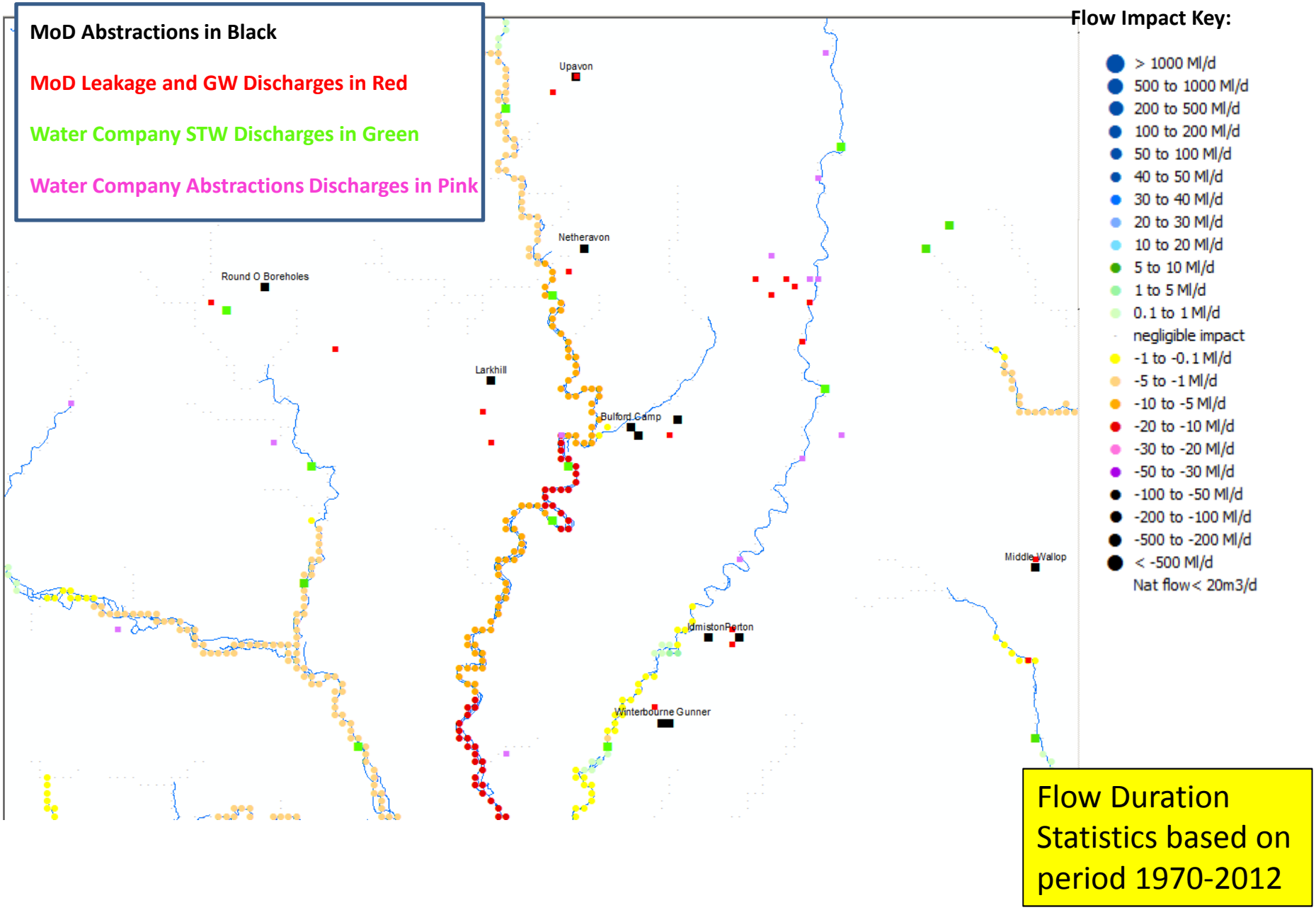
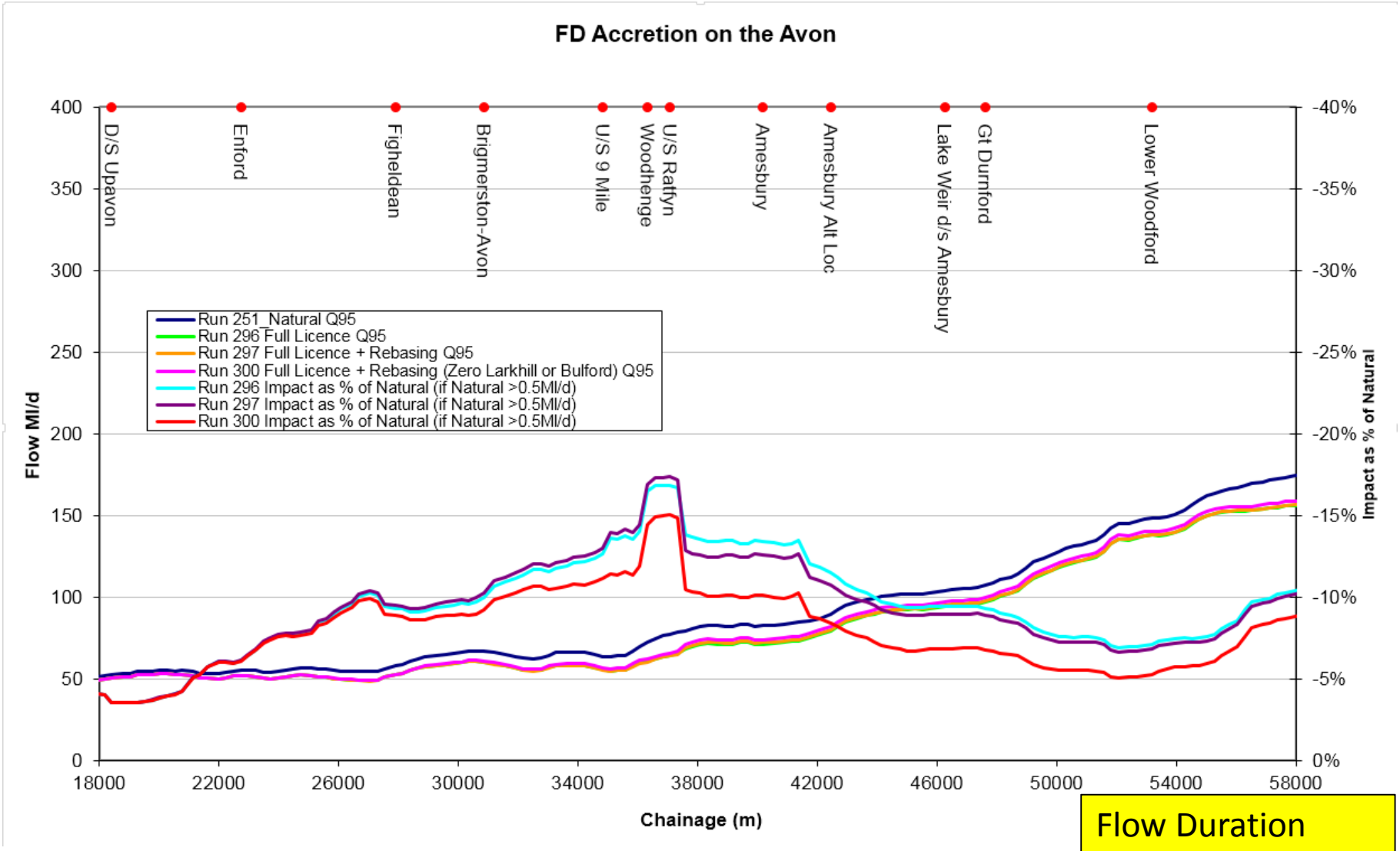
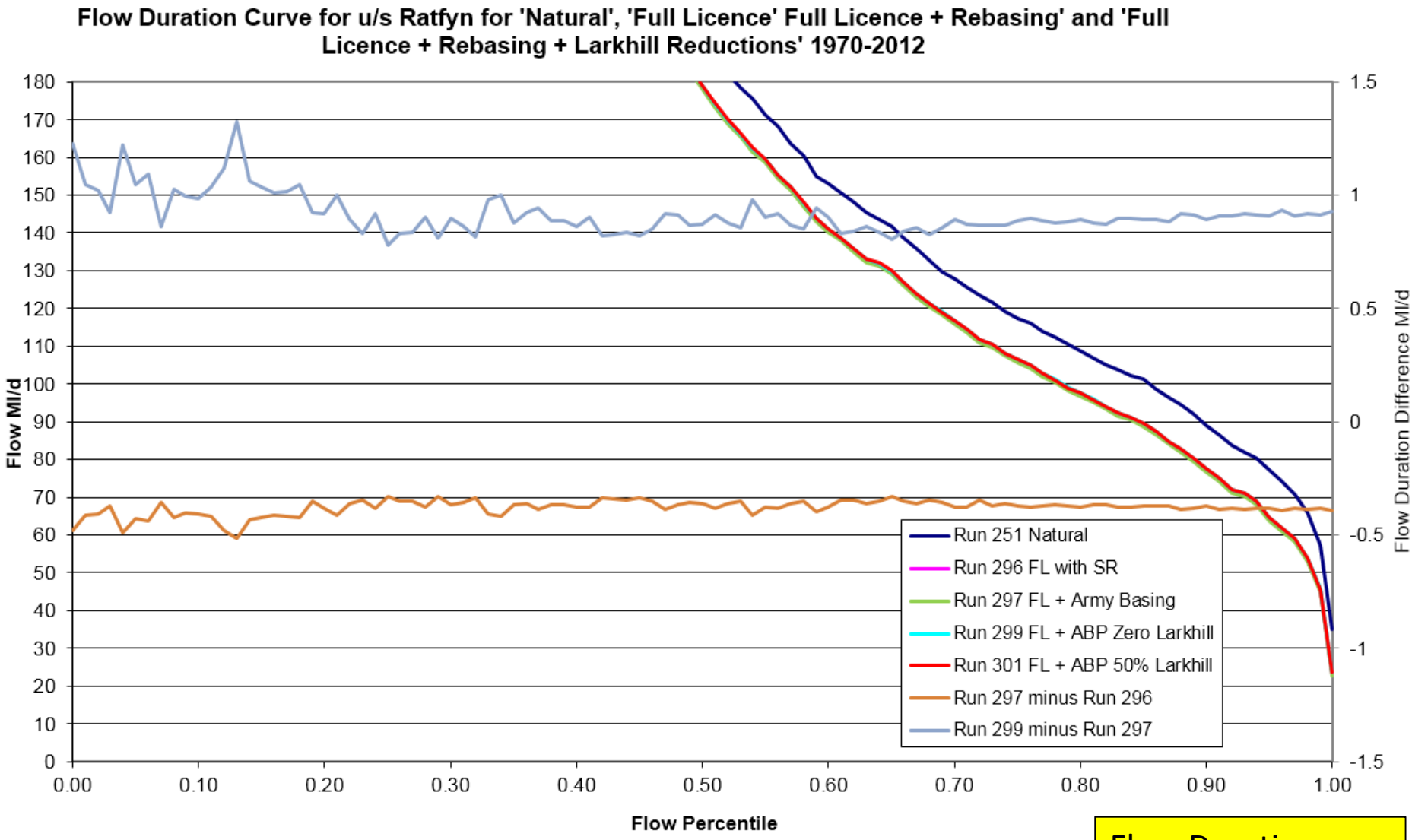


Figure 8 – Accretion Profile down the Avon at Q95



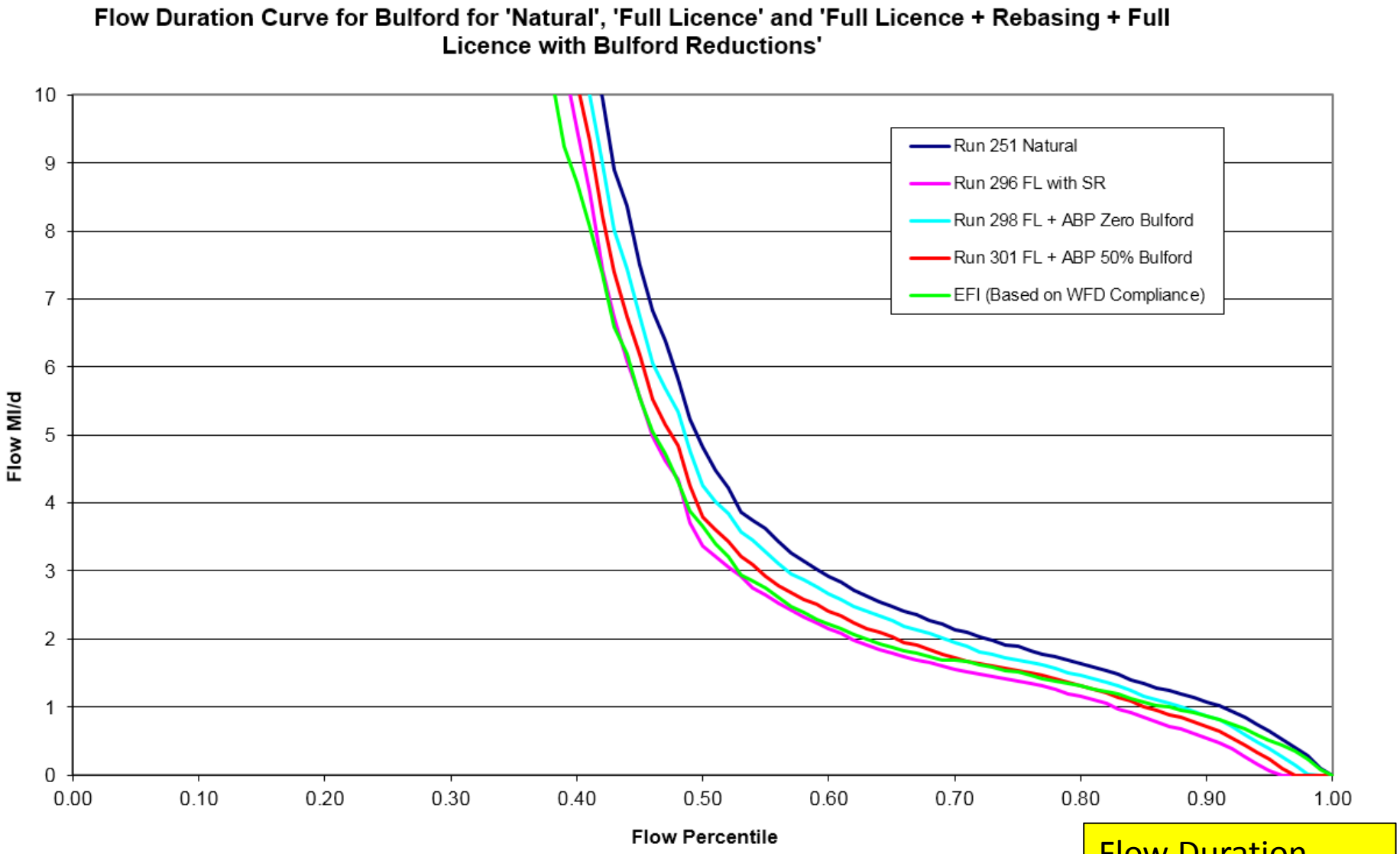
Flow Duration Statistics based on period 1970-2012

Figure 9 – Flow Duration Curve u/s Ratfyn STW



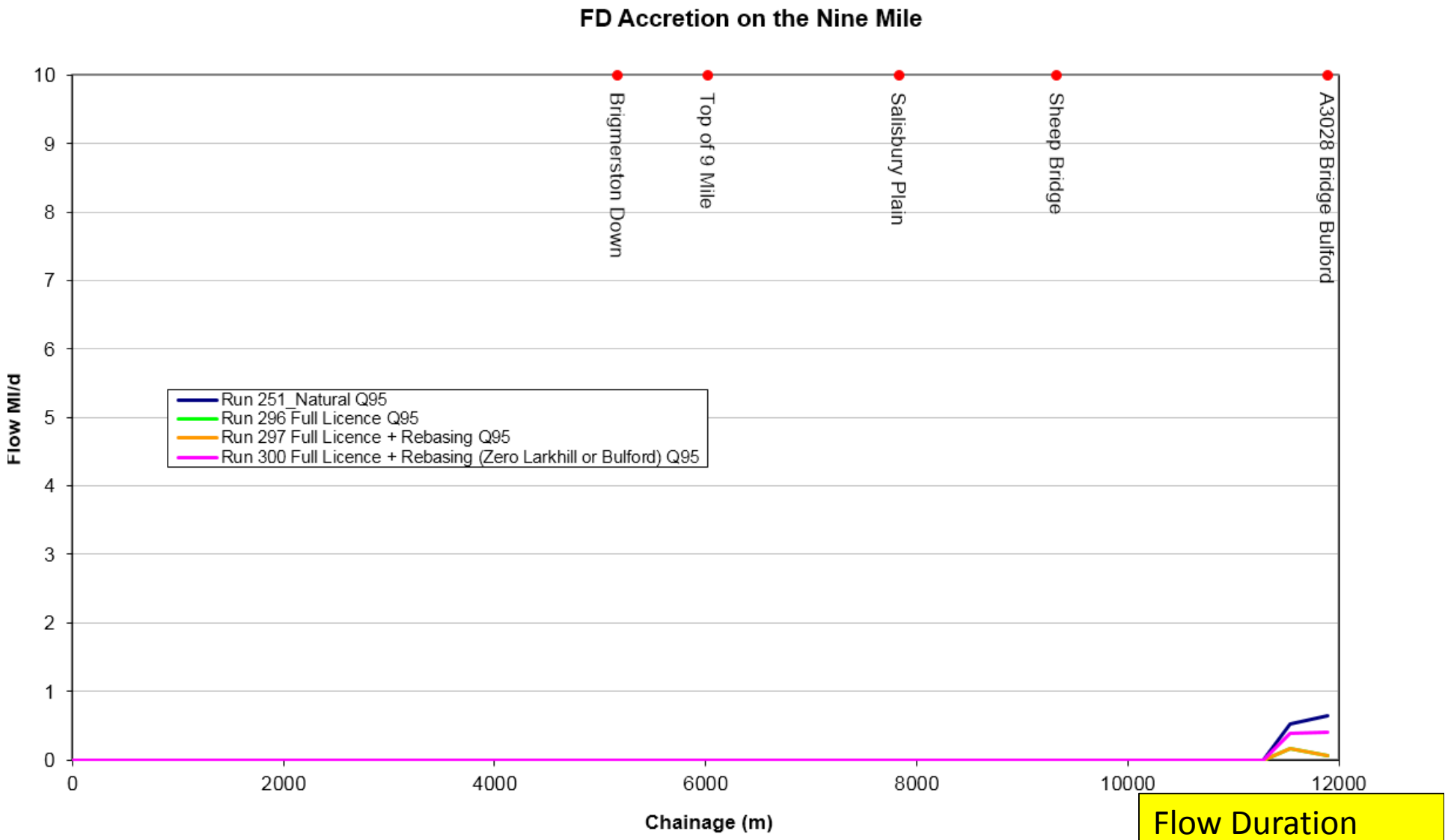
Flow Duration Statistics based on period 1970-2012

Figure 10 – Flow Duration Curve at Bulford



Flow Duration Statistics based on period 1970-2012

Figure 11



Flow Duration Statistics based on period 1970-2012

Figure 12

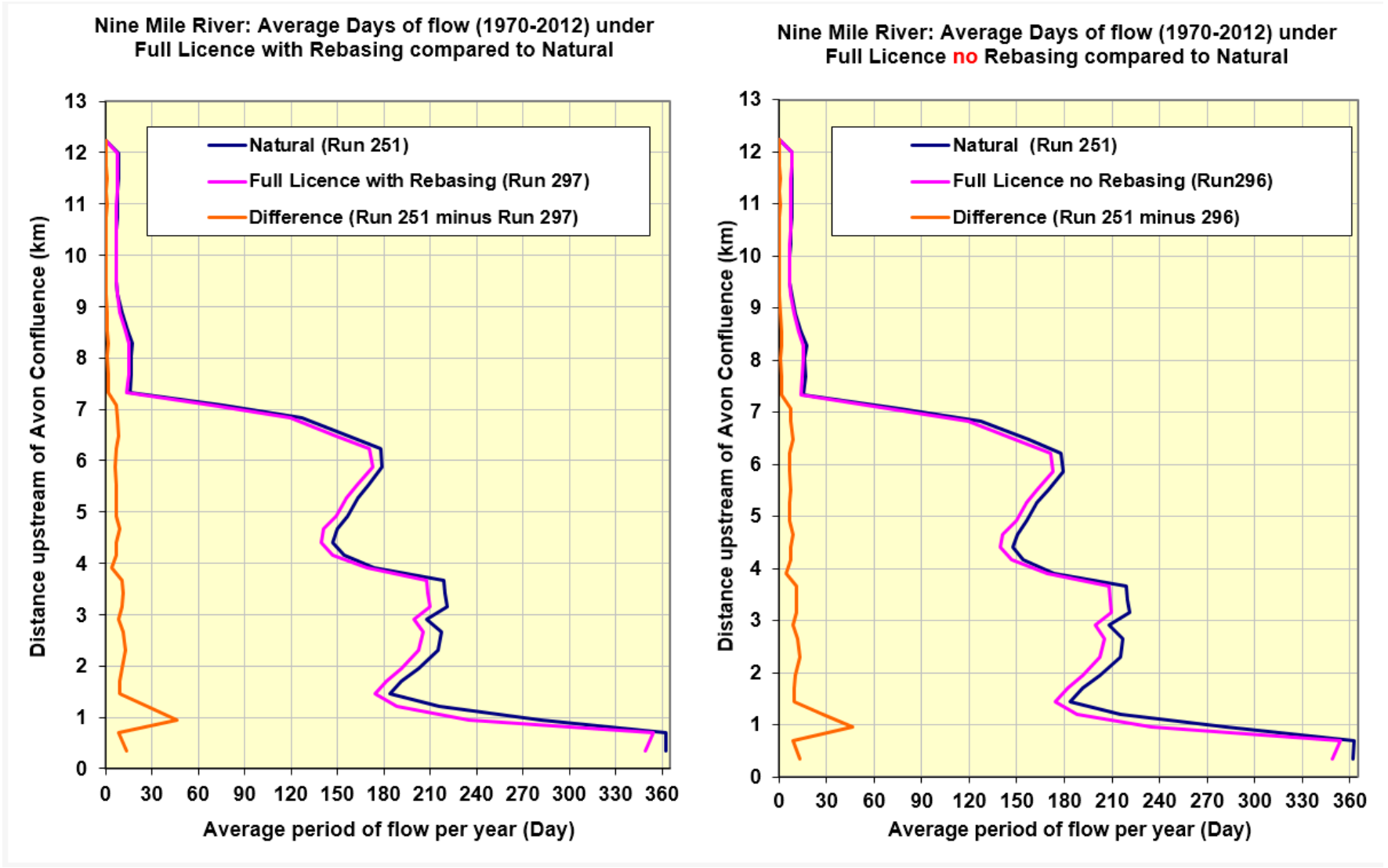

Nine Mile River: Average Days of flow (1970-2012) under Full Licence with Rebasing compared to Natural
Natural (Run 251)
Full Licence with Rebasing (Run 297)
Difference (Run 251 minus Run 297)
Distance upstream of Avon Confluence (km)
Average period of flow per year (Day)
Nine Mile River: Average Days of flow (1970-2012) under Full Licence no Rebasing compared to Natural
Natural (Run 251)
Full Licence no Rebasing (Run296)
Difference (Run 251 minus 296)
Distance upstream of Avon Confluence (km)
Average period of flow per year (Day)

Figure 13

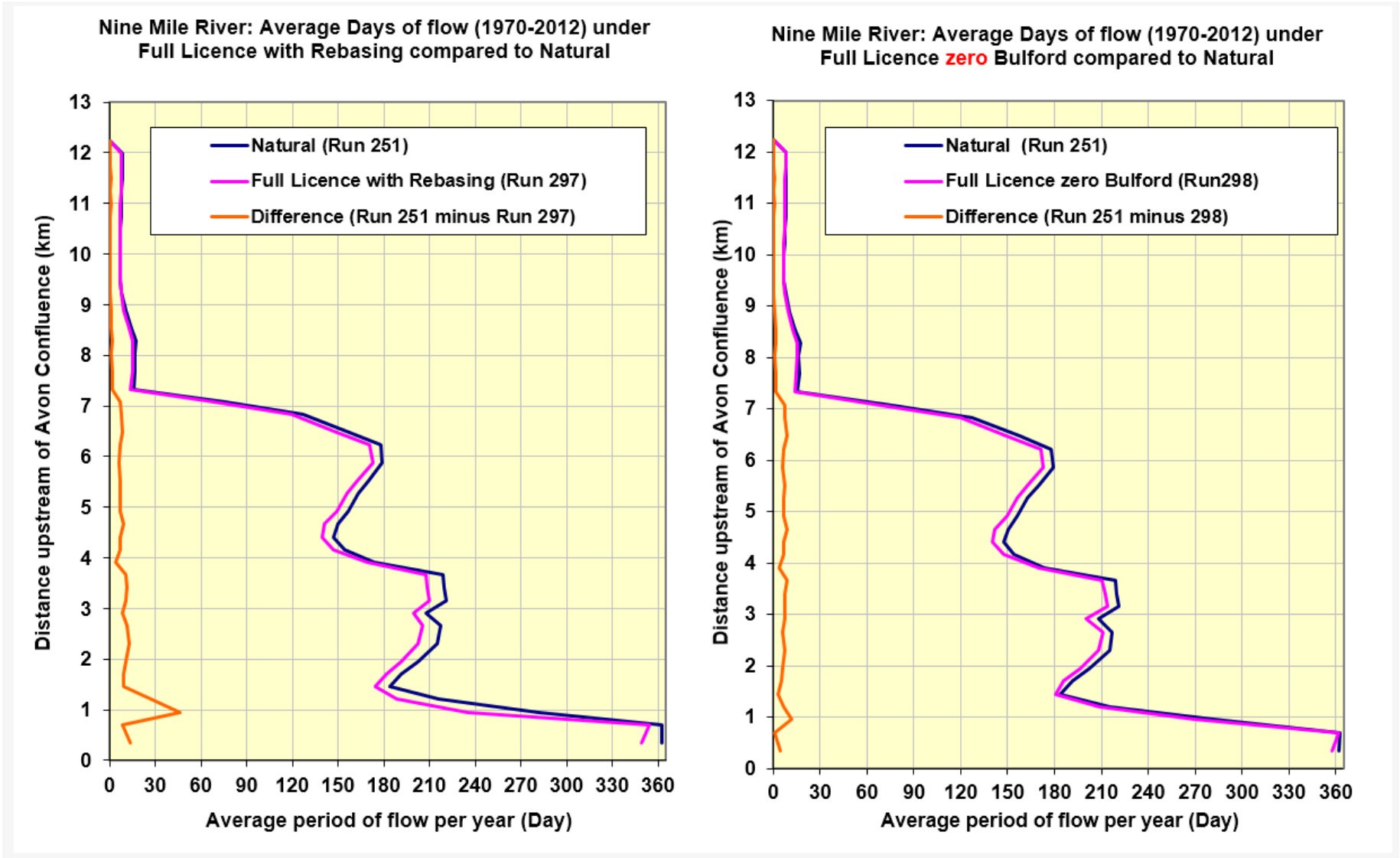

Nine Mile River: Average Days of flow (1970-2012) under Full Licence with Rebasing compared to Natural
Natural (Run 251)
Full Licence with Rebasing (Run 297)
Difference (Run 251 minus Run 297)
Distance upstream of Avon Confluence (km)
Average period of flow per year (Day)
Nine Mile River: Average Days of flow (1970-2012) under Full Licence zero Bulford compared to Natural
Natural (Run 251)
Full Licence zero Bulford (Run298)
Difference (Run 251 minus 298)
Distance upstream of Avon Confluence (km)
Average period of flow per year (Day)

Figure 14 – Impact of Groundwater Abstraction on Groundwater Levels underneath Ponds in the Nine Mile Valley

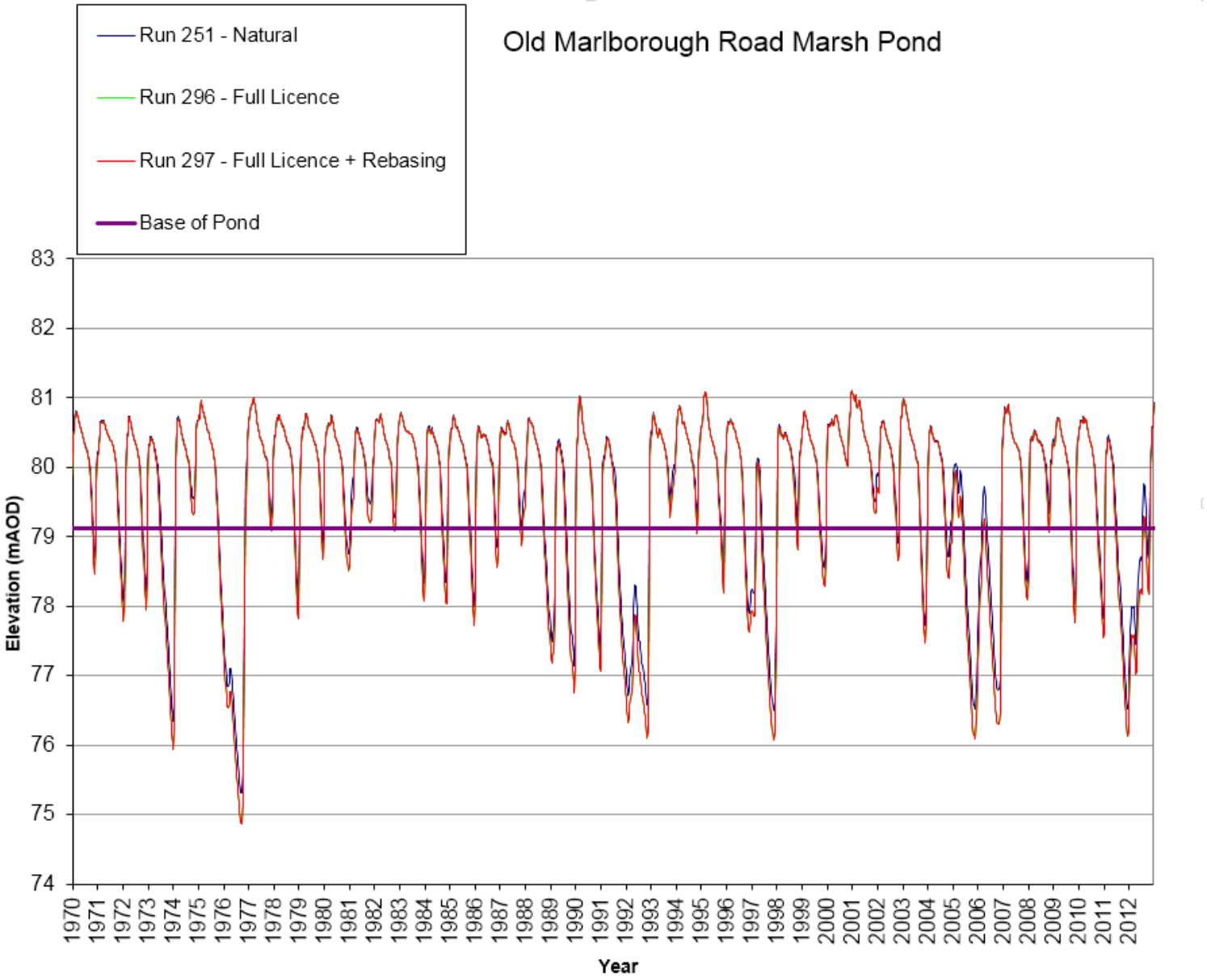


Figure 15 – Impact of turning off Bulford on Groundwater Levels underneath Ponds in the Nine Mile Valley

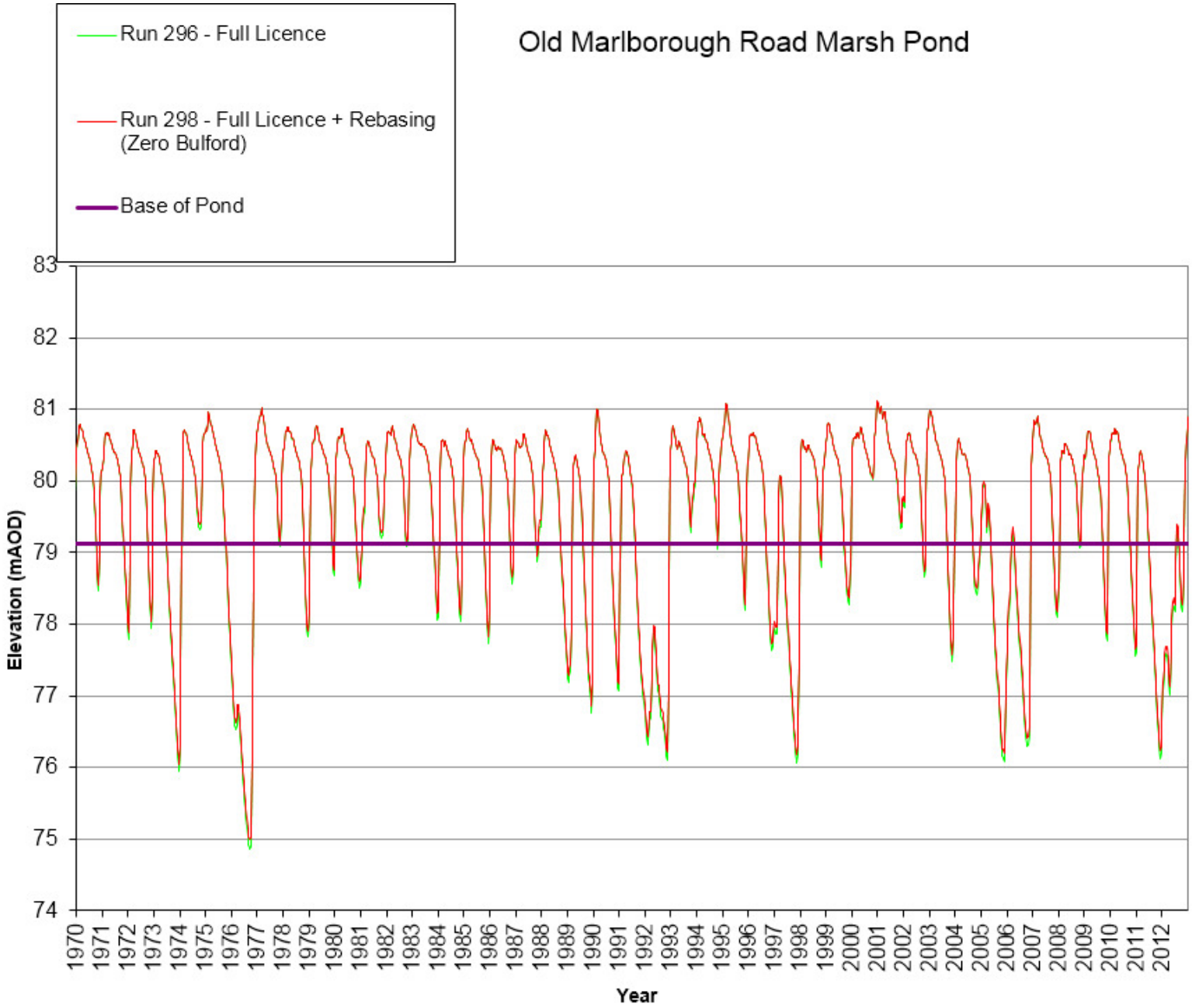


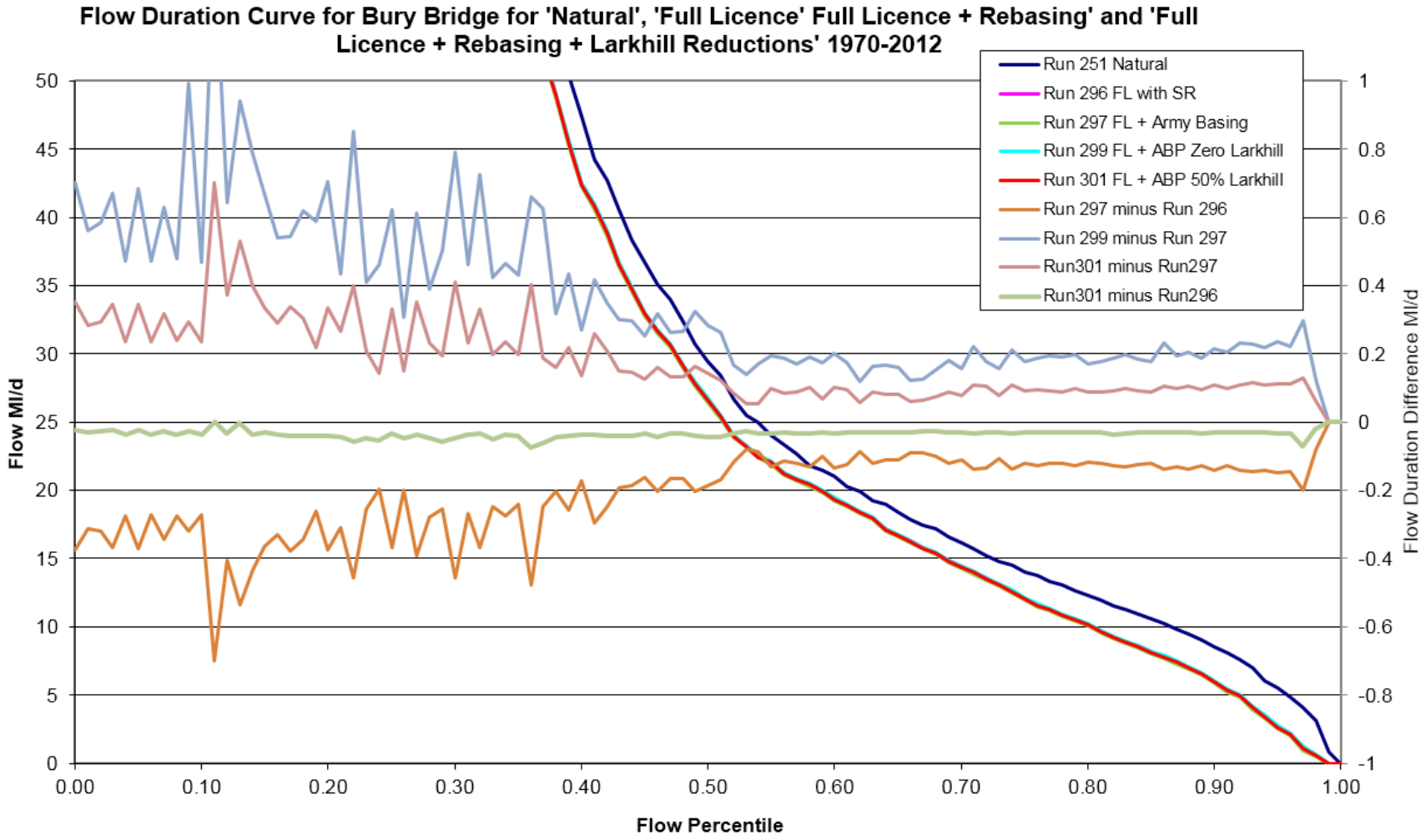
Figure 16 – Duration of wetted pond each year under different scenarios at Old Marlborough Road Marsh Pond

Pond Bottom Elevation

79.12 mAOD Topo says 79.12mAOD

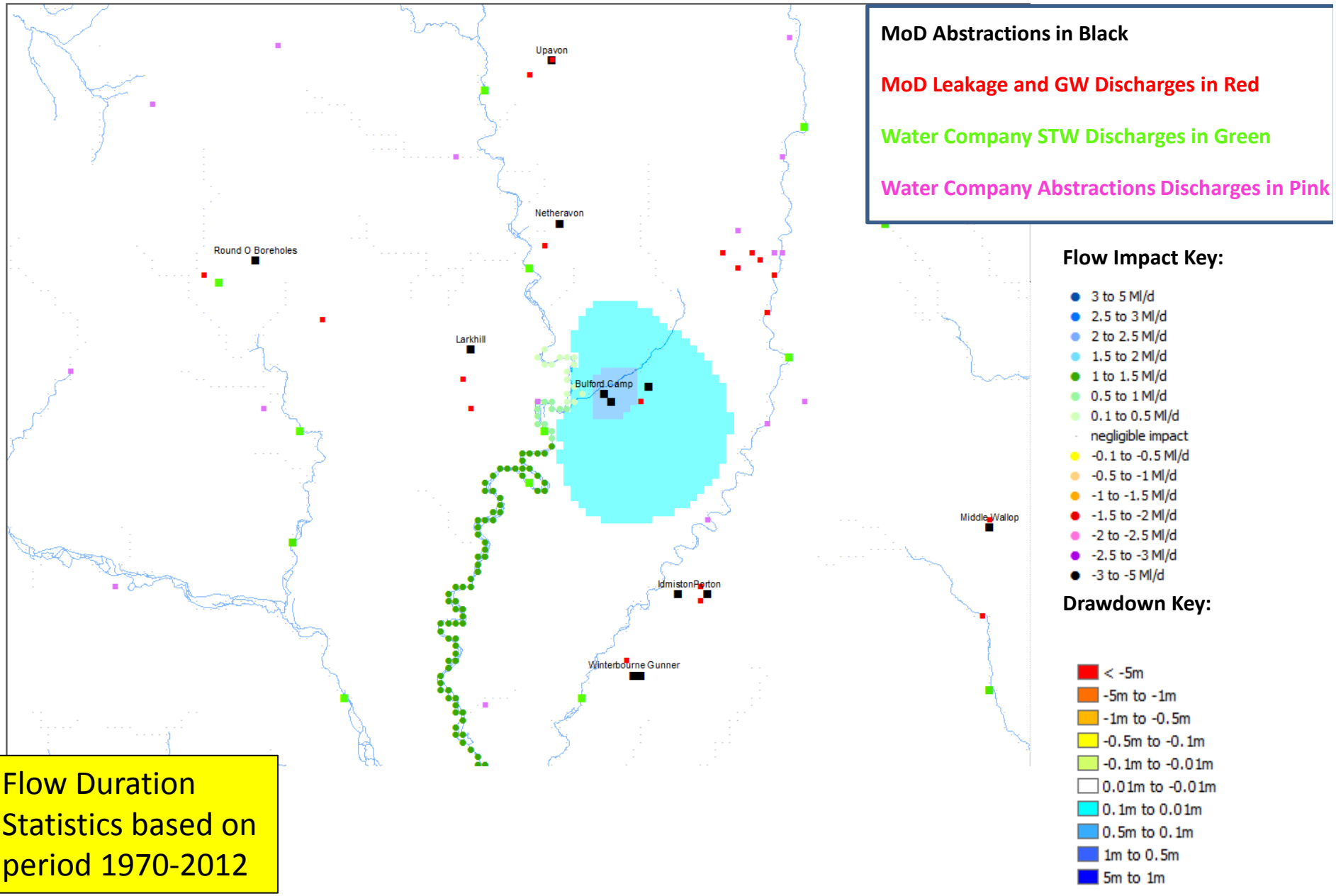
	Natural		Recent Actual		Full Licence		Full Licence + Rebasing		Full Licence+Rebase (Zero Bulford)		Full Licence+Rebase (50% Bulford)	
Year	Pass/Fail	Wet Critical Stress Periods	Pass/Fail	Wet Critical Stress Periods	Pass/Fail	Wet Critical Stress Periods	Pass/Fail	Wet Critical Stress Periods	Pass/Fail	Wet Critical Stress Periods	Pass/Fail	Wet Critical Stress Periods
1970	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1971	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1972	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1973	Fail	12	Fail	11	Fail	11	Fail	11	Fail	11	Fail	11
1974	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1975	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1976	Fail	0	Fail	0	Fail	0	Fail	0	Fail	0	Fail	0
1977	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1978	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1979	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1980	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1981	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1982	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1983	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1984	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1985	Fail	19	Fail	19	Fail	18	Fail	18	Fail	19	Fail	19
1986	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1987	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1988	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1989	Pass	20	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
1990	Fail	16	Fail	16	Fail	15	Fail	15	Fail	15	Fail	15
1991	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
1992	Fail	9	Fail	9	Fail	8	Fail	8	Fail	8	Fail	8
1993	Fail	7	Fail	7	Fail	7	Fail	7	Fail	7	Fail	7
1994	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1995	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1996	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
1997	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
1998	Fail	8	Fail	8	Fail	7	Fail	7	Fail	7	Fail	7
1999	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2000	Pass	20	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
2001	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2002	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2003	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2004	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
2005	Pass	20	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
2006	Fail	9	Fail	8	Fail	7	Fail	7	Fail	8	Fail	8
2007	Fail	6	Fail	5	Fail	1	Fail	1	Fail	2	Fail	2
2008	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2009	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2010	Pass	20	Fail	19	Fail	19	Fail	19	Fail	19	Fail	19
2011	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20	Pass	20
2012	Fail	12	Fail	12	Fail	11	Fail	11	Fail	11	Fail	11

Figure 17 – Flow Duration Curve at Bury Bridge on the the Till



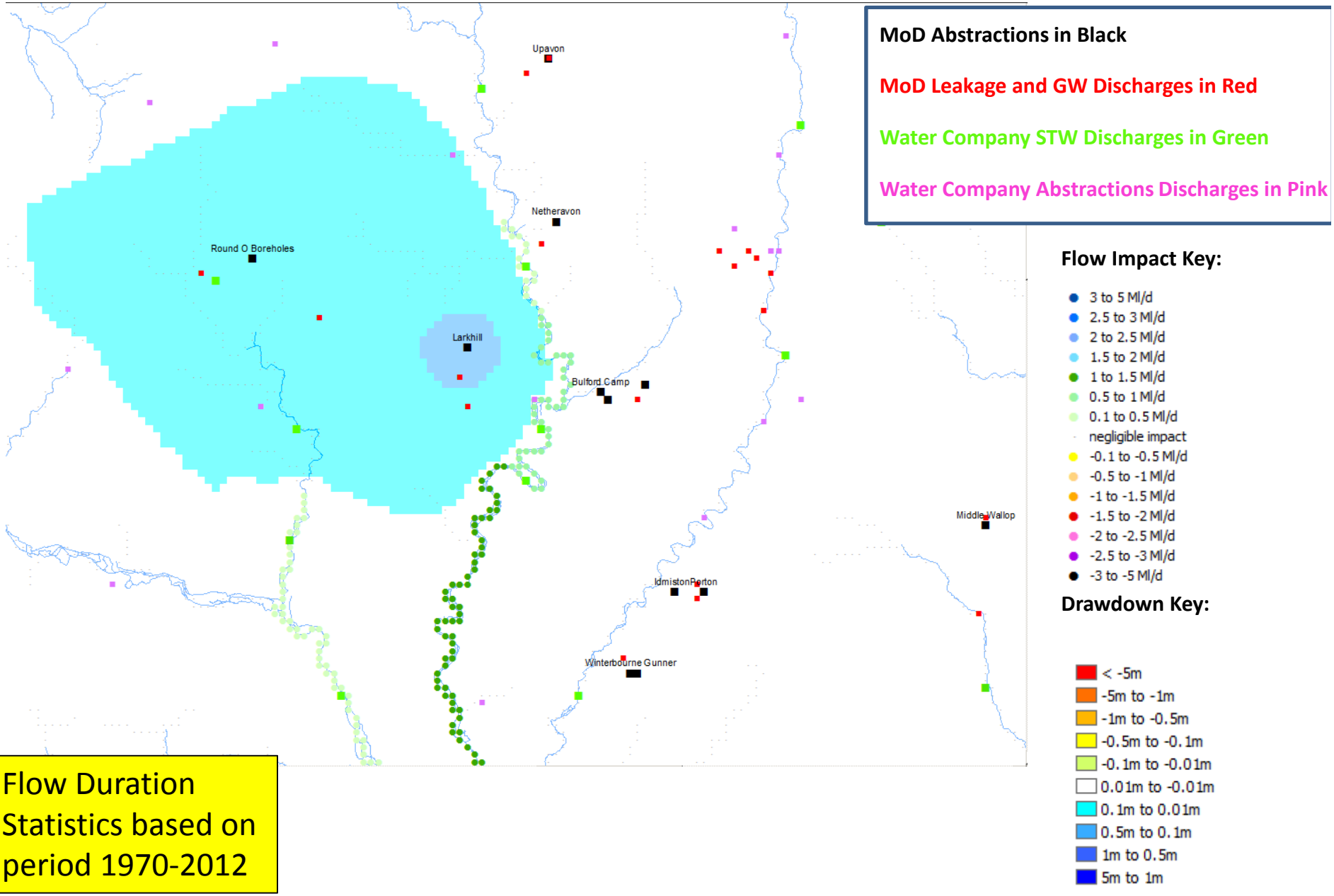
Flow Duration Statistics based on period 1970-2012

Figure 18 – Impact of turning off Bulford (Run 298) compared to Full Licence ABP (Run297)



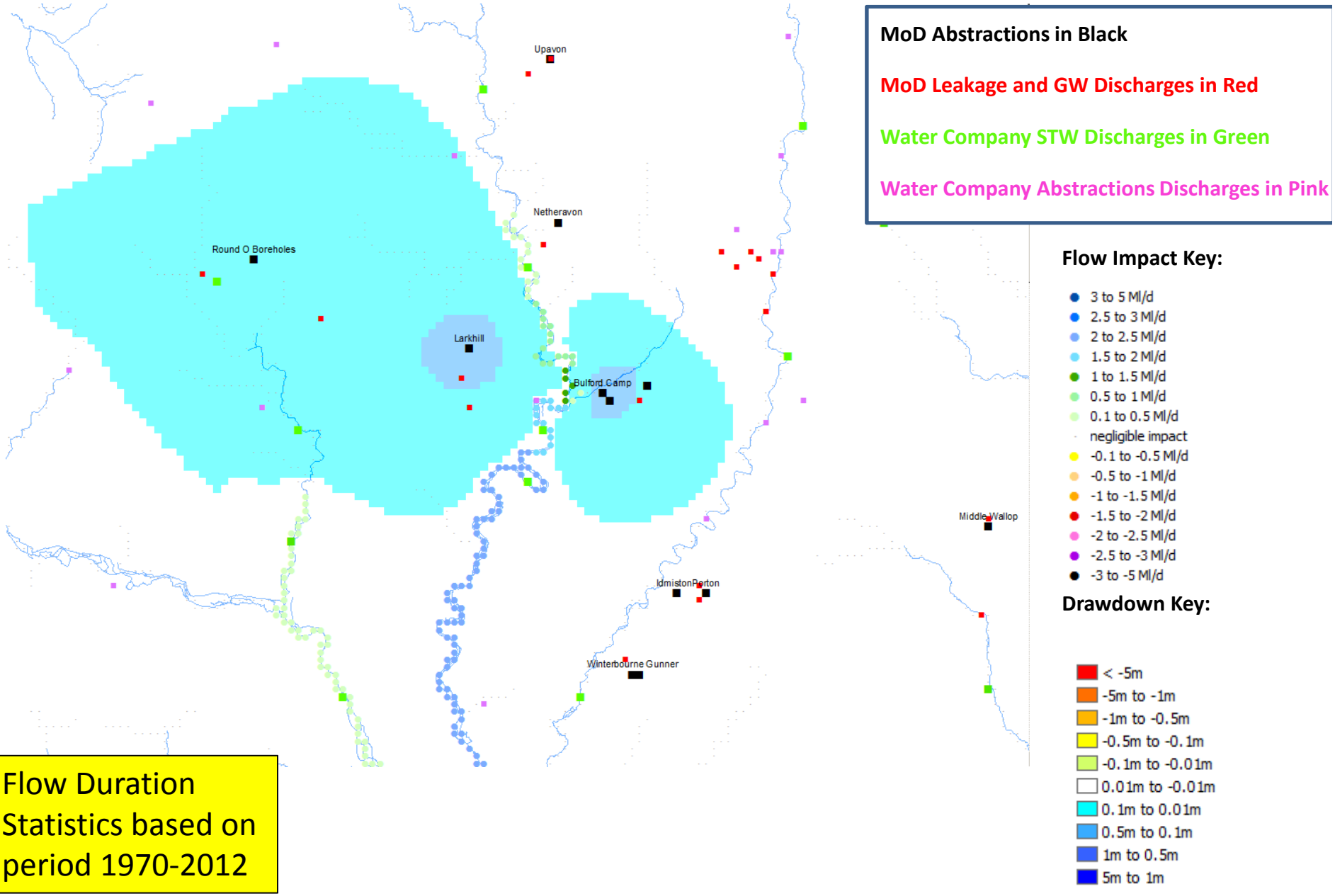
Flow Duration Statistics based on period 1970-2012

Figure 19 – Impact of turning off Larkhill (Run 299) compared to Full Licence ABP (Run297)



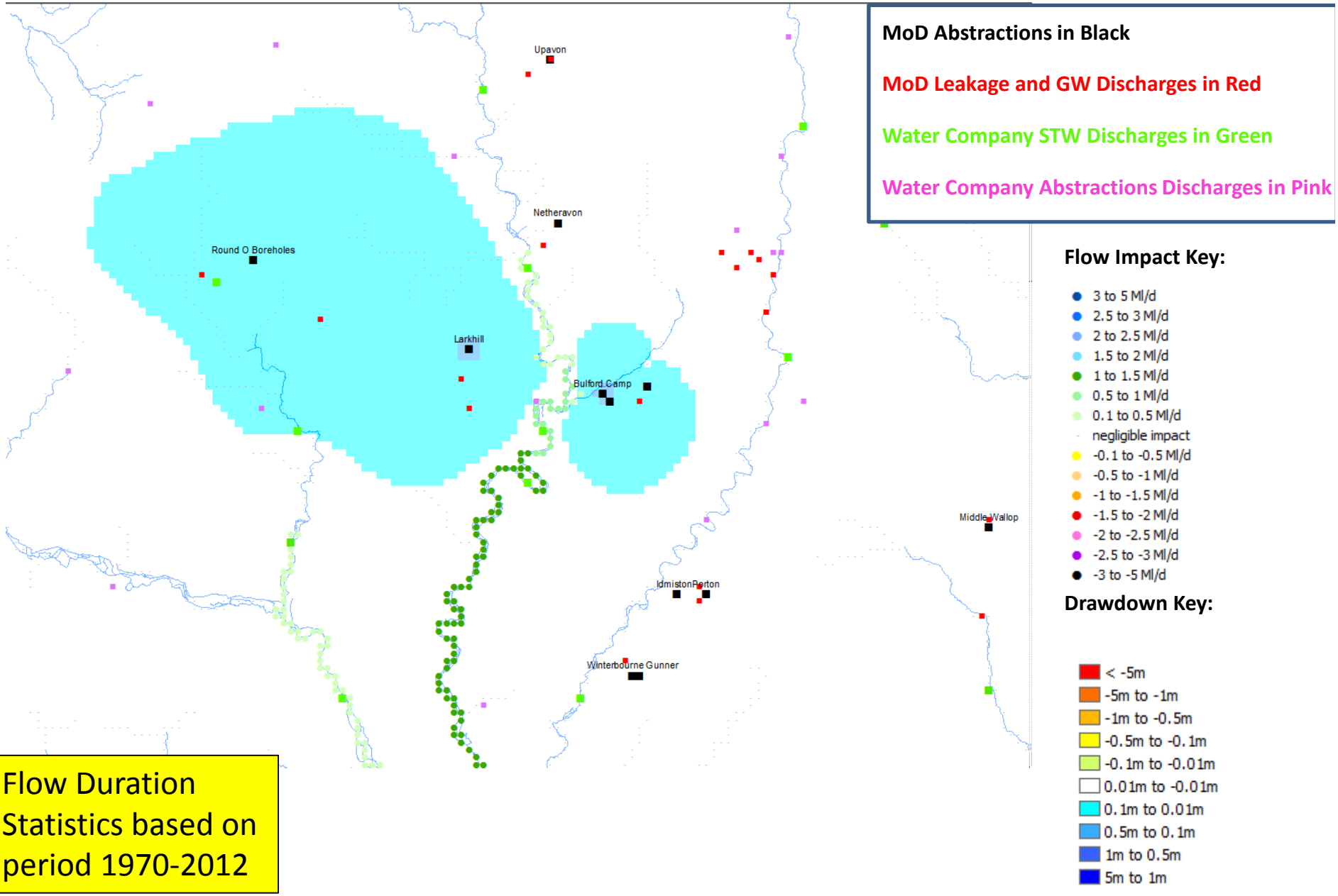
Flow Duration Statistics based on period 1970-2012

Figure 20 – Impact of turning off Bulford & Larkhill (Run 300) compared to Full Licence ABP (Run297)



Flow Duration Statistics based on period 1970-2012

Figure 21 – Impact of turning down Bulford & Larkhill by 50% (Run 301) compared to Full Licence ABP (Run297)



Flow Duration Statistics based on period 1970-2012