UKTAG Lake Assessment Method

Phosphorus

Lake Phosphorus Standards

by

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Health and safety statement

WARNING. Working in or around water is inherently dangerous; persons using this standard should be familiar with normal laboratory and field practice. This published monitoring system does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate health and safety practices and to ensure compliance with any national regulatory guidelines.

It is also the responsibility of the user if seeking to practise the method outlined here, to gain appropriate permissions for access to water courses and their biological sampling

UKTAG Guide to Lake Phosphorus Standards

1. Introduction

This method statement describes how to determine the WFD lake total phosphorus standards for the supporting element phosphorus in lakes. Lake phosphorus standards remained unchanged between the first and second river basin planning cycles.

Phosphorus standards are used in managing the risk of adverse ecological impacts. Where lakes are already adversely affected, phosphorus standards can indicate the likely degree to which phosphorus concentrations would need to be reduced (e.g. by reducing concentrations in discharges) to improve ecological quality. Where a new discharge is proposed, phosphorus standards can indicate whether or not the lake is likely to be able to accommodate the additional inputs without significant risk of adverse ecological effects.

The relevant standards for phosphorus must be met for a lake to be classed as being at good or high ecological status. Although standards for moderate, poor and bad status have been derived, to inform management decisions, these do not drive overall classification of status below moderate, as this is determined only by the status of biological elements.

2. Phosphorus standards

The phosphorus standards (also referred to as class boundary values) for a lake are calculated using the equations below. The standards are expressed as the boundary between each status class, and this value represents the phosphorus concentration required to support biological status in each class. Thus the terms “standard” and “boundary value” are used interchangeably e.g. the High/Good boundary value represents the phosphorus concentration that must be achieved for the water body to be in High Status.

Phosphorus standards for lakes are determined first by calculating a reference concentration for each lake, then calculating boundary Ecological Quality Ratio (EQR) values for each lake and finally using the EQR and the reference concentrations to determine the phosphorus concentration at each boundary. Calculation of site-specific values is recommended, but where insufficient data is available, type-specific boundary values are provided. For Marl lakes, only type-specific values can be used.

The equations produce standards in the form of annual geometric mean total phosphorus (TP) concentration in ug/L.

Lake phosphorus standards are calculated using Total Phosphorus data, determined using the phosphomolybdenum method with an acid digestion step on a whole (unfiltered) water sample. Samples for analysis of total phosphorus should be collected from a location representative of the water body being assessed. Samples should ideally be taken at evenly spaced intervals e.g. monthly, over the course of a year or years. Sampling and laboratory

analysis should conform to relevant CEN/ISO standards.

The standards calculated are applicable to freshwater and brackish lakes in the UK.

The calculations can be carried out manually, but a calculator spreadsheet in MS Excel has been created to aid the calculation process for multiple sites. The most recent version of this spreadsheet is available on the UKTAG website. The filename is Lake Phosphorus Calculator_05042016.xls

3. Data and information requirements

To determine reference phosphorus concentrations it is necessary to have information on alkalinity, mean depth and altitude for the lake in question. For lakes in Northern Ireland a humic category is also required and for lakes in England and Wales, the geographic location is important.

If information of this level of detail is not available, type-specific reference conditions can be used (see section 4.3)

Alkalinity: The alkalinity value should be fixed for each lake, it should be the long-term average for the lake and it is assumed it represents the natural (reference) alkalinity. Ideally the alkalinity value used for a lake should be the same as that used for biological classification tools, and should be derived from a minimum of one year of monthly sampling, as alkalinity can vary with season. However, the minimum data requirement for alkalinity is 4 samples, taken at regular intervals throughout the year.

Note that within the calculations, alkalinity data is log-transformed, therefore needs to be a positive value. Some lakes have very low alkalinities which can be negative. To avoid the problems this can cause in the calculations, any mean alkalinity values < 5 uEq/L should be replaced with a value of 5 uEq/L (0.005mEq/L).

Humic lakes. This category only applies to lakes in Northern Ireland and includes lakes which have a mean colour value > 30 mg/L Platinum units.

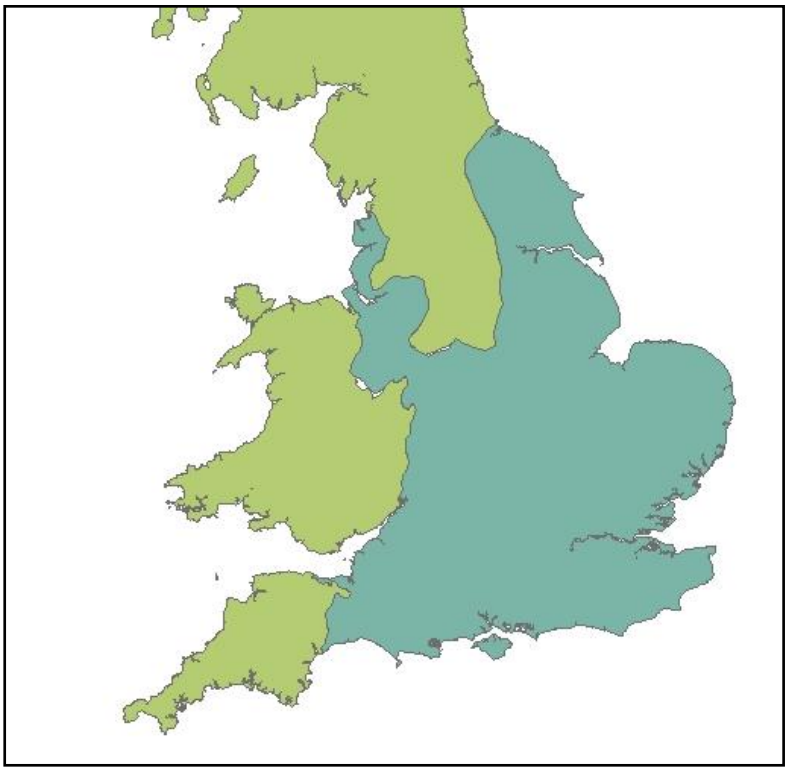
Lake mean depth, measured in meters. Where there is no bathymetry data and the mean depth is not known accurately, a type-specific standard should be used. Where a measured mean depth is available, if < 1m, a value of 1m should be used.

Lake Altitude, in meters above sea level. This value should not be <1m, so for lakes which are lower than this, a value of 1m should be used.

Geographic region. The models used for the prediction of site-specific reference TP differ according to geographic region (Figure 1). Region 1 includes all of Scotland and Northern Ireland and parts of England and Wales. It reflects the hard rock conditions in these areas and thus the low levels of background phosphorus. Region 2 includes only the lower lying areas of England and Wales and reflects the soft rock, alluvial conditions in this region which

leads to greater concentrations of background phosphorus. **Appendix A** lists all the WFD lake waterbodies in Region 2. All other WFD lake waterbodies are in Region 1.

Figure 1 shows the areas covered by each of the regions. Region 1 is indicated by green shading, region 2 by blue shading.



4. Calculating lake total phosphorus standards

This can be done on either a site-specific or a type-specific basis. If sufficient information about the lake is available to calculate site-specific standards, this is recommended. The following sections provide information enabling the calculation of site, then type-specific standards.

Note. All Marl lakes are assigned type-specific boundary values only; there are no reference predictions or EQRs for marl lakes.

4.1 Calculation of site specific reference phosphorus concentrations

"Reference phosphorus" means the total phosphorus (TP) concentration at near natural conditions. The formulae give a *geometric* mean TP concentration.

To calculate reference TP concentrations choose the appropriate equation according to region and for lakes in Northern Ireland, humic conditions;

Region 1:

Reference TP = 10^(1.36 – 0.09LogAltitude + 0.24LogMEI)

Region 2:

Reference TP = 10^(1.55 – 0.09LogAltitude + 0.24LogMEI)

Northern Ireland lakes with colour > 30 mg/L Platinum units:

Reference TP = 10^(1.62 – 0.09LogAltitude + 0.24LogMEI)

Where:
MEI (Morpho-edaphic index) = alkalinity (mEq/L) ÷ mean depth (m)

If the predicted value of reference phosphorus is > 35 µg/L, the reference phosphorus value is set to 35 µg/L.

4.2 Calculation of the site specific boundary values

This is done in two steps.

Step 1 Calculate EQRs

EQRs for H/G and G/M class boundaries are calculated for each lake. The formulae used are the same for all lakes irrespective of region or water colour. The EQRs will be used to determine the width of the status class.

H/G EQR = 0.755 + 0.012Alkalinity – 0.001Depth
If this value is < 0.7, it should be set at 0.7

G/M EQR = 0.505 + 0.023Alkalinity – 0.002Depth
If this value is < 0.46, it should be set at 0.46

Where;

Depth = mean depth, m,
Alkalinity = mean alkalinity for the lake in mEq/L

Step 2 Calculate site-specific boundary TP concentrations

The site-specific boundary TP concentrations are calculated by dividing the site-specific reference TP concentration (from 4.1) by the appropriate EQR (for H/G and G/M boundaries – section 4.2, Step 1) and by doubling the G/M boundary TP concentrations to determine the M/P and quadrupling the G/M boundary concentration to determine the P/B boundary concentration.

The calculations for each boundary value are shown below;

Boundary	Boundary TP concentration, ug/L	Minimum boundary TP concentration, ug/L
High/Good	Ref TP concentration ÷ H/G EQR	5
Good/Moderate	Ref TP concentration ÷ G/M EQR	8
Moderate/Poor	G/M TP concentration ÷ 0.5	16
Poor/Bad	G/M TP concentration ÷ 0.25	32

Note that if the boundary TP concentration is lower than the corresponding minimum value for that boundary, the minimum value should be used.

The calculated boundary TP concentrations are in effect geometric mean values.

4.3 Determination of type-specific reference and boundary TP concentrations

Where there is insufficient information to allow site specific predictions of reference and boundary concentrations, a type specific value for boundary TP phosphorus concentrations can be used.

For all marl lakes type-specific boundary values should be used.

Brackish lakes should be classed as High alkalinity, with the appropriate depth class.

The following tables provide information with which to assign lakes to a type, based on alkalinity and depth.

Geological characteristics used to identify geological categories to which the type-specific total phosphorus standards apply			
Geological category	*Annual mean alkalinity, uEq/L*	*Annual mean conductivity, uS/cm*	*Solid geology of the catchment of the [lake] (% of catchment)*
Low alkalinity	< 200	≤ 70	> 90% siliceous
Moderate alkalinity	200 - 1000	> 70 - 250	> 50% siliceous and ≤ 90% siliceous
High alkalinity	> 1000	> 250 - 1000	≥ 50% calcareous
Marl	> 1000	> 250 - 1000	> 65% limestone

Depth characteristics used to identify depth categories to which the type-specific phosphorus standards apply	
Depth category	*Mean depth, m*
Very shallow	< 3
Shallow	3 - 15
Deep	> 15

Type specific TP reference and boundary concentrations can be read for the appropriate lake type from the table below.

Note that for type-specific boundaries the geographic region in which the lake occurs is only

applicable for High Alkalinity lakes.

Lake Type	Type-specific annual geometric mean TP concentration, ug/L				
	Reference	High/ Good	Good/ Moderate	Moderate/ Poor	Poor/ Bad
High alkalinity, deep (Region 1)	13	16	23	46	92
High alkalinity, deep (Region 2)	20	25	35	70	140
High alkalinity, shallow (Region 1)	13	16	23	46	92
High alkalinity, shallow (Region 2)	20	25	35	70	140
High alkalinity, very shallow (Region 1)	18	23	31	62	124
High alkalinity, very shallow (Region 2)	28	35	49	98	196
Moderate alkalinity, deep	6	8	12	24	48
Moderate alkalinity, shallow	8	11	16	32	64
Moderate alkalinity, very shallow	12	15	22	44	88
Low alkalinity, deep	4	5	8	16	32
Low alkalinity, shallow	5	7	10	20	40
Low alkalinity, very shallow	7	9	14	28	56
Marl, shallow	---	9	20	40	80
Marl, very shallow	---	10	24	48	96

There are no type-specific boundaries for humic lakes.

5. Assessment of lake total phosphorus status

Phosphorus status is assessed by comparing the *geometric* mean value from measured phosphorus data with the derived standards.

Confidence of classification for supporting elements such as phosphorus should be reported, and is calculated using standard procedures for water quality assessments. A calculator is provided in Lake Phosphorus Calculator_05042016.xls, the most recent version of which is available on the UKTAG website.

6. Example Calculation

This example is for a lake where there is sufficient data for site-specific calculations

6.1 Determine the mean alkalinity, mean depth, altitude and region of the lake:

Mean alkalinity = 0.15365 mEq/L

Mean depth = 7.74 m

Altitude of site = 61 m

Region = 1

Calculate Morpho-edaphic index (MEI) = 0.15365/7.74 = 0.0199

6.2 Calculate the **reference total phosphorus:**

For lakes in Region 1, calculate reference TP as follows

Reference TP = 10^(1.36 - (0.09$\log_{10}$(61) + (0.24 x log0.0199)

= 10^ (1.36 – 0.1607 + (-0.4085))

= 10^0.79079

Reference TP = **6.177 µg/l**

6.3 Calculate the EQRs for each boundary

H/G EQR = 0.755 + 0.012Alkalinity – 0.001Depth

= 0.755 + 0.00184 – 0.00774

High/Good EQR = **0.75**

This value is not <0.7, therefore 0.766 is used.

G/M EQR = 0.505 + 0.023Alkalinity – 0.002Depth

= 0.505 + 0.00353 – 0.015

Good/Moderate EQR = **0.49**

This value is not <0.46, therefore 0.507 is used.

6.4 Calculate boundary TP concentrations

High/Good boundary	= Ref TP ÷ H/G EQR	= 6.18/0.75	= **8.2 ug/L**
Good/Moderate boundary	= Ref TP ÷ G/M EQR	= 6.18/0.49	= **12.6 ug/L**
Moderate/Poor boundary	= G/M TP ÷ 0.5	= 12.6/0.5	= **25 ug/L**
Poor/Bad boundary	= G/M TP ÷ 0.25	= 12.6/0.25	= **50 ug/L**

None of these boundary values are lower than the minimum concentration set for each class and so are used as they are.

The lake has an annual geometric mean TP concentration of 17 ug/L and is therefore placed in **Moderate status** for phosphorus because this value lies between the Good/Moderate and Moderate/Poor boundary values.

7. References

UKTAG (2008); UK Environmental Standards and Conditions; (Phase 1); Final report (SR1 – 2006), April 2008.
http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/Environmental%20standards%20phase%201_Finalv2_010408.pdf

Appendix A

All WFD lake watebodies in geographic Region 2 for the purposes of setting total phosphorus reference conditions and boundary values.

Water body ID	Name	Country
GB30538199	Pitsford Water	England
GB30538230	Ravensthorpe Reservoir	England
GB30538310	Grafham Water	England
GB30538633	Stow Cum Quy Fen	England
GB30538826	Felmersham Gravel Pits	England
GB30539264	Glemsford pits	England
GB30539450	Stewartby Lake	England
GB30640514	Blenheim Lakes	England
GB30641690	Welsh Harp	England
GB30539554	Brogborough Reservoir	England
GB30539601	Alton Water Reservoir	England
GB30539699	Foxcote Reservoir	England
GB30539944	Ardleigh Reservoir	England
GB30540418	Abberton Reservoir	England
GB30541427	Hanningfield Reservoir	England
GB30547009	Ormesby Broad	England
GB30547010	Rollesby Broad	England
GB30547011	Ormesby Little Broad	England
GB30547012	Filby Broad	England
GB30937864	Stanford Reservoir	England
GB30937926	Coombe Pool	England
GB30938250	Draycote Water	England
GB30938586	Westwood Great Pool	England
GB30940411	Dowdeswell Reservoir	England
GB30547028	Syderstone Common	England
GB30639472	Grimsbury Reservoir	England
GB30640488	Cornbury Park Lakes	England
GB30641011	Farmoor Reservoir	England
GB30641193	Seventy Acres	England
GB30641198	North Metropolitan pit	England
GB30641274	Cheshunt Lake	England
GB30641313	Bowyers Water	England
GB30641523	King Georges Reservoir	England
GB30641559	Cotswold Water Park Lake 12	England
GB30641659	William Girling Reservoir	England

GB30641796	Bentley Priory	England
GB30641865	Lockwood Reservoir	England
GB30641884	High Maynard Reservoir	England
GB30641900	Low Maynard Reservoir	England
GB30641907	Broadwater Lake	England
GB30641922	Walthamstow Reservoir No 4	England
GB30641924	Walthamstow Reservoir No 1	England
GB30641939	Warwick Reservoir East	England
GB30641956	Warwick Reservoir West	England
GB30641975	Stoke Newington East Reservoir	England
GB30642155	Coate Water	England
GB30642334	The Queen Mother Reservoir	England
GB30642393	Sonning Eye gravel pit	England
GB30642407	Cliffe Pools North Lake	England
GB30642417	Wraysbury Reservoir	England
GB30642424	Cliffe Pools South Lake	England
GB30642430	Wraysbury Lake	England
GB30642488	King George VI Reservoir	England
GB30642489	Wraysbury No 2	England
GB30642490	Staines Reservoir North	England
GB30642525	Staines Reservoir South	England
GB30642538	Heron Lake	England
GB30642569	Queensmead	England
GB30642611	Farnham Flint or Englefield Lagoon	England
GB30642614	Kempton Park East Reservoir	England
GB30642622	Ameys Lake or Theale Lakes	England
GB30642639	Queen Mary Reservoir	England
GB30642691	Virginia Water	England
GB30642753	Thorpe Park Lakes	England
GB30642757	Englemere Pond	England
GB30642779	Bessborough Reservoir	England
GB30642791	Knight Reservoir	England
GB30642813	Queen Elizabeth 2 Storage Reservoir	England
GB30642841	Island Barn Reservoir	England
GB30642875	Swinley Park Pond	England
GB30642945	Heath Lake	England
GB30642956	Murston Lakes, angling lakes	England
GB30643001	Wasing Wood Ponds	England
GB30643054	Black Pond	England
GB30643117	Snodland Reservoir	England
GB30643125	Epsom Stew Pond	England

GB30643126	Milford Lake	England
GB30643218	Boldermere	England
GB30643315	Fleet Pond	England
GB30643339	Mytchett Lake	England
GB30643359	Whitmoor Common Pond	England
GB30643485	Bay Pond	England
GB30643602	Bough Beech Reservoir	England
GB30643758	The Tarn	England
GB30643943	Frensham Little Pond	England
GB30644023	Hedgecourt Lake	England
GB30644031	Frensham Great Pond	England
GB30644310	Weir Wood Reservoir	England
GB30644358	Douster Pond	England
GB30644398	Bewl Water	England
GB30644464	Cranmer Pond	England
GB30644482	Woolmer Pond	England
GB30644576	Forest Mere	England
GB30647003	Banbury Reservoir	England
GB30647022	Littleworth Ponds	England
GB30647024	Marden Meadow Ponds	England
GB30743087	Stodmarsh Nature Reserve Pool	England
GB30743097	Great Puckstone	England
GB30743127	Westbere Lakes	England
GB30743156	Fordwhich lake East	England
GB30743164	Fordwich Lakes	England
GB30744067	Vann Lake	England
GB30744422	Marsh Court Lake	England
GB30744431	Old Alresford Pond	England
GB30744522	Shillinglee Lake	England
GB30744533	Ardingly Reservoir	England
GB30744545	Stew Pond	England
GB30744588	Hawkins Pond	England
GB30744738	Romney Warren Pond	England
GB30744935	Greatstone Lake	England
GB30744955	Darwell Reservoir	England
GB30745009	North Point Lake, Rye golf club	England
GB30745011	Powdermill Reservoir	England
GB30745015	Dungeness Gravel Pit	England
GB30745035	Castle Water	England
GB30745055	Nook Beach	England
GB30745060	Burrows Pit	England

GB30745061	Hookers Pit	England
GB30745064	Long Pit	England
GB30745108	Burton Mill Pond	England
GB30745429	Arlington Reservoir	England
GB30745606	Titchfield Haven	England
GB30745652	Hatchet Pond	England
GB30745790	Sowley Pond	England
GB30844158	Ashford Reservoir	England
GB30844261	Durleigh Reservoir	England
GB30844267	Hawkridge Reservoir	England
GB30845095	Breamore Marsh Ponds	England
GB30845115	Luxhay Reservoir	England
GB30845117	Leigh Reservoir	England
GB30845143	Sherborne Lake	England
GB30845271	Otterhead Reservoir	England
GB30845316	Sutton Bingham Reservoir	England
GB30845377	Mockbeggar Lake	England
GB30845412	Ivy Lake	England
GB30845427	Ellingham Lake	England
GB30845428	Blashford Lake	England
GB30845441	Snails Lake	England
GB30845446	Linbrook Lake	England
GB30845598	North Common Lake	England
GB30845729	Holmsley Gravel Pit	England
GB30846102	Little Sea	England
GB30846129	Sqabmoor Reservoir	England
GB30847016	Ibsley Water	England
GB30847017	Rockford Lake	England
GB30847044	Priors Park Reservoir	England
GB30934859	Maer Pool	England
GB30935079	Cole Mere	England
GB30935091	White Mere	England
GB30935211	Crose Mere	England
GB30935212	Sweat Mere	England
GB30935570	Morton Pool	England
GB30935620	Fenemere	England
GB30935724	Aqualate Mere	England
GB30936544	Bomere Pool	England
GB30936566	Betton Pool	England
GB30936578	Shomere Pool	England
GB30936634	Berrington Pool	England

GB30937599	Fens Top Pool	England
GB30328751	Lakes at Cassop	England
GB30328825	Hurworth Burn Reservoir	England
GB30328850	Crookfoot Reservoir	England
GB30329022	Lovell Hill Pools	England
GB30431809	Cadney Reservoir	England
GB30432002	Sprotborough Flash	England
GB30432209	Covenham Reservoir	England
GB30432240	Misson Line Bank	England
GB30433056	Clumber Lake	England
GB30433100	Welbeck Great Lake	England
GB30433316	Thoresby Lake	England
GB30433908	L Lake	England
GB30434381	Sledder Wood Pond	England
GB30434401	Bulwell Wood Ponds	England
GB30434709	Kedleston Hall Lower Lake	England
GB30434977	Attenborough Nature Reserve - Beeston Pond	England
GB30434995	Attenborough Nature Reserve - Main Pond	England
GB30435028	Holme Pit	England
GB30435060	Attenborough Nature Reserve - Coneries Pond	England
GB30435122	Church Wilne Reservoir	England
GB30435238	Cop Mere	England
GB30435310	The Old Dove	England
GB30435478	Blithfield Reservoir	England
GB30435548	Foremark Reservoir	England
GB30435554	Staunton Harold Reservoir	England
GB30435572	Ticknall Quarries	England
GB30435928	Blackbrook Reservoir	England
GB30436069	Colony Reservoir	England
GB30436108	Swithland Reservoir	England
GB30436331	Cropston Reservoir	England
GB30436396	Belvide Reservoir	England
GB30436433	Stowe Pool	England
GB30436523	Chasewater	England
GB30436536	Groby Pool	England
GB30437109	Bracebridge Pool	England
GB30437497	Shustoke Reservoirs	England
GB30437758	Edgbaston Pool	England
GB30447001	Moor Monkton Storage Reservoir	England
GB30447020	Clumber Park Lake West	England
GB30533132	Sea Bank Clay Pits	England

GB30533426	Swanholme Lakes	England
GB30533852	Tattershall Old Gravel Pits	England
GB30535397	Captains Pond	England
GB30535640	Hickling Broad	England
GB30535645	Horsey Mere	England
GB30535655	Barton Broad	England
GB30535738	Martham Broad	England
GB30535953	Wroxham Broad	England
GB30535959	Decoy Broad	England
GB30535977	Hoveton Great Broad	England
GB30536029	Cockshoot Broad	England
GB30536050	Ranworth Broad	England
GB30536202	Upton Broad	England
GB30536219	Costessey Pits	England
GB30536344	Langtoft Gravel Pits	England
GB30536422	Tallington Lakes Main Lake	England
GB30536479	Rutland Water	England
GB30536730	Rockland Broad	England
GB30536975	Sea Mere	England
GB30536980	Lound Mill Water	England
GB30536989	Fritton Decoy	England
GB30537182	Eyebrook Reservoir	England
GB30537306	Thompson Water	England
GB30537461	Old Buckenham Fen Mere	England
GB30537913	Thrapston Lake	England
GB30538132	Hollowell Reservoir	England
GB30538167	Upware North Pit	England
GB30940946	Frampton Gravel Pits	England
GB30942598	Monkswood Reservoir	England
GB30942798	Barrow Reservoir	England
GB30943096	Chew Valley lake	England
GB30943135	Blagdon Lake	England
GB30943348	Cheddar Reservoir	England
GB30943528	Mineries Pool	England
GB30947023	Lyppard Grange	England
GB31134780	Hanmer Mere	Wales
GB31134813	Llyn Bedydd	Wales
GB31232085	Pennington Flash	England
GB31232650	Rostherne Mere	England
GB31232665	Appleton Reservoir	England
GB31232729	Little Mere	England

GB31232744	The Mere Tatton Park	England
GB31232787	Melchett Mere	England
GB31232804	Tatton Mere	England
GB31232895	Tatton Mere West	England
GB31232898	Tatton Mere South	England
GB31232960	Tabley Mere	England
GB31233210	Hatch Mere	England
GB31233310	Black Lake	England
GB31233344	Petty Pool	England
GB31233474	Oakmere	England
GB31234162	Chapel Mere	England
GB31234260	Norbury Meres	England
GB31234328	Bar Mere	England
GB31234330	Betley Mere	England
GB31234438	Quoisley Big Mere	England
GB31234441	Quoisley Little Mere	England
GB31234480	Combermere	England
GB31234545	Oss Mere	England
GB31247019	Black Mere	England
GB31247027	Sound Common North Pond	England
GB30329099	Lockwood Beck Reservoir	England
GB30329148	Hell Kettles	England
GB30429122	Scaling Dam Reservoir	England
GB30429296	Cod Beck Reservoir	England
GB30429545	Gormire Lake	England
GB30429697	Black Heath Pond	England
GB30430244	Hornsea Mere	England
GB30430722	Barmby	England
GB30430809	Mickletown Ings	England