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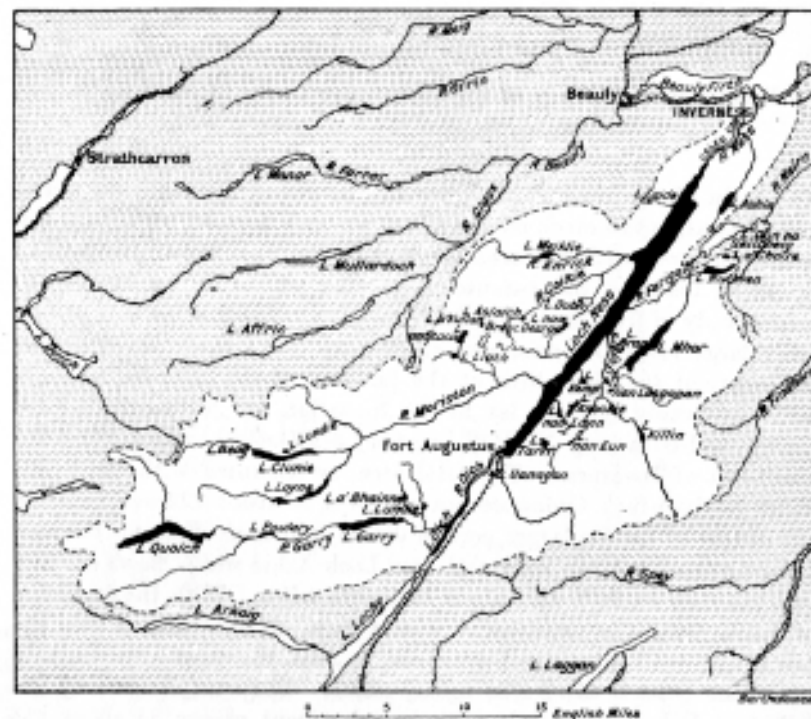
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For Notices as to the Society's Meetings and other important matters see p. 12.

Bathymetrical Survey of the Freshwater Lochs of Scotland
under direction of John Murray and Laurence Fullar

The basin of the river Ness is one of the most important of Scottish river-basins, not so much on account of the area drained, which is small when compared with the areas drained by the Tay, Tweed, Clyde, and Spey, for instance, but because it includes within its boundaries the largest body of fresh water in Scotland (Loch Ness), as well as several other large lochs and numerous small ones. The basin extends from the mouth of the river Ness, at the junction of the inner Moray Firth with the Beauly Firth, in lat. $57^{\circ} 30' N.$ to lat. $57^{\circ} N.$, south of Loch Quoich, and from long. $5^{\circ} 30' W.$, west of Loch Quoich, to long. $4^{\circ} 10' W.$, south-east of Inverness. The total area, as measured with the planimeter on the 1-inch Ordnance Survey maps, is about 722 square miles, and of this by far the larger portion drains into Loch Ness, for the area draining into the river Ness, and into Loch Ashie which flows directly into the river Ness, is only about 36 square miles. With the exception of Loch Ashie, the superfluent waters from all the lochs within the basin find their way into Loch Ness, so that the total area draining into Loch Ness is about 686 square miles. The area drained by the tributary lochs, to be dealt with in subsequent papers, is about 354 square miles, leaving about 332 square miles draining directly into Loch Ness, independent of the other lochs.

The principal river-systems within the basin lie to the west of Loch Ness, viz. the Enrick, which flows through Glen Urquhart into Loch Ness at Urquhart Bay, where it is joined by the shorter river Coiltie; the Moriston, with its tributaries the Clunie and the Loyne, which flows through Glen Moriston into Loch Ness at Invermoriston; the Garry, with its tributaries the Quoich and the Kingie, which flows through Glen Garry into Loch Oich at Invergarry, and thence by the Oich into the head of Loch Ness at Fort Augustus. To the south of Loch Ness lies the Tarff, also entering Loch Ness near Fort Augustus; and to the east lie the Foyers, with its tributaries the Breinag and the Fechlin, which flows into Loch Ness at Foyers, and the Farigaig which



enters Loch Ness at Inverfarigaig. Finally, to the north-east of Loch Ness lies the Allt Mor (or Big Burn), draining Loch Ashie, which flows into the river Ness 2 or 3 miles below Inverness, while the river Ness, after issuing from Loch Dochfour, at the northern end of Loch Ness, follows a winding course of about 6 miles, and pours its waters into the Moray Firth. Besides these, there are many shorter streams and burns flowing directly into Loch Ness, or into the tributary rivers or lochs.

As will be seen from the summary table, the staff of the Lake Survey sounded thirty-three lochs within the Ness basin, while a number of small lochs could not be surveyed for lack of facilities. These lochs vary in size, from the little Loch nan Losganan, covering an area of only 7 acres, and containing only a million cubic feet of water, to the mighty Loch Ness covering an area exceeding 20 square miles, and containing many thousands of millions of cubic feet of water. None of the other lochs in the basin can be compared with Loch Ness, neither as regards area, volume, nor depth, but still a few of the lochs are of considerable importance. For instance, Loch Quoich is 7 miles in length, while Loch Garry and Loch Mhor are nearly 5 miles in length, and Loch Clunie and Loch Oich exceed 4 miles in length. Loch Quoich,

again, covers an area of nearly 3 square miles, while Lochs Garry, Mhor, and Clunie exceed a square mile in area. Two of the lochs (Quoich and Garry) exceed 200 feet in depth, and three other lochs (Oich, Clunie, and nan Lann) exceed 100 feet in depth, while no fewer than twelve others include depths exceeding 50 feet.

The basin lies almost entirely in Inverness-shire, but a small portion of Ross-shire extends within the basin on its western border, the boundary-line running along the centre of West Loch Loyne and for a short distance along the centre of East Loch Loyne, and thence turning northward it crosses Loch Clunie in its central part; thus Lochs Loyne and Clunie lie partly in Ross-shire and partly in Inverness-shire, while the little Loch Beag, at the west end of Loch Clunie, is the only one lying wholly in Ross-shire. The scenery of the basin is varied, and as fine as anything to be seen in the Scottish highlands: towards the north the ground is low, but proceeding southwards it becomes more elevated, culminating on the south-western borders in several giant peaks exceeding 3000 feet in height, and on the south-eastern borders in mountains slightly less elevated. The district is a veritable sportsman's paradise, the deer-forests, grouse-moors, and fishings (both in river and loch) being of the best. Trout abound in nearly every loch, with salmon and *salmo ferox* in some of the larger lochs, and char in some of the smaller lochs lying to the east of Loch Ness; the fishing in most of the lochs is preserved.

Loch Ness (see Plates I. and II.).—Loch Ness formed the subject of discussion at a meeting of the Research Department of the Royal Geographical Society on January 18, 1904, and preliminary notes on the bathymetry, temperatures, and seiches were published in the *Journal* in October, 1904.* Since then many temperature and seiche observations and supplementary soundings have been taken, and the preliminary measurements and calculations have been carefully revised, the final results being given in this paper. Loch Ness is one of the best known of the larger Scottish lochs, since it forms a considerable part (nearly one-half) of the waterway known as the Caledonian canal, which occupies the great glen running in a north-east and south-west direction from the Moray Firth on the east coast of Scotland to Loch Linnhe on the west coast, thus cutting Scotland into two portions. Through the Caledonian canal thousands of visitors are carried each season on the route between Inverness and Fort William, and the splendid scenery of the canal and surrounding district has furnished a theme for many pens. The absence of islands in Loch Ness is a striking characteristic,

and gives a touch of monotony to the grand and sombre scene, as one sails up or down; the little Cherry island, lying at the opening of Inchnacardoch bay near the head of the loch, is invisible except at close quarters. Castle Urquhart, on its rocky headland at the south side of Urquhart bay, forms a picturesque and noteworthy landmark.

In his journey to the Western islands of Scotland in the autumn of 1773, Dr. Johnston travelled along the shores of Loch Ness, which, he says, is in some places 140 fathoms deep, and he remarks further that "Natural philosophy is now one of the favourite studies of the Scottish nation, and Loch Ness well deserves to be diligently examined." After the lapse of 130 years this has been done, and it is proposed in this place to summarize the results obtained by the staff of the Lake Survey during their prolonged and "diligent examination" of Loch Ness.

The survey of Loch Ness was commenced on April 2, 1903, and by the end of that month the preliminary survey was completed, but subsequently, at various periods during the years 1903 and 1904, many additional lines of soundings and numerous isolated soundings were taken, some of them in connection with the work of collecting samples of the deposits from all parts of the loch, others in connection with the work of taking temperatures at various depths in different parts of the loch. The total number of soundings recorded is about 1700, but some of them have been omitted on the accompanying map to avoid overcrowding. On April 1, 1903, the level of the surface of the loch was determined from bench-marks as being 52.6 feet above the sea, and to this datum-level all soundings have been reduced. A levelling-staff was erected first at Fort Augustus, then at Invermoriston, Foyers, and Temple piers, and the height of the water on this staff was read daily during the progress of the survey, so that the variations in level from day to day, and the variations from the starting-point, were readily known. These staff readings showed that the water fell gradually but irregularly, and by April 15 it was 1 foot lower, and by the 18th it was $1\frac{1}{2}$ feet lower, than on April 1.

Loch Ness proper may be said to extend from the head of the loch at Fort Augustus to the narrows at Bona ferry, a distance of $22\frac{2}{3}$ miles following the axis of maximum depth. This figure is inferior to the length of Loch Awe ($25\frac{1}{2}$ miles), and slightly in excess of the length of Loch Lomond ($22\frac{2}{3}$ miles); if we regard the small basin of Loch Dochfour, which is continuous with Loch Ness at its northern end, as forming part of the loch, then the total length, from the exit of the river Ness to the head of the loch, is about $24\frac{1}{4}$ miles.

In this place it is proposed to include Loch Dochfour in dealing with

* *Geogr. Journ.*, vol. 24, p. 429.

Loch Ness; it is a basin about $1\frac{1}{2}$ miles in length, with a maximum depth of 50 feet in the wide central portion, whence it narrows towards the two ends, the southern narrows leading into Loch Ness, and the northern termination being divided into two branches, the eastern branch forming the river Ness, and the western branch the continuation of the canal. With a strong south-westerly wind there is a surface current from Loch Ness into Loch Dochfour through the narrows at Bona ferry, and, if long continued, the water becomes banked up in Loch Dochfour, and gives rise to a return current along the bottom into Loch Ness; with a strong wind from the north-east the surface current sets in the opposite direction, *i.e.* from Loch Dochfour into Loch Ness. Cut off from the western margin of Loch Dochfour, by embankments carrying the towing-path for the canal, are two small basins, one called Abban water, having a maximum depth of 9 feet, the other without a distinctive name, having a maximum depth of 23 feet; they stand at the same level as Loch Dochfour, the water evidently percolating through the embankments.

Loch Ness may be said to be fairly uniform in breadth, though varying to some extent, but on the whole its shore-line is very regular when compared with other large lochs. The upper portion between Fort Augustus and Foyers for about 10 miles is under a mile in width, except at the opening of Glen Moriston, where the breadth slightly exceeds a mile. The portion between Foyers and Castle Urquhart for about 5 miles is almost exactly a mile in width, while the lower portion between Castle Urquhart and Torr point for about 5 miles exceeds a mile in width. The widest part of the loch is at Urquhart bay, from the mouth of the river Enrick due east to the opposite shore, where the width is 2 miles. The portion of the loch from Torr point to Bona ferry for about $1\frac{1}{2}$ miles varies in width from a half to a quarter of a mile, and the central portion of Loch Dochfour is about a quarter of a mile in width. The mean breadth of the entire loch is nine-tenths of a mile, or less than 4 per cent. of the length; a smaller percentage of mean breadth to length has been recorded only in Loch Shiel and Loch Shin, with $2\frac{1}{2}$ and 3 per cent. respectively.

The waters of Loch Ness cover an area of nearly 14,000 acres, or $21\frac{3}{4}$ square miles. Among the Scottish fresh-water lochs this is exceeded only by Loch Lomond, which has a superficial area of nearly $27\frac{1}{2}$ square miles. As already stated, the area draining directly into Loch Ness is about 332 square miles, while its total drainage area, including the area draining into all the tributary lochs, is about 686 square miles—an area over thirty times greater than that of the loch.

The maximum depth observed by the Lake Survey staff in Loch Ness was 754 feet, about a mile due south of Castle Urquhart in the centre of the loch. A greater depth than this has been recorded in only one Scottish loch, *viz.* Loch Morar, which has a maximum depth of 1017 feet, and after Loch Ness come Loch Lomond and Loch Lechy, with maxima of 623 and 531 feet respectively.

The volume of water contained in Loch Ness is estimated at 263,000 millions of cubic feet, or $1\frac{3}{4}$ cubic miles. In no other Scottish loch does the bulk of water amount to a cubic mile, in fact Loch Ness contains about three times as much water as the two lochs which most nearly approach it in this respect, *viz.* Loch Lomond with 92,800 million cubic feet, and Loch Morar with 81,500 million cubic feet. The largest volume of water recorded by Dr. Mill among the lakes of the Cumberland district is only 12,250 million cubic feet. As far as we are aware, the volume of water contained in the large lakes of Ireland has not yet been carefully worked out, but, taking Loch Neagh, for instance, which is said to cover an area of 153 square miles (or seven times greater than the area of Loch Ness), and to have a maximum depth of only 48 feet, a rough calculation will show that the bulk of water in Loch Neagh must be less than that in Loch Ness. It seems quite possible, therefore, that Loch Ness may be the largest body of fresh water, not only in Great Britain, but in the United Kingdom.

Correlated with the enormous volume of water in Loch Ness is the high value of the mean depth, which works out at 433 feet for the entire loch. This far exceeds that of Loch Morar, *viz.* 284 feet, which comes next in this respect. The mean depth of Loch Ness is equal to 57.4 per cent. of the maximum depth—a higher percentage than has been observed in any other large deep loch, the nearest approach to it being in the case of Loch Avich, with a maximum depth of 188 feet and a mean depth of 98 feet, the percentage being 52.4. It is true that in some shallow flat-bottomed basins the percentage of mean depth to maximum depth exceeds that in Loch Ness; as, for instance, Loch Watten in Caithness (70 per cent.), and Loch Bruadale in Lewis (74 per cent.), but the maximum depths are here only 12 feet and 6 feet respectively. Except for Lochs Ness and Avich, in all the deep Scottish lochs, *i.e.* those having depths exceeding 100 feet, the mean depth is less than one-half of the maximum depth, the percentage varying from 19.4 in Loch Shiel, and 19.5 in Loch Lomond, to 49.4 in Loch Lungard, and 49.6 in Loch Suanival (Lewis).

It has been stated that the surface of Loch Ness stands about 52 feet above mean sea-level, so that by far the greater portion of its floor falls

below the level of the sea.

An inspection of the bathymetrical map of Loch Ness shows (1) the comparative simplicity of the basin; (2) the steep shore-slope throughout the greater part of the loch; and (3) the large area of the lake-floor covered by very deep water. The 100-foot, 200-foot, 300-foot, 400-foot, and 500-foot contours are continuous, and only the 600-foot and 700-foot contours are interrupted by a shoaling opposite the entrance of the river Foyers, probably due to the deposition of material brought down by that river. This shoaling is covered by 515 to 524 feet of water, and both to the north-east and south-west the bottom sinks to depths exceeding 700 feet.

The 100-foot basin is about $22\frac{1}{2}$ miles in length, the southern extremity approaching to within 100 yards from the shore at the entrance of the river Tarff, and the northern extremity extending into the narrow part of the loch beyond Torr point, approaching to within a quarter of a mile from Bona ferry.

The 200-foot basin is $21\frac{3}{4}$ miles in length, approaching to within 150 yards from the Monastery boat-house slip at Fort Augustus, and quite close to the south-western shore off the entrance of the river Oich, and extending beyond Torr point on the north to within less than a mile from Bona ferry.

The 300-foot basin is $20\frac{1}{2}$ miles in length, extending from less than 300 yards from the Monastery boat-house slip on the south to just beyond Torr point, or $1\frac{1}{2}$ miles from Bona ferry, on the north.

The 400-foot basin is 20 miles in length, distant over a quarter of a mile from the Monastery boat-house slip on the south, and about three-quarters of a mile from Torr point, or over 2 miles from Bona ferry, on the north.

The 500-foot basin is about $18\frac{1}{2}$ miles in length, distant less than a mile from the Monastery boat-house slip on the south, and about $1\frac{1}{2}$ miles from Torr point on the north. The southern extremity of this basin differs somewhat from the usual truncate form, partaking of a rectangular character.

The two 600-foot basins are separated by an interval of little over half a mile, and are almost exactly equal in length, both of them slightly exceeding 8 miles in length. The northern one is distant about 2 miles from Torr point, and the southern one less than 2 miles from the Monastery boat-house slip at Fort Augustus.

The two 700-foot basins are separated by an interval of nearly $2\frac{1}{2}$ miles, the northern one being nearly twice as long as the southern one, and including the maximum depth of the loch—754 feet. The

northern basin is $6\frac{1}{2}$ miles in length, and distant about $2\frac{3}{4}$ miles from Torr point, while the southern basin is $3\frac{1}{2}$ miles in length, and nearly 6 miles distant from Fort Augustus. The maximum depth recorded in the southern basin was 739 feet near the southern end of the basin, while towards the northern end of the basin a depth of 735 feet was recorded, the intervening soundings being slightly shallower.

These details show how extremely symmetrical Loch Ness is in all its bathymetrical characteristics. All the contour-lines, except the deepest one, approach rather closer to the southern than to the northern end of the loch, but in the case of the 700-foot contour this is reversed.

The shore-slope on both sides of the loch is nearly everywhere steep. Gradients exceeding 1 in 1 are of frequent occurrence, and in certain places the slope approaches the precipitous. Near the southern end of the loch, off the south-western shore at the entrance of the river Oich, a sounding in 204 feet was taken about 100 feet from shore, but the steepest slopes were observed off the north-eastern shore in the vicinity of the Horseshoe craig, where a sounding in 236 feet was taken about 100 feet from shore; another in 175 feet about 50 feet from shore; and, off what is known as the Cormorant rock, a sounding in 206 feet was taken about 50 feet from shore. This last-mentioned sounding gives a gradient exceeding 4 in 1, or an angle of about 15° from the perpendicular.

The steep shore-slope is further seen by the manner in which the contour-lines of depth as a rule hug the shores, leaving a comparatively very large area of the lake-floor along the central line of the loch covered by very deep water. This is strikingly shown by the fact that nearly one-half of the entire basin is covered by more than 500 feet of water, and over one-third by more than 600 feet of water. In the following table are given the approximate areas in acres between the consecutive contour-lines drawn in at equal intervals of 100 feet, and the percentages to the total area of the loch:—

Feet.	Acres.	Per cent.
0 to 100	1892	13.6
100 „ 200	1340	9.6
200 „ 300	1610	11.6
300 „ 400	1121	8.0
400 „ 500	1329	9.5
500 „ 600	1627	11.7
600 „ 700	2461	17.7
Over 700	2556	18.3
	<hr/> 13,936	<hr/> 100.0

This table brings out several interesting peculiarities when compared with the similar tables published for the other large Scottish lochs. The most remarkable point is that the two deepest zones are larger than any of the other shallower zones, the deepest zone of all, though the interval between the 700-foot contour and the maximum depth is only half the usual interval between the contour-lines, being the largest of all. Such a distribution of the depth-zones has not been observed in any other loch, and is a reversal of the usual rule of the shallowest zone being the largest one, though one or two exceptions to this rule have been recorded, as, for instance, in Loch Treig, where the zone between 200 and 300 feet is larger than either of the two shallower zones, and in Loch Lochy, where the zone between 100 and 200 feet is a little larger than the shore-zone. In the deepest of all Scottish lochs, Loch Morar, the shore-zone is equal to 42 per cent. of the total area, and the second zone between 100 and 200 feet is equal to 13 per cent., while of the deeper zones not one exceeds 9 per cent. of the total area. In Loch Lomond, again, the shore-zone is equal to 68 per cent. of the entire area, and the second zone between 100 and 200 feet is equal to 16½ per cent., while the deeper zones are in each case less than 6 per cent. In Loch Erich the shore-zone is equal to 34 per cent., the second zone between 100 and 200 feet is equal to 25 per cent., and the third zone between 200 and 300 feet is equal to 19 per cent. of the total area, the deeper zones in each case not exceeding 10 per cent. In Loch Tay there is a regularly decreasing percentage in the zones of depth from the shore into deep water, the numbers for each zone at intervals of 100 feet being respectively 30, 23½, 21, 15½, 9.