

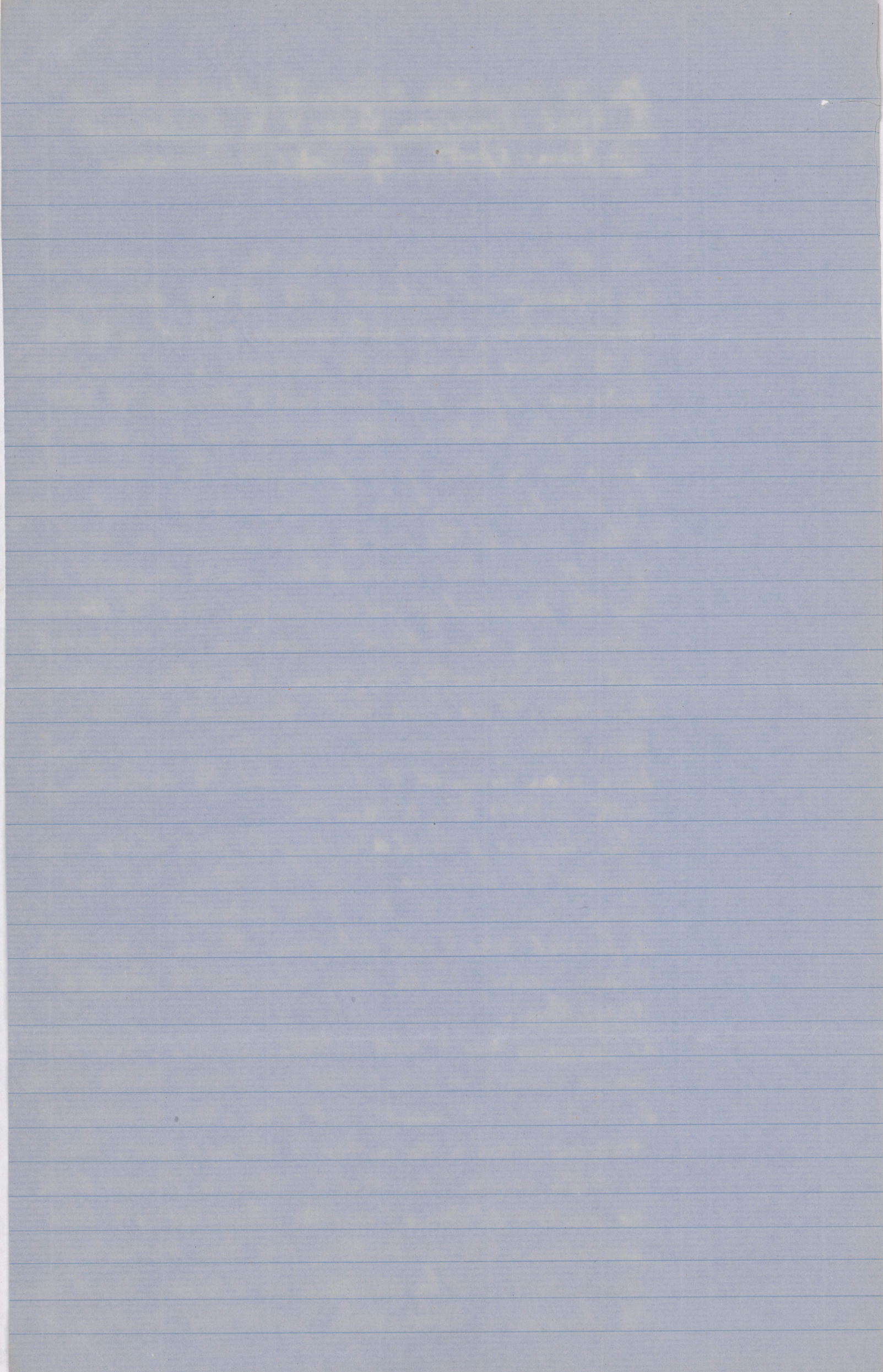
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On the connection between the fluctuations of
the Great American Lakes & the development
of Sun-spots. By George M. Dawson.

In the course of an investigation undertaken in my capacity as geologist to the B.N.A. Boundary Commission, as to late changes of level in the lake of the Woods bearing on the accuracy of certain former surveys; I found it desirable to tabulate the better known fluctuations of the Great Lakes for a series of years as a term of comparison. The observations of secular change in L. Erie are the most complete, & these when plotted out to scale showed a series of well marked undulations which suggested to me the possibility of a connection with the 11-yearly periods of Sun-spot maxima. A comparison with Mr Carrington's diagram of the latter confirmed this idea, & as I do not remember to have seen these phenomena connected previously, I have been induced to draw out the reduction of both curves here presented.

The changes of level affecting the Great Lakes are classed as follows by Col Whittlesey, who has given much attention to the subject.

1. General rise & fall extending through a period of many years, which may be called the Secular variation.
2. Annual rise & fall within certain limits the period of which is completed in about twelve months.
3. A sudden, frequent, but irregular movement varying from a few inches to several feet. This is of two kinds, one due to obvious causes such as winds & storms; another described as a slow pendulum-like oscillation, has been somewhat fully discussed by Whittlesey in a paper read before the American Association at its last meeting, &



is due probably to barometric changes in the superincumbent atmosphere.

The first class is the only one, ^{directly} included in the present enquiry.

The curve for Lake Erie from 1788 to 1857 inclusive, is plotted from observations collected by Whittlesey, & given most fully in his memoir in the Smithsonian Contributions to Knowledge for 1860. From 1788 to 1814 there are no accurate measurements to any well recognised datum line, & I therefore give below the measurements & approximations on which the general curve for these years has been constructed. The description of the fluctuation of the lake will be seen in many cases to apply with verbal accuracy to the Sun-spot Curve.

1788 to 90. By traditions derived from the early settlers very high; according to some as high as 1838 but this is doubtful.

1796. By the first emigrants & surveyors reported as very low - five feet below 1838.

1797. Rising rapidly.

1798. Water continues to rise, but three feet below June 1838.

1800. Very high, old roads flooded.

1801. Still high.

1802. Very low; reported by old settlers as lower than 1797.

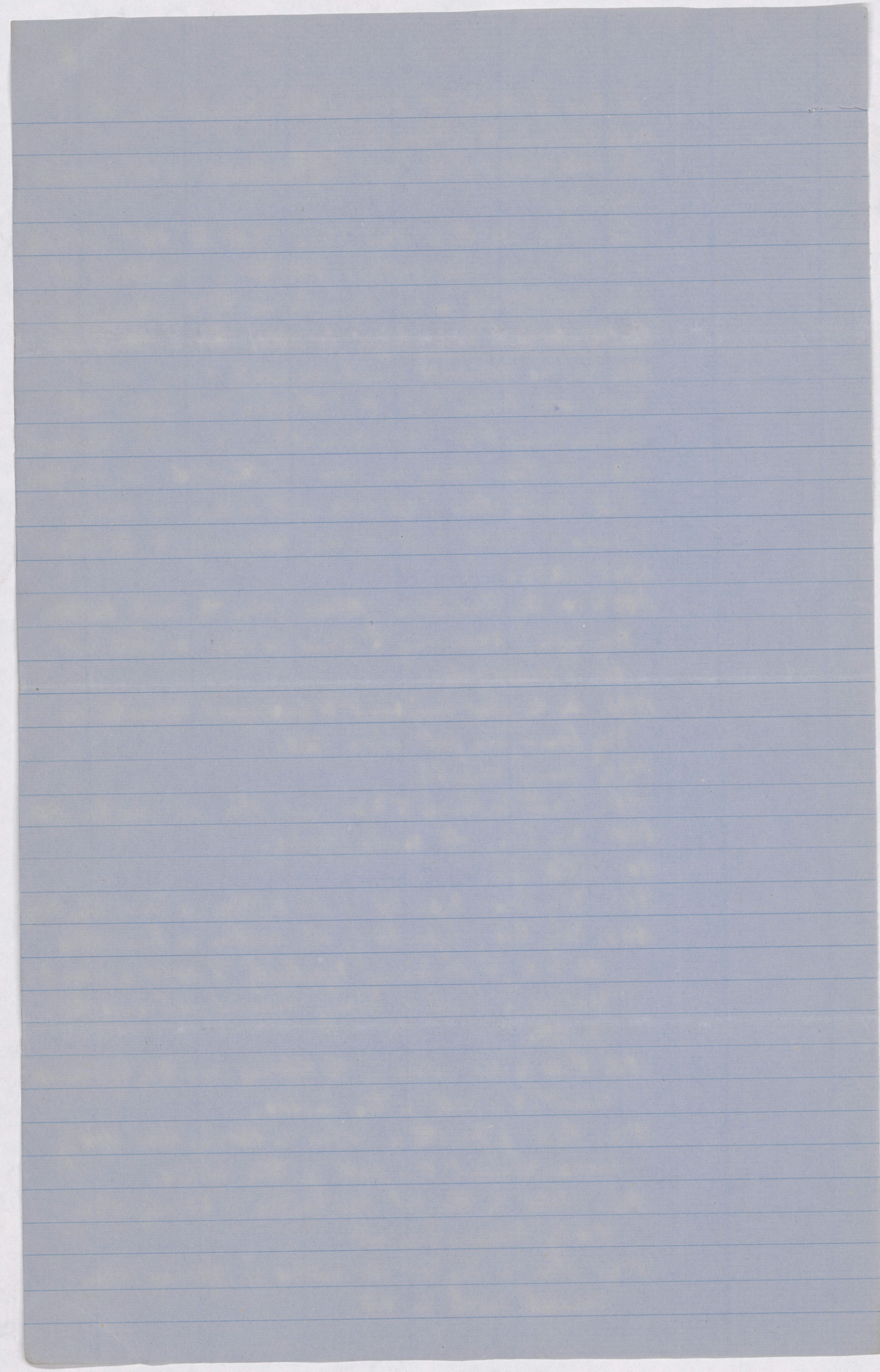
1806. Very low; reported by old settlers as lower than 1801 & 2, & declining regularly to 1809 & 10, when it reached a level by many regarded as low as that of 1819.

1811. Rise of six inches in the spring over 1810, by measurement, & a fall of two inches.

1812. Rise of fourteen inches in spring over 1810 by measurement & a fall of three inches.

1813. Rise of two feet two inches in spring over 1810 by measurement

1814. Rise of two feet six inches in spring over general level of 1813.



From 1815 to 1833 both inclusive, occasional measurements to fixed data exist; the supplementary notes are here given.

1815. Rise of three feet above average level of 1814.

(This statement is not confirmed by an actual measurement made in August & is probably exaggerated)

1816. Water still high but falling & continued to fall till 1819.

1819. Lowest well ascertained level of the waters in L. Erie.

1820. Stated to be in August as low as 1819.

1821. Rising

1822. Rising; in the spring four feet below June 1838.

1823. Rising; in the spring three feet three inches below 1838.

1824. Rising; gradually.

1825. Rising; lowest level three feet below June 1838.

1826. Rising; lowest level two feet ten inches below June 1838.

1827. About the general level of 1815.

1829. Water still rising

1830. General level same as 1828.

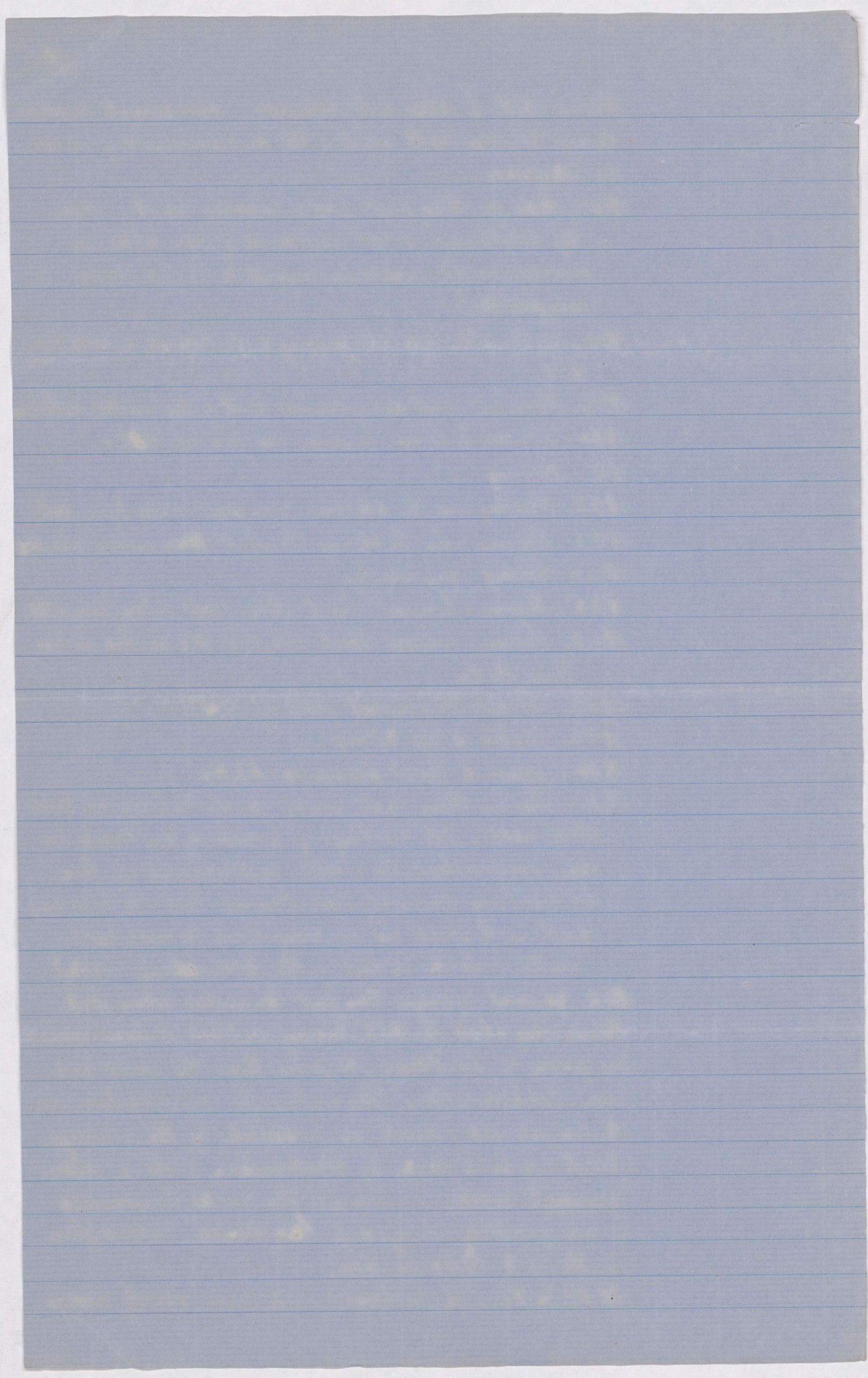
1831. Lower than last year, yearly change at least three feet. Col Whiting. (probably an error as this would place the water unprecedentedly low.

Col Whiting probably ascertained that the lake was falling & erred in taking some former high water mark for that of the preceding year.)

1832. General average two feet ten inches below 1838.

From this date to 1857 many actual measurements are given by Whittelsey, & from these the curve has been constructed. The whole of the observations are reduced as nearly as possible to the average level for each year by comparison with a mean annual curve for about ten years constructed from monthly averages of six-five-day means given by the U.S. Lake Survey.

1859 to 69 both inclusive are from yearly means



derived from continuous observations at Charlotte by the U. S. Lake Survey, 1871 to 73 are from information kindly furnished by General Comstock director of the Survey.

The curves for Lakes Superior & Ontario for the same years are constructed on data from the same sources & have been reduced to yearly averages in a similar way.

The observations of our fiddings on St. Ontario from 1815 to 1827 as given by Whittelsey, are not represented. He only noted extremes but an approximate line of means with reference to these shows a tolerably close resemblance to the Erie Curve.

The earlier & less systematic observers of the fluctuation of the lakes would scarcely give attention to any but the more important changes of level, but it is improbable from the number of observations which have come down to us, that any variations of importance escaped them.

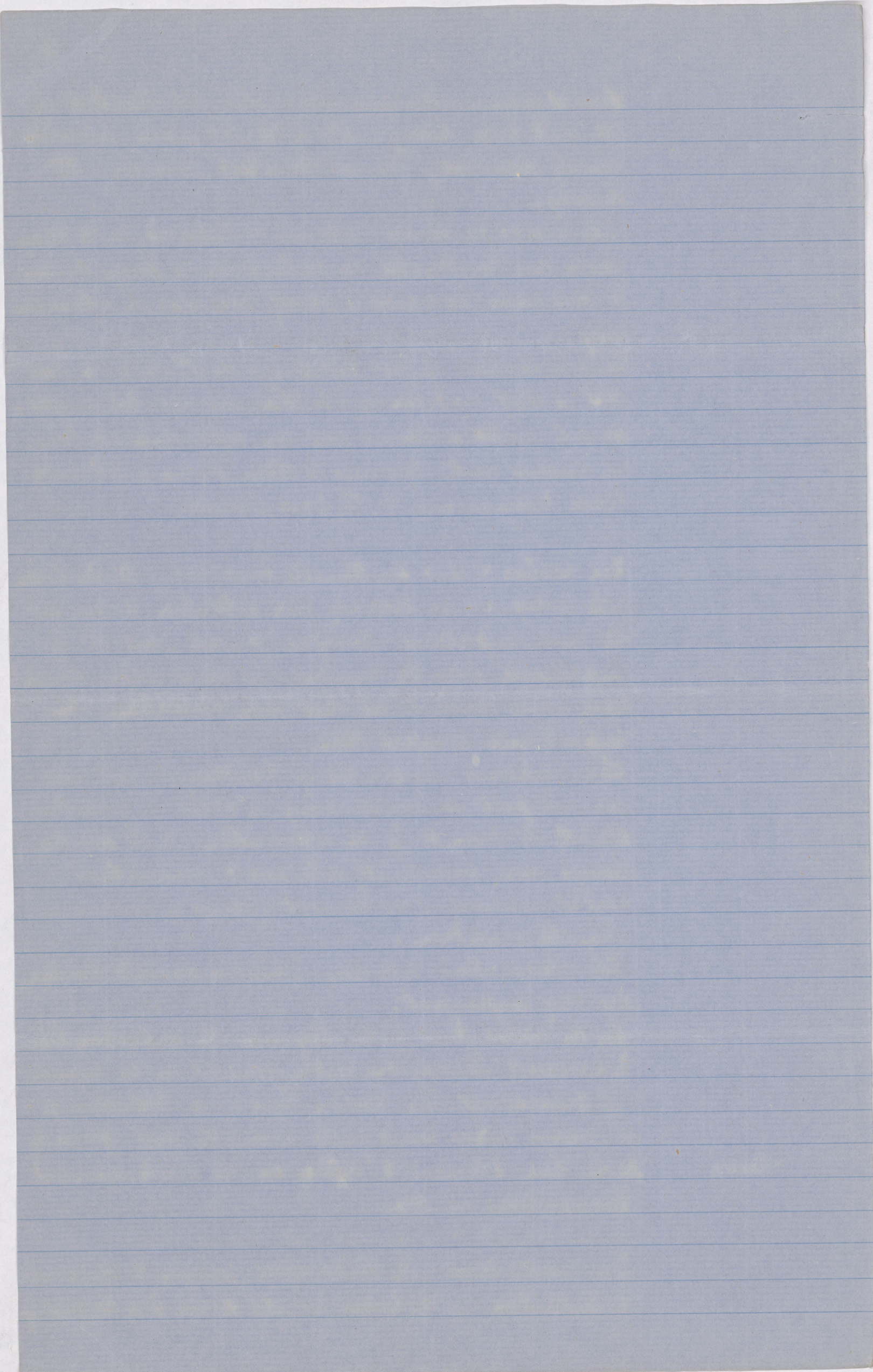
Lake Superior, as stated by Whittelsey, is the only one of the great Lakes showing the effect of conditions strictly its own, & if the observations of its secular change were sufficiently extensive & accurate, it might probably offer the best gauge of change in climatic conditions.

The observations relating to Lakes Huron & Michigan are very imperfect.

In the upper part of the diagram the unbroken line represents Carrington's Curve founded on the number of Sun-spots. The broken line is a reduction of a mean curve based on the area of the spots, given by De La Rue, Stewart, & ^{Loewy} in the Philosophical Transactions for 1870.

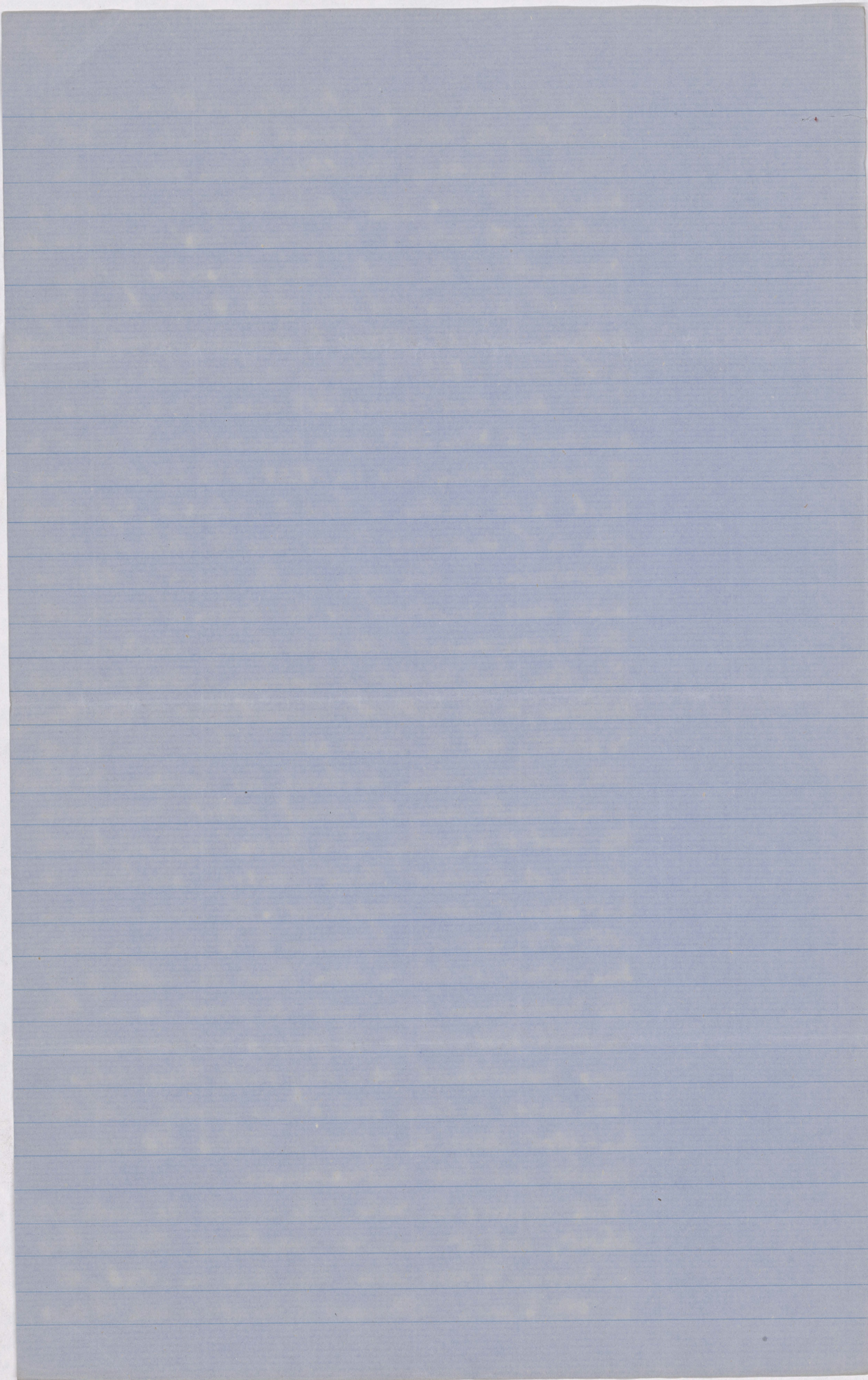
+Loewy

The coincidence of the Solar-spot periods & the periods of fluctuation of the lakes would seem to be sufficiently



Close to open a very interesting field of enquiry. The latter often seems to precede the former a little, as though the activity resulting in an increase of Sun-spots was first exhibited by an increase of water in the lakes. The first Maxima of Sun-spots represented in the table, being separated by long intervals of years with few spots, & not being very intense, would appear to have been closely followed by L. Erie. 1837, the year of greatest intensity according to both Sun-spot curves (333 new groups of spots according to Schwabe) was marked in its effect on the lakes, giving rise in 1838 to the highest-known level of the waters of Erie & Ontario, & probably also in L. Superior though here the data are not so certain. The high water mark of 1838 has since been employed as the datum to which all the measurements of the Lake Survey are reduced. The three last periods of Maxima of Sun spots are extreme, & the intervals characterized by their deficiency so short, that the lakes seem to have been hardly able to follow them so closely as before. One period of high water being to a great extent merged in the next & resulting in a general high state of the lakes for the last thirty years. The lakes do not seem to have responded to the maximum of 1857-59, but by a reference to the curve of Area of Sun-spots it will be seen that the intensity of this maximum was not so great as in those on either side of it, & the period of maximum was maintained for a very short time only. The Curve for Lake Erie shows equally with the Sun-spot Curve the effect of Wolf's 56 year period of Solar disturbance.

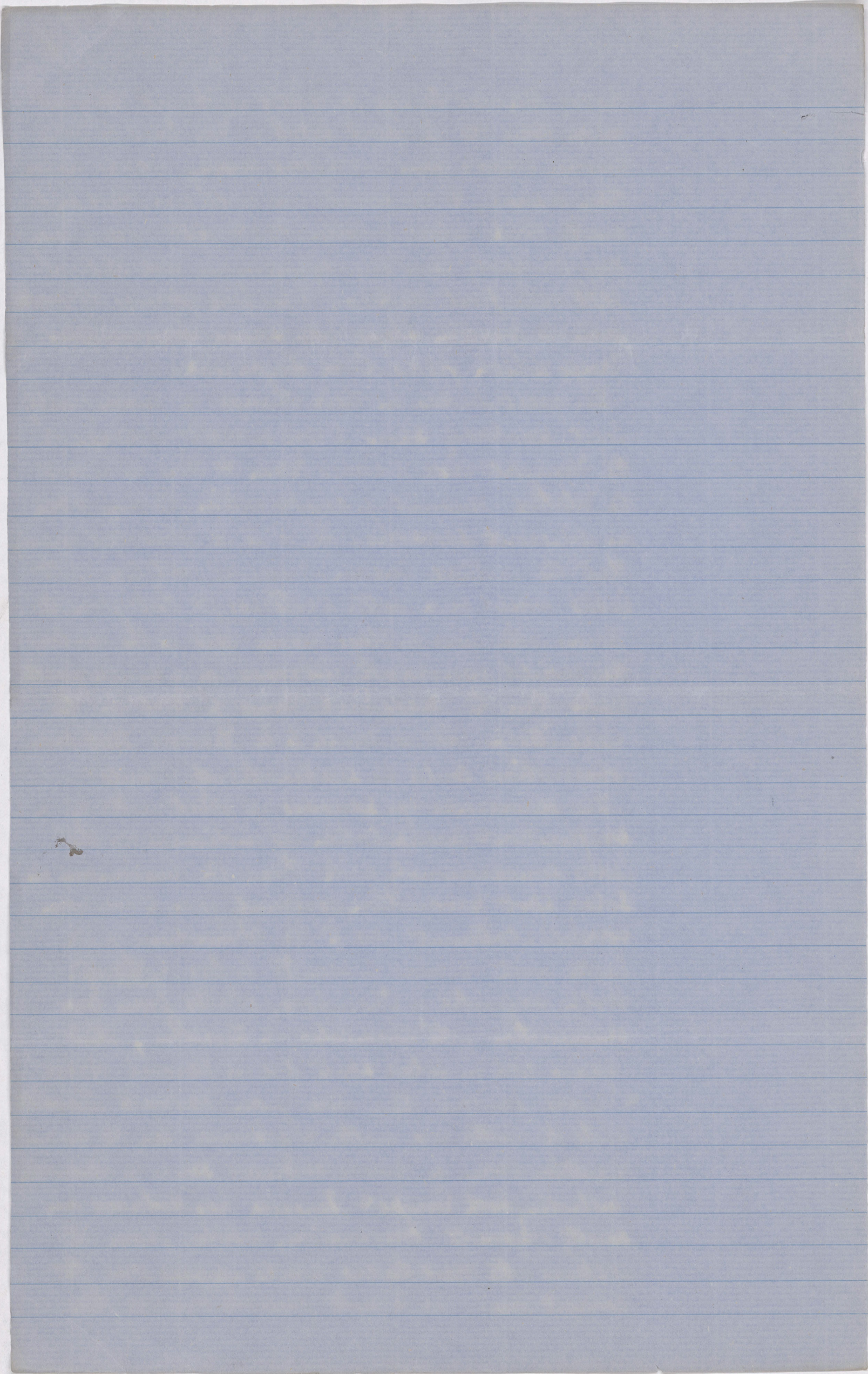
With regard to the Lake of the Woods the data are slight, but it may be mentioned that the lake is known to have been very low in 1823, & in 1859 to have attained a point which it has



never touched since, & which is about three feet higher than the present level. The lake is also known to have been for a good many years higher than usual, & at least one well marked high water took place between 1828 & 1859 which may very probably have been synchronous with that of 1838 on the great Lakes. This lake derives its waters from the western slope of the same Laurentian range which feeds Lake Superior.

The great Lakes in their change of mean yearly level probably show a very correct average of the rainfall over a large area & thus indicate the relative amount of evaporation taking place in different seasons. It is to be observed however that the actual mean annual outflow of the Lakes would be a better criterion, & that from the forms of the river valleys giving exit to the waters this would necessarily increase in a much greater ratio than the measured change of level in the lake itself. It is much to be desired that such observations could be systematically made.

The occurrence of seasons of great activity of evaporation & precipitation as indicated by the lakes synchronously with those of maximum in solar spot production, certainly goes to confirm Herschel's statement as to the coincidence of the latter with periods of greater solar activity. Wolf, as quoted by Chambers, states from an examination of the chronicles of Zurich; "that years rich in solar spots are in general drier & more fruitful than those of an opposite character, while the latter are wetter & stormier than the former". Saundries, from a more extended series of observations including both Europe & America has deduced an exactly opposite conclusion, which, from the evidence of the great Lakes would appear to be the correct one. It is quite possible however that



both may be true. The Great Lakes lying at the base of the Laurentides where moisture bearing winds from the Southward & Westward are interrupted in their course & meet with cold currents pouring over these hills from the North, are essentially in an area of precipitation, & greater precipitation would be the natural result of greater solar energy. In other regions excessive evaporation may result from the same cause, & this may account for the gradual desiccation observed to be going on at present in many parts of the great inland plains of the West.

The study of the fluctuations of the lakes would thus seem to promise, by furnishing an average on a very large scale, the foundation of that desideratum in Meteorology, a world-wide cycle.

its tendency

It is unnecessary to point out the action of increased evaporation in removing heat from the surface of the earth, & in so doing to prevent the extremes of temperature due to periods of Equilibrium solar activity being so sensible. The connection between increased evaporation & rainfall & electrical phenomena including Auroræ & several Sabine's periods of Magnetic Variation will also be apparent.

Illustrations
of St. Peter's
Original Form