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TREASURY DEPARTMENT

U. S. COAST AND GEODETIC SURVEY

U. S. COAST AND GEODETIC SURVEY.

Henry S. Pritchett, Superintendent.

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DESCRIPTIVE REPORT.

Topographic Sheet No. 2171

LOCALITY:

Establishment of the U. S. Naval Observatory Circle and the Determination of the Geographical Position of the Center of the Clock-Room

1896.

CHIEF OF PARTY:

E. D. Preston, Assistant

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1897

TREASURY DEPARTMENT

U. S. COAST AND GEODETIC SURVEY

W. W. DUFFIELD
SUPERINTENDENT

GEODESY

ESTABLISHMENT OF THE U. S. NAVAL OBSERVATORY CIRCLE AND THE DETERMINATION OF THE GEOGRAPHICAL POSITION OF THE CENTER OF THE CLOCK ROOM

By E. D. PRESTON, Assistant

APPENDIX No. 6—REPORT FOR 1896

WASHINGTON
GOVERNMENT PRINTING OFFICE
1897

APPENDIX No. 6.—1896.

ESTABLISHMENT OF THE UNITED STATES NAVAL OBSERVATORY CIRCLE, AND THE DETERMINATION OF THE GEOGRAPHICAL POSITION OF THE CENTER OF THE CLOCK ROOM.

By E. D. PRESTON, Assistant.

On the 1st day of August, 1894, a joint resolution of Congress was approved, which provided for the establishment of a circle around the United States Naval Observatory. The said act was embodied in public resolution No. 36, and was entitled:

Joint resolution to establish an observatory circle as a provision for guarding the delicate astronomical instruments at the United States Naval Observatory against smoke or currents of heated air in their neighborhood, and undue vibrations from traffic upon the extension of public thoroughfares in the vicinity, and for other purposes.

Section 10, of the act just cited, reads as follows:

That the said appraisers are hereby authorized to call upon the Superintendent of the Coast and Geodetic Survey to make such surveys as may be necessary to carry into effect the provisions of this act, and the said Superintendent is authorized and required to make such surveys under the direction of the said Commissioners.

The appraisers named by the honorable Secretary of the Navy, and under whom the survey was undertaken and carried out, were Hon. John W. Ross, chairman of the Commissioners of the District of Columbia; Mr. T. E. Waggaman, and Capt. F. V. McNair, U. S. N., Superintendent of the Naval Observatory. I was most efficiently aided in the field and office work by Messrs. J. B. Boutelle and C. C. Yates, of the Coast and Geodetic Survey.

The provisions of the joint resolution, briefly stated, were as follows:

A circle with the centre coinciding with the centre of the clock room and with a radius of 1 000 feet was to be established and described on the ground. All that portion of the original Naval Observatory property lying outside the said circle was to be sold, and all that land lying within the said circle and not then belonging to the United States was to be acquired by purchase. The methods by which these transfers were to be made, as well as the steps to be taken in case of non-agreement as to price between purchasers and sellers, and other possible contingencies, are well defined in the act of Congress. They form, however, no part of the work undertaken by the Coast and Geodetic Survey, and are entirely without the province of this service. The present paper, therefore, has for its object a brief account of the method employed in laying out the circle, a statement of the accuracy attained in the final results, and, as incident thereto, a new determination of the position of the centre of the clock room, which is the initial point of longitudes for the United States.

Several methods were suggested for the establishment of the circle. The first one was simply to select that radius of the proposed circle which lay over the most level part of the grounds, determine one point of the circumference by direct measurement, and run in the entire circle by the ordinary method of tangents, as employed by railroad engineers. This did not appear feasible, or at least did not seem capable of giving a high degree of accuracy in the results, without extraordinary care, on account of the extremely abrupt nature of the topography of some parts of the circle. Moreover, this method had already been employed by some surveyors a few years ago, and the closing error was given as 1 foot. It was desirable to mark the boundaries more closely than this. Besides, a different method of getting at the same results would check the previous determination and give increased confidence in the work.

The second method proposed was that of using a tapeline of 100 feet length as a telemeter and determining its distance by measuring the angle subtended at the centre of the circle. Four such distances were to be fixed, and the intervening quadrants were to be established by the ordinary way, already mentioned. This plan, although elegant in conception, when examined closely did not turn out to be practicable. In the first place, because it would have involved cutting a number of lines through the beautiful groves of the Observatory, and secondly, because it required a very high degree of accuracy for the measure of the angles at the centre.

A simple geometrical construction shows that the uncertainty in the length of one of the radii is about twenty times that of the angular measures at the centre: or, using the formula for finite differences,

$$\triangle b = \frac{-a \sin \triangle C}{\sin (C + \triangle C)}.$$

it appears that an error of 1 second in the angle (C) at the centre would imply an error of about one-tenth of a foot in the distance (b) from the centre; a is taken as 1 000 feet, the radius of the circle; the value of C for this particular case is $2^\circ\ 51'\ 57''.5$, this being half the angle subtended by a chord of 100 feet on a circle of the dimensions given. Besides, since 1 second on the circumference of a circle of this radius is in the neighborhood of one-sixteenth of an inch, the pointings with the telescope must define the limiting lines of the telemeter to this degree of accuracy, which would require an instrument capable of supporting a power greater than was then available. Moreover, it would have been a difficult matter to keep the tapeline at a known length within one-sixteenth of an inch. Although quite easy under favorable conditions, in the present case the precautions necessary as regards temperature, tension, inclination, etc., would have made the operation a troublesome and unsatisfactory one. It was therefore evident that by this method the uncertainty of the length of the radii of the circle would be about a quarter of a foot.

The third method (see Pl. I), which was adopted, consisted in inscribing a decagon within the proposed circle, making the apices of the angles at the centre coincident with the centre of the clock room, and the exterior sides as near to the circumference as the configuration of the ground would admit. It was desirable to have all the corners of the decagon near and within the circle; in two cases, however, in order to get intervisibility, it was necessary to place the stations a short distance outside the circle, and in others, to avoid building exceptionally high signals, the points were located considerably inside the circumference. But these distances were not so great that their measurement involved errors greater than would necessarily ensue from the instruments and methods employed in the triangulation. One of the exterior sides of the decagon was measured as a base line. Three angles were measured in each triangle, and the triangulation was carried around to close on the original line. Owing to the fact that two of the exterior points (H and I) were not intervisible, the point I was determined in two ways, which supplied a check equal in point of accuracy to that accorded any of the other stations. The station at the centre was on a scaffold 20 feet high, built over the clock room, and having the point of occupation vertically over the centre of the room. By this procedure the greatest uncertainty in the lengths of the radii did not exceed three-hundredths of a foot.

The following were the angles at the centre adjusted for station error:

	°	′	″
AOB	25	54	36.7
BOC	39	17	27.0
COD	35	27	10.0
DOE	35	40	35.4
EOF	29	04	58.5
FOG	27	15	31.5
GOH	41	09	36.0
HOI	36	58	54.0
IOK	70	18	49.3
KOA	18	52	21.6

Additional angles for the determination of the position of the centre of clock room by the three-point problem were measured as follows:

	°	′	″
Capitol to Monument	17	14	07·3
Monument to Fairfax Theological Seminary	48	43	34·5

BASE LINE.

The base line was measured with a steel tape 100 feet in length, supported at eight points under a tension of 5 kilogrammes. After correcting for inclination, temperature, and tension, the following results were obtained:

Length of base.

	Ft.
1st measure	444·798
2d "	·809
3d "	·802
4th "	·803
5th "	·803
Mean	444·803 ± 0·001

The following corrections were applied:

For inclination $\frac{(\text{Difference in height})^2}{\text{Twice the distance.}}$

For temperature 0·000011 per degree Centigrade.

For tension 0·013 feet per tape length.

The above table shows that any one of the five measures is sufficiently accurate for the triangulation which it was intended to construct upon the base line. It is, however, but a reassertion of a fact many times established that it is much easier to attain high accuracy in linear measurement than it is to preserve it in the angular measurement of geodetic work.

The following were the resulting lines in the different triangles:

Radial sides.		Exterior sides.	
O to *A*	993·87	*A* to *B*	444·80
B	990·21	*B* *C*	662·52
C	980·22	*C* *D*	570·84
D	849·62	*D* *E*	585·05
E	1 001·22	*E* *F*	500·07
F	990·03	*F* *G*	454·89
G	916·43	*G* *H*	637·48
H	896·31	*H* *K*	1 538·59
I	903·50	*I* *K*	1 106·62
K	1 012·20	*I* *A*	1 333·62
		K *A*	329·42

The average correction to an angle at the center to close the horizon was 0″·16, while the average correction to an angle to close the triangles was 2″·1. It should be stated here that different instruments were employed in the two cases. The angles at the center were measured with theodolite No. 140 (8″ diam.), reading to 2 seconds. The exterior points were occupied with theodolite No. 156 (6″ diam.), reading to 5 seconds; moreover, the measures were not made by the same observer. Since one of the sides is about 330 feet in length, an error of 2″ in an adjacent angle would imply an inaccuracy of centering and pointing not greater than one-twenty-fifth of an inch. There are few signal poles used in triangulation that will give the same centre to this degree of precision when observed from different sides, so that an error of a few seconds was quite within unavoidable discrepancies.

The average length of a radial line is 953 feet; the average exterior side is 742 feet long. The side of a triangle is then, say, approximately 850 feet. Two seconds being about 1-100 000 part of the radius, we might expect in each new base an error of less than one one-hundredth of a foot from angular errors in its own triangle; but there would be some compensation of errors in the continuous development of the scheme of figures.

As a matter of fact, we may readily calculate the error to be expected in the last or closing side from the known probable errors of the base and measured angles. Applying the usual formula

$$r_a^2 = \left(\frac{a r_1}{b}\right)^2 + a^2 r_2^2 \sin^2 1'' \, \Sigma \, (\cot^2 B + \cot^2 A)$$

where a and b are the lengths of the last side and base, and where A indicates angles opposite the required sides and B those opposite the given sides, and where r_1 and r_2 stand for the probable error of the base and of an angle, respectively, we find a resulting probable error of 0·02 feet from both base line and angle measures. That of the base line is, however, without significance when compared with the uncertainties in the angle measures.

The actual discrepancy found agrees sufficiently well with this, and we may therefore conclude that an accuracy has been attained in the final result commensurate with the precision of the instruments employed and in reasonable accord with the method of observing.

If we start from the measured base A B with length of 444·80 feet, and carry the computation around the decagon to close again in the same line, we derive a value for A B of 444·79 feet. This circuit is by the most direct way, and ignores for our present purpose the point I, as well as the figures K O I and A O I. If, however, we carry the computation by the same route around to the line K O and then set out from the base again and proceed in the opposite direction, meeting the previous computation on the line K O, we get a discrepancy of 0·03 feet. This might have been expected, since the probable error of the last side, as we see from the formula, is a function of its length.

If we calculate the error to be expected in this line from the known probable errors of the base line and the angular measures, we get 0·04 feet, which is also practically the discrepancy found. As the computation was carried to the third decimal place only, a difference in results of one unit in the second place may occur through loss by decimals. We may therefore give 0·03 feet as the greatest uncertainty of any of the radii of the circle.

With the establishment of the Observatory Circle arose the necessity for an accurate survey of the original property. This was done in October, 1894, all the original points being recovered, and the astronomical azimuth of the sides being determined by connection with the side O C of the triangulation.

The bearings of the lines, together with the distances, are given in Pl. I.

The following table of areas shows the superficial contents in the various divisions adopted:

Contents in acres to be bought (additive) or sold (subtractive).

		+	—
Plat I (north and east of Mass. Ave.)			14·449
Massachusetts avenue (triangle 2)	0·184		
" " " 1	0·162		
" " Curve	3·355		
" " Southeast	3·164		
	6·865		6·865
Plat II (south and west of Mass. Ave.)			1·218
Normanstone		1·732	
Plat III (south of circle)			1·706
Weaver North of avenue	0·034		
South of avenue	8·398		
Avenue	0·213		
	8·645	8·645	
Barnes		0·389	
Young		0·714	
Avenue South of Barbour	0·066		
Barbour	0·359		
	0·425	0·425	
Industrial Home		6·764	
Dumbarton		7·895	
		26·564	24·238
		24·238	
Amount to be added		2·326	
Area of original tract		69·795	
Area of circle		72·121	

At the request of the Navy Department, Plot I, lying north and east of Massachusetts avenue, was subdivided into 31 lots, as shown in Pl. I. The approximate dimensions were furnished by Capt. F. V. McNair, and the boundaries were traced on the ground and permanently marked by heavy stakes. This plot was subsequently rearranged by the Department into three subdivisions. The bearings and distances of the two arrangements are on file in the archives of the Survey.

As a matter of curiosity it may be stated that in disposing of this land the Department was forced to name the price of one of the subdivisions to eight decimal places.

The two conditions imposed were that Subdivision B, together with Lots XI to XVIII, i. e., 4·25 acres, should be sold for 30 cents per foot, and to satisfy certain other conditions the total area of 14·45 acres should be sold for \$141 454·27. These conditions being rigid, the remaining 10·20 acres had to be disposed of at \$0·19336765 per square foot.

THE DETERMINATION OF THE POSITION OF THE NAVAL OBSERVATORY.

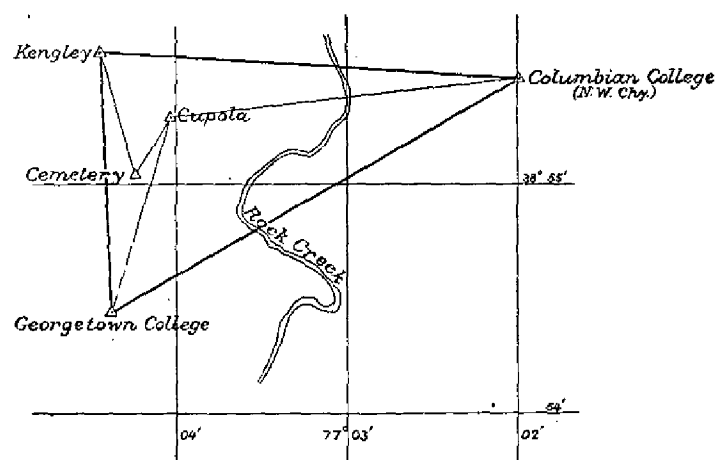
The occupation of the center of the clock room made it possible to make an independent determination of the initial point for longitudes in the United States. Three prominent triangulation points of the Coast and Geodetic Survey were visible from this station, which enabled us to fix the position by the three-point problem with a very short series of observations.

Each pointing at the center was made in three positions of the circle 120° apart with two series in each position; one series consists of a pointing with telescope direct, and one with telescope reversed, so that each angle was given twelve independent measures. The facility with which this last determination was made, as well as the accuracy of the results, seems to warrant a statement here of the different determinations.

I.

In July, 1881, Mr. F. O. Doun, under the direction of Mr. Charles Junken, of the United States Coast and Geodetic Survey, made a triangulation to determine the proposed site of the new Naval Observatory. It was based on the known points, Kengley, Columbian College, and Georgetown College, as shown by the following sketch:

No. 1



Scale $\frac{1}{60000}$

The adjustment of this work gave two angle equations and one side equation, from which the position of the cupola on the old house standing at the time near the present Observatory was

$$\varphi = 38^\circ\ 55'\ 17''\cdot46$$
$$\lambda = 77^\circ\ 4'\ 1''\cdot80$$

By subsequent linear measurements, Prof. William Harkness connected the position of this cupola with the center of the clock room. These give as the result of Junken's triangulation:

$$\begin{array}{lrrr} & ^\circ & ' & '' \\ \varphi= & 38 & 55 & 17{\cdot}01 \\ \lambda= & 77 & 04 & 2{\cdot}22 \end{array}$$

II.

In 1893 Prof. William Harkness determined the position of the new Naval Observatory, by means of a small 4-inch theodolite, reading to 20 seconds of arc. The following stations were occupied:

New Naval Observatory, center of small dome.

Old Naval Observatory, center of small dome.

Soldiers' Home, center of southwest turret of tower.

The following sketch (No. 2) shows the relative poitions:

Professor Harkness kindly furnished a copy of his observations to the Superintendent of the Coast and Geodetic Survey, and from them Mr. Schott has deduced the position of the new Naval Observatory, employing in the adjustment one angle equation and four side equations.

The position from these observations is

$$\begin{array}{lrrr} & ^\circ & ' & '' \\ \varphi= & 38 & 55 & 17{\cdot}03 \\ \lambda= & 77 & 04 & 2{\cdot}25 \end{array}$$

III.

In 1894 the occupation of the clock room in the prosecution of the work connected with the Observatory circle furnished an occasion for a new determination of the geographical position of the new Observatory, and three known points of the triangulation of the Coast and Geodetic Survey were incidentally included in the regular series of angle measurements.

The following sketch (No. 3) shows the relative positions of the points used and of the point of occupation:

These data were also submitted to Mr. Schott, who deduces the following result from the position sought:

$$\begin{array}{lrrr} & ^\circ & ' & '' \\ \varphi= & 38 & 55 & 17{\cdot}05 \\ \lambda= & 77 & 04 & 2{\cdot}25 \end{array}$$

We then have for the geodetic position of the new Naval Observatory the following results:

Derived from—	Observer.	ϕ	λ	Date.	Remarks.
		$''$	$''$		
5 trig. pts.	Junken.	17·01	2·22	1881	6-inch theod. reading to 10″. Triang. 2 angle and 1 side equations.
7 trig. pts.	Harkness.	·03	2·25	1893	4-inch theod. reading to 20″. Triang. 1 angle and 4 side equations.
3 trig. pts.	Preston.	·05	2·25	1894	8-inch theod. reading to 2″. Three-point problem.

The position of the new Naval Observatory (center of clock room) has been determined astronomically by Professor Eastman, and the results are given in Astronomy and Astro-Physics (vol. 12, p. 699). Giving the work a differential character and basing his results on previous determinations of the old Naval Observatory, Professor Eastman arrives at the following results:

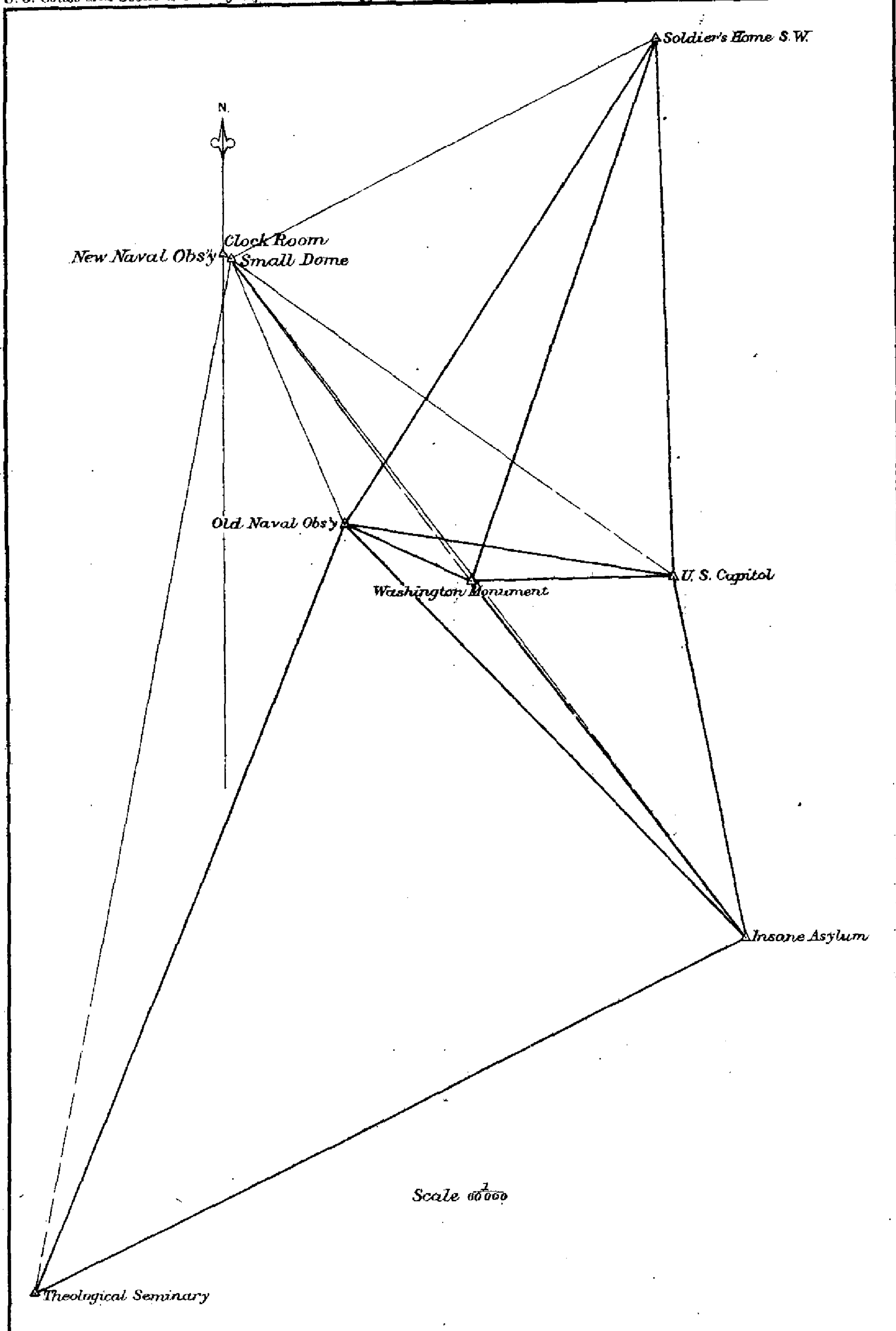
$$\varphi = 38^\circ\ 55'\ 14''{\cdot}68$$
$$\lambda = 5^h\ 8^m\ 15{\cdot}71^s = 77^\circ\ 3'\ 55''{\cdot}65$$

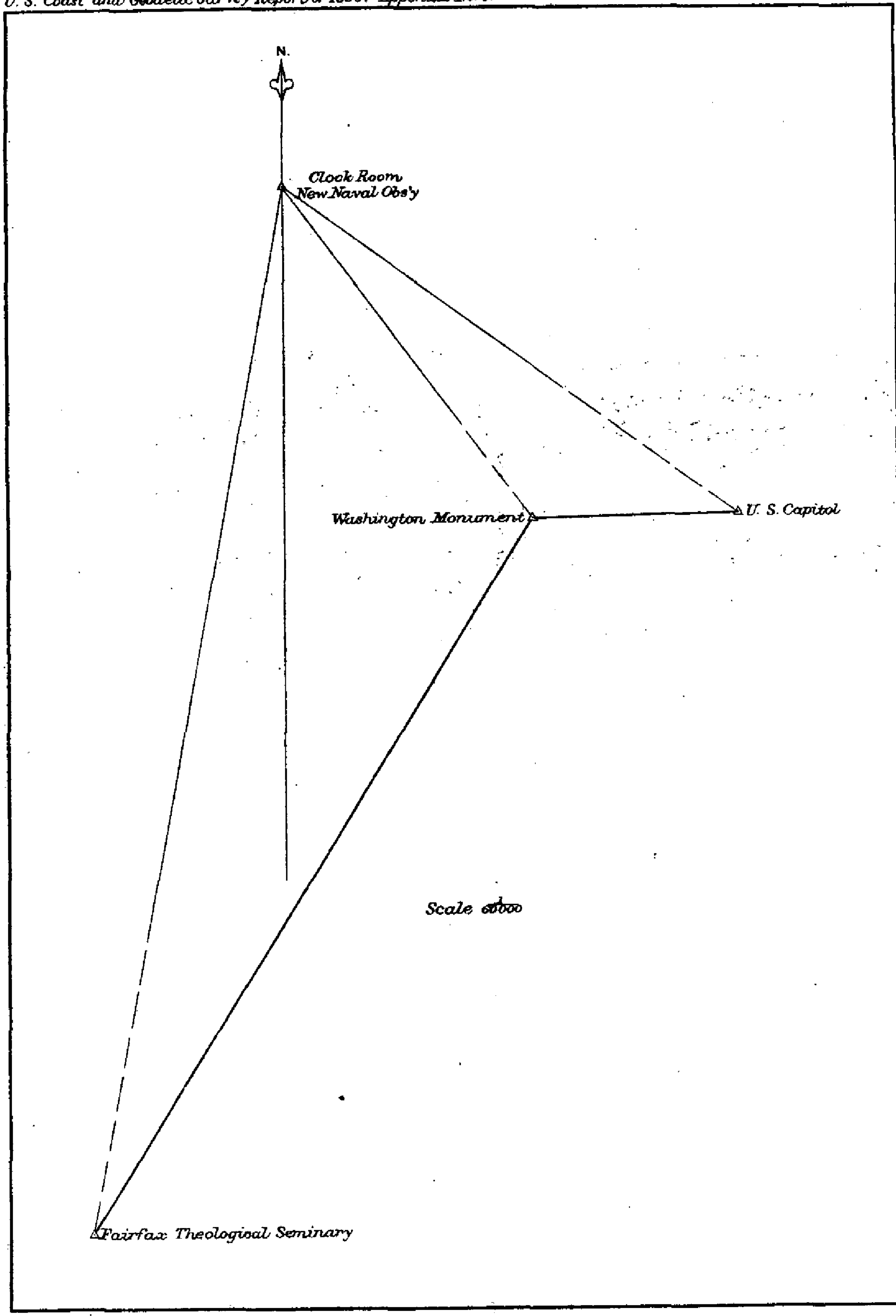
Comparing these with the mean of the geodetic determinations already given, and assuming that the deviations of the vertical are the same in amount and direction at the two stations, we have a deflection of the zenith at the new Naval Observatory of 2″·35 toward the south, and one of 6″·59 toward the east.

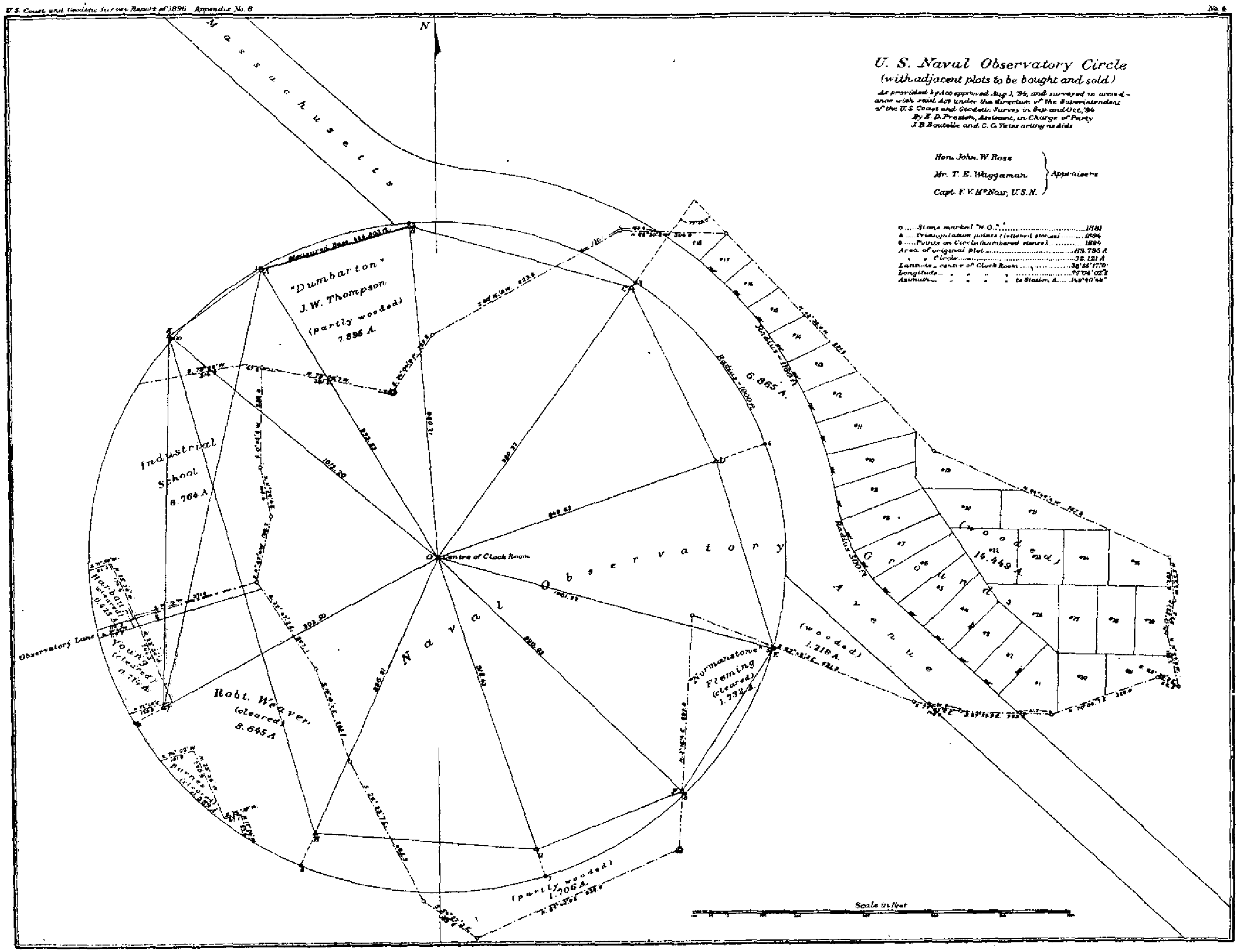
We may safely assume that the deflections of the vertical are fairly compensated in the combination of observations from 12 points, and therefore, giving equal weights to the three determinations, that the geodetic position of the center of the clock room at the new Naval Observatory is

	°	′	″
Latitude	38	55	17·03
Longitude	77	04	2·24 = $5^h\ 08^m\ 16{\cdot}15^s$

The probable error for either coordinate is less than 1 foot, corresponding in accuracy with the position of the geodetic points upon which the work is based.


N.
Soldier's Home S.W.
Clock Room
New Naval Obs'y
Small Dome
Old Naval Obs'y
Washington Monument
U. S. Capitol
Insane Asylum
Scale $\frac{1}{60\,000}$
Theological Seminary


N.
Clock Room
New Naval Obs'y
Washington Monument
U. S. Capitol
Scale 1/60000
Fairfax Theological Seminary


U. S. Naval Observatory Circle
(with adjacent plots to be bought and sold)
As provided by Act approved Aug 1, '94, and surveyed in accordance with said Act under the direction of the Superintendent of the U. S. Coast and Geodetic Survey in Sep and Oct, '94
By E. D. Preston, Assistant, in Charge of Party
J. B. Boutelle and C. C. Yates acting as Aids
Hon. John W. Ross
Mr. T. E. Waggaman
Capt. F. V. McNair, U. S. N.
Appraisers
o ..... Stone marked "N.O." 1881
▵ ..... Triangulation points (lettered stones) 1894
o ..... Points on Circle (numbered stones) 1894
Area of original Plot ..... 69.795 A
" " Circle ..... 72.121 A
Latitude – centre of Clock Room ..... 38°55'17.0"
Longitude – " " " " ..... 77°04'02.2
Azimuth – " " " " to Station A ..... 149°40'44"
Massachusetts Avenue
Naval Observatory
Centre of Clock Room
"Dumbarton" J. W. Thompson (partly wooded) 7.896 A.
Industrial School 8.764 A
Robt. Weaver (cleared) 8.645 A
Normanstone Fleming (cleared) 1.732 A
(wooded) 1.218 A.
(partly wooded) 1.706 A.
6.865 A.
Ground (wooded) 14.449 A.
Observatory Lane
Young (cleared)
Radius = 1000 ft.
Radius 500 ft.
Scale in feet
N