

**OCCOQUAN RESERVOIR WATERSHED:  
AREA DETERMINATION**

**Prepared by**

**Erik R. Hagen  
Roland C. Steiner**

**April, 1998  
Report No. 98-1**

**Interstate Commission on the Potomac River Basin  
6110 Executive Boulevard, Suite 300  
Rockville, Maryland 20852**

---

## OCOCOQUAN RESERVOIR WATERSHED: AREA DETERMINATION

---

This report provides an estimate of the total drainage area to the Occoquan reservoir, owned and operated by Fairfax County Water Authority and located in northern Virginia. The area of the reservoir watershed can be used to help calculate the rate of inflow to the reservoir, which is useful for planning purposes such as assessing the reliability of the reservoir water supply at year 2020 demands or for determining the size of a water treatment plant.

Estimates of the Occoquan reservoir watershed area are reported in several documents, but no document cites how the area determination was made or provides uncertainty limits for the estimate. Furthermore, the areas reported are inconsistent, ranging from 570 to 616 square miles. Several examples are listed below:

- 570 square miles (Metcalf and Eddy, 1970; Camp Dresser and McKee, 1980; Hirsch, 1978; Schwartz, 1996)
- 587.5 square miles (Norman Goulet, Northern Virginia Planning District Commission, personal communication, April 9, 1998)
- 595 square miles (Harza, 1978 and 1989)
- 598.3 square miles (Northern Virginia Planning District Commission and USDA Soil Conservation Service, 1973)
- 616 square miles (Vorheers & Associates, 1974)

Some of the variability in the measurements may be due to confusion as to whether or not to include the drainage area between the upper and lower Occoquan dams, as shown in Figure 1. The main water supply intakes are located at the upper dam, so the drainage area between the two dams should not be included in the calculation of reservoir drainage area. A water supply intake is located in the lower dam but this intake is not typically used because of sedimentation problems. In the long-term, FCWA plans to breach the lower dam (subject to board approval) (Christopher Triolo, Fairfax County Water Authority, personal communication, April 9, 1998).

The 570 square mile estimate was probably based on the USGS estimate of drainage area for the Occoquan River at Occoquan gage site (570.0 square miles). However, this gage site was submerged after construction of the reservoir and there is substantial reservoir drainage between the gage site and the upper dam (Figure 1).

A planimeter was used to determine the area of the drainage between the Occoquan River at Occoquan gage site and the upper dam. The planimeter was calibrated on a known area (Table 1). A USGS 1:24,000 topographic map with a contour interval of 10 feet (photo-revised 1971) was used for the drainage analysis. The drainage area was divided into sections, and each section was measured several times (Table 2). Uncertainty in the calibration and drainage area measurements was used to develop an estimate of the uncertainty limits for the drainage area using standard error propagation techniques (Ramette, 1981).

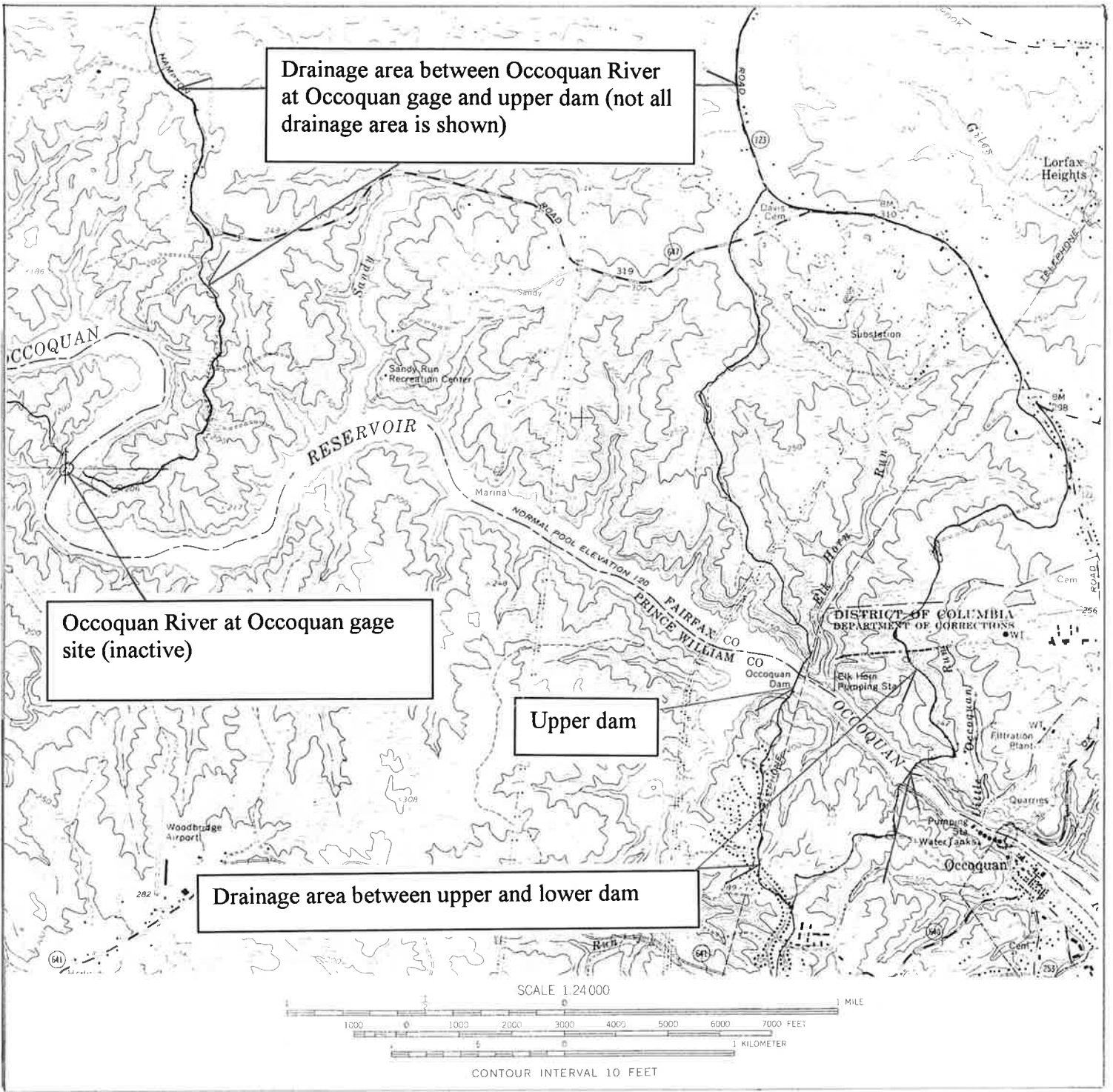


Figure 1: Occoquan River at Occoquan USGS gage site, upper and lower dams, and drainage-area delineation (Map source: USGS 7 1/2 minute Occoquan quadrangle)

The drainage area between the Occoquan River at Occoquan gage and the upper dam was calculated to be  $21.9 \pm 0.1$  square miles. This estimate excludes the area of the reservoir watershed between the upper and lower dams ( $1.836 \pm 0.004$  square miles). Assuming that the USGS estimate of 570.0 square miles for the watershed area above Occoquan River at Occoquan gage is correct, then the total drainage area of the reservoir watershed excluding the drainage area between the upper and lower dam is  $570.0 + (21.9 \pm 0.1) = 591.9$  square miles. Uncertainty limits for this estimate are dropped since no uncertainty limits are given for the USGS estimate of 570.0 square miles. This value agrees well with the Harza estimate of 595 square miles and with the Northern Virginia Planning District Commission estimate of 587.5 square miles, calculated using GIS analysis.

A second planimetric analysis was conducted to verify the first planimetric analysis. A USGS 1:100,000 topographic map (1986) with a contour interval of 10 meters was used for the analysis. The entire drainage area of the Occoquan reservoir watershed was measured, including the area above the lower dam. The area was divided into sections, and each section was measured several times (Table 3). After subtracting the area between the upper and lower dams a drainage area of  $590 \pm 3$  square miles was found for the reservoir watershed, which verifies the NVPDC and USGS estimates of drainage area and comes close to the Harza estimate of 595 square miles.

Therefore, the best available estimate of the Occoquan reservoir watershed area is calculated to be **591.9** square miles. The 591.9 estimate is chosen because:

- The area-adjustment methods used to generate reservoir inflows typically utilize USGS estimates of other gaged areas in the basin; this estimate would likely be most consistent with how the USGS measured other gaged areas in the watershed.
- This estimate roughly splits the difference between the Harza and NVPDC estimates.
- This estimate was verified by planimetric analysis of a second map at a different scale.

TABLES AND CALCULATIONS

Table 1: Calibration data, measured on 5.00 x 5.00 square inches engineering paper

Calibration data point	Planimeter units	Calibration data point	Planimeter units
1	1.499	8	1.499
2	1.492	9	1.503
3	1.499	10	1.502
4	1.501	11	1.509
5	1.499	12	1.506
6	1.500	13	1.482
7	1.503	14	1.500

The average planimeter reading for the 14 calibration data points is 1.500, with a standard deviation of 0.006. The standard deviation is used to help determine the uncertainty in the calculation of square mileage in the watershed.

Table 2: Determination of drainage area between Occoquan River at Occoquan gage and lower dam, and between upper and lower dams

Data points	Planimeter measurements of drainage area between Occoquan River at Occoquan gage and lower dam			Planimeter measurements of drainage area between upper and lower dam <sup>a</sup>
	Section A	Section B	Section C	Measured in one section
1	1.137	4.110	4.674	0.769
2	1.146	4.108	4.662	0.770
3	1.144	4.108	4.662	0.768
4	1.146	4.100	4.666	0.769
Average	1.143	4.107	4.666	0.769
Standard deviation (SD)	0.004	0.004	0.006	0.0008

Notes: <sup>a</sup> Different reference calibration (1.500, 1.502, 1.507, 1.503, 1.500; average = 1.502, SD = 0.0029)

The calculations to determine the square mileage and uncertainty for the drainage area between Occoquan River at Occoquan gage and the lower dam are given below:

- Total (Sum of averages for sections A, B and C) 9.92 planimeter units
- Uncertainty  $[(\text{Sum of SD}^2)^{0.5}]$  0.01 planimeter units
- Convert total planimetric units into  $\text{in}^2$   $(9.92 * 25.00 / 1.500)$  165.3<sup>1</sup>  $\text{in}^2$
- Area of watershed  $[165.3 * (8,000^2/4^2) * (1/5280)^2]$  **23.7**  $\text{mi}^2$   
(map scale: 8,000 feet per 4 inches; 5,280 feet per mile)
- Uncertainty  $[23.7 * ((0.01/9.92)^2 + (0.006/1.500)^2)^{0.5}]$  **0.1**  $\text{mi}^2$

<sup>1</sup> One extra digit is given beyond the significant digit for calculation purposes and is underlined.

Similar calculations provide an area of  $1.835 \pm 0.004$  square miles for the drainage between the upper and lower dams. The drainage area between the Occoquan River at Occoquan gage and upper dam is thus  $(23.79 \pm 0.1)$  minus  $(1.835 \pm 0.004) = 21.9 \pm 0.1$  square miles.

Table 3: Determination of area of Occoquan reservoir watershed including lower dam

Data points	Planimeter units Section A	Planimeter units Section B	Planimeter units Section C	Planimeter units Section D
1	4.378	3.246	3.450	3.180
2	4.366	3.246	3.470	3.172
3	4.360	3.249	3.470	3.177
4	4.355	3.239	3.454	3.180
5	4.358	3.235	3.460	3.178
6	4.360	3.251	3.461	3.178
Average	4.363	3.244	3.461	3.178
SD	0.008	0.006	0.008	0.003

The calculations to determine the square mileage and uncertainty for the drainage area of the Occoquan reservoir (including lower dam) are given below:

- Total (Sum of averages for sections A, B, C, and D) 14.25 planimeter units
- Uncertainty  $[(\text{Sum of SD}^2)^{.5}]$  0.01 planimeter units
- Convert total planimetric units into  $\text{in}^2$   $(14.25 * 25.00 / 1.500)$  237.49  $\text{in}^2$
- Area of watershed  $[237.49 * (100,000/1)^2 * (1/12)^2 * (1/5280)^2]$  592  $\text{mi}^2$   
(map scale: 1:100,000; 12 inches per foot; 5,280 feet per mile)
- Uncertainty  $[592 * ((0.006/1.5)^2 + (0.01/14.25)^2)^{.5}]$  3  $\text{mi}^2$

The drainage between the upper and lower dams is  $1.835 \pm 0.004$  square miles. Thus, the drainage area between the Occoquan River at Occoquan gage and upper dam is  $(592 \pm 3)$  minus  $(1.835 \pm 0.004) = 590 \pm 3$  square miles.

---

## REFERENCES

---

Black and Veatch, 1996. *Technical Memorandum No. 1: Safe Yield of the Occoquan Reservoir*, prepared for the Fairfax County Water Authority.

Camp, Dresser & McKee, 1980. *Occoquan Policy Reevaluation, Phase III Report*, presented to the Virginia State Water Control Board.

Harza Engineering Company, 1978. *Report on Increase in Height of Upper Occoquan Dam*, prepared for Fairfax County Water Authority. Chicago, Illinois.

Harza Engineering Company, 1989. *Minor Water power Project--Volume I: Initial Statement Exhibits A,E,F,G*, prepared for the Fairfax County Water Authority.

Hirsch, R. 1978. *Risk Analyses for a Water-Supply System-- Occoquan Reservoir, Fairfax and Prince William Counties, Virginia*. US Geological Survey, Open-File Report 78-452.

Metcalf and Eddy, Inc., 1970. *1969 Occoquan Reservoir Study*, presented to the Virginia State Water Control Board.

Northern Virginia Planning District Commission and United States Department of Agriculture, Soil Conservation Service. 1973. *Occoquan Watershed Impoundment Study*. Arlington, Virginia.

Ramette, Richard. 1981. *Chemical Equilibrium and Analysis*. Addison-Wesley Publishing Company. Reading, Massachusetts.

Schwartz, S. 1996. *Operating Alternatives for Occoquan Treatment Capacity*. Prepared for Black and Veatch, Washington, D.C.

Vorheers and Associates, 1974. *Study Design for a Comprehensive Water Resources Management Program for the Occoquan Watershed*, prepared for NVPDC.