CITY IN THE COUNTRY: QUANTIFYING THE EFFECTS OF LAND USE CHANGE ON THE HYDROLOGY OF A WATER SUPPLY WATERSHED, SARATOGA SPRINGS, NY

Wiles-Skeels, Robin H.[1] and Nichols, Kyle K.[2],
[1]Environmental Studies and [2]Geosciences, Skidmore College, Saratoga Springs, NY 12866

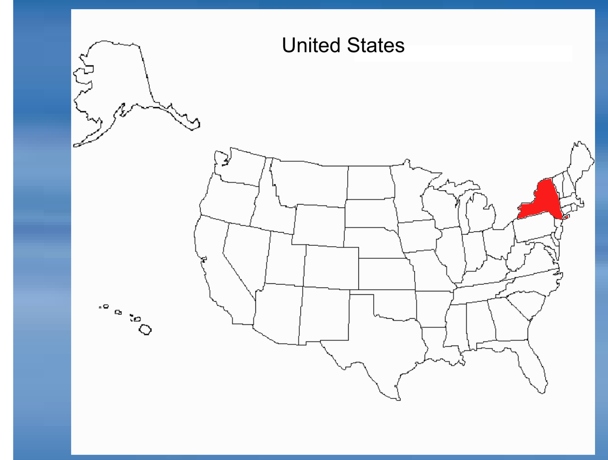
ABSTRACT

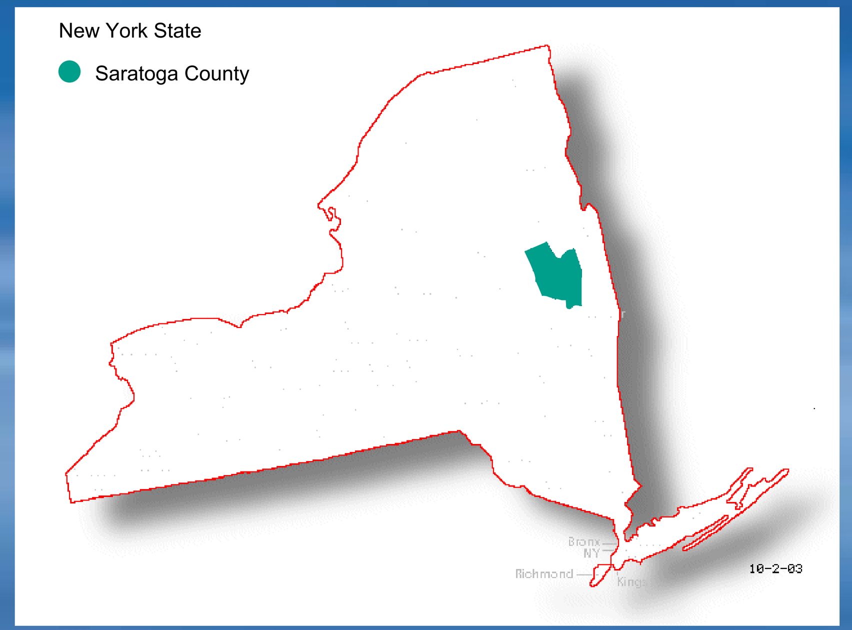
Significant recent and projected future growth in Saratoga County, New York, and in the 13.7 km^2 Loughberry Lake watershed in particular, creates impermeable surfaces, such as roads, parking lots and roofs, that increase runoff volume and peak storm water discharge. In the Loughberry Lake watershed, most land use change is from well-drained, sandy forests to the mixed impermeable and greenspace land uses of commercial and residential zones. Such land use change increases the surface runoff and decreases the groundwater recharge that is important to sustain reservoir levels through the high-demand summer months.

We quantified land use change from 1980 to 2001, a period of rapid development in the Lake Loughberry watershed. We used Geographic Information Systems (GIS) to quantify the 1980 data from the Earth Resources Observation Systems (EROS) Data Center (EDC) land use classification that only allows for a generalized estimate of land use areas. We digitized the 2001, using GIS, from 12" per pixel high-resolution orthophotographic images. For the 2001 data, we digitized all impermeable surfaces including houses, roads, and parking lots, greenspace, and forested areas. Thus, the 2001 data are more precise than the 1980 data.

Based on a 10-year 24-hour storm, and using the curve number approach, the total runoff volume has increased 304% from undeveloped conditions of 100% forest cover, similar to the conditions in the 1870s when the reservoir was built. The runoff volume from 1980 to 2001 for the same design storm has increased 26%. Using the rational runoff model, peak discharges in 2001 are 160% over the undeveloped condition and 54% higher than the 1980 land use cover.

Such time-series measurements of land use change provide useful research experience for undergraduate students and also provides valuable data on the expansion of impermeable surfaces within critical watersheds. In Saratoga Springs, this project is providing important information on land use practices at a time when the city is looking to expand its summer water supply.



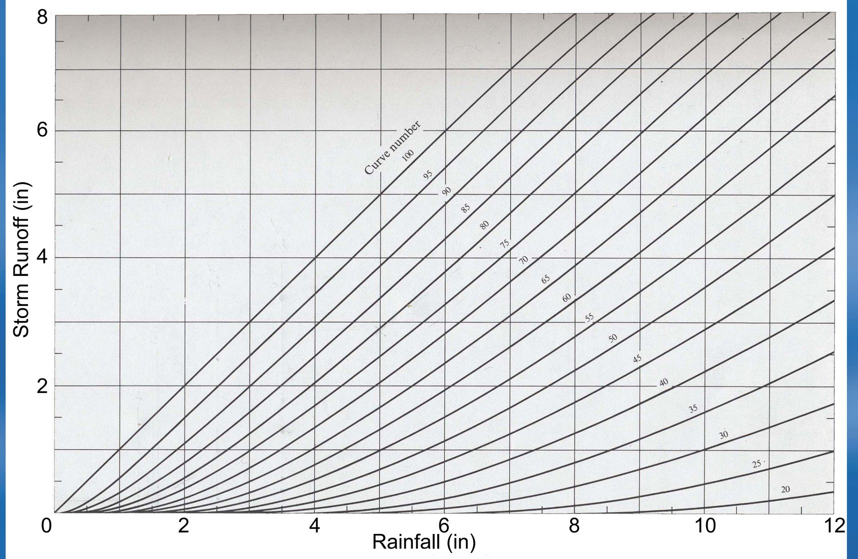


INTRODUCTION

- Loughberry Lake supplies Saratoga Springs with its drinking water
- Demand for water increases yearly, and doubles during the summer horse racing (tourist) season
- Development in the Loughberry Lake watershed has increased significantly over the past two decades
- Development and impervious surfaces decrease groundwater recharge areas
- Groundwater recharge is essential for the lake to maintain reservoir levels during high-demand summer months
- Groundwater sustains Loughberry Lake reservoir levels suitable for Saratoga Springs use

METHODS

- U.S.G.S. 1:24,000 topographic maps used to define watershed boundary
- Earth Resources Observation Systems (EROS) data used to quantify 1980 land use
- 12" per pixel high-resolution orthophotographic images used to delineate 2001 land use (houses, roads, parking lots, greenspace, forested areas)
- GIS used to quantify 2001 land use areas
- Soil names from Engineering Handbook 4 (1972) used to verify hydrologic soil conditions
- Rational runoff model (Dunne and Leopold, 1978) used to quantify peak discharges from 1980 and 2001 land uses
- Curve number approach (Dunne and Leopold, 1978) used to quantify runoff volume from 1980 and 2001 land uses
- Calculations based on 10-yr design storms of 24, 6, 1, and 0.5 hour durations



curve numbers from Dunne and Leopold, 1978

CURVE NUMBERS USED FOR 2001 DATA

Land use	Curve #	Hydrologic Condition
Forest (sandy)	30	good condition
Forest (not sandy)	60	good condition, low infiltration
Greenspace	40	good condition
Roads	98	paved
Roofs	98	impervious

soil groups from Soil Conservation Service, 1972
curve numbers from Dunne and Leopold, 1978

CURVE NUMBERS USED FOR 1980 DATA

Land use	Curve #	Hydrologic Condition
Mixed Forest	30	good condition
Cropland and Pasture	60	good condition
Commercial	70	<70 % impervious
Built up areas	40	<25% impervious
Residential	54	good condition
Roads	98	paved

soil groups from Soil Conservation Service, 1972
curve numbers from Dunne and Leopold, 1978

10-yr STORM RUNOFF VOLUME (m^3)

	24hr	6hr	1hr	30min
1870	50,000	25,000	0	0
1980	161,000	101,000	39,000	31,000
2001	203,000	140,000	60,000	49,000
% increase 1980-2001	26	38	53	58

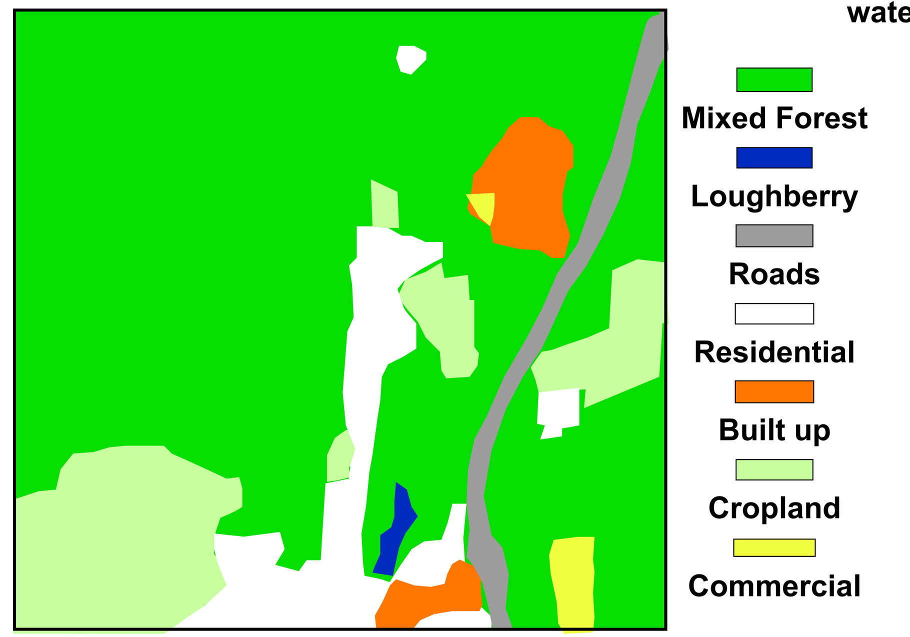
10-yr STORM PEAK DISCHARGE (m^3/s)

	24hr	6hr	1hr	30min
1870	2.2	6.6	22	37
1980	3.7	11	38	62
2001	5.7	17	58	96
% increase 1980-2001	54	54	54	54

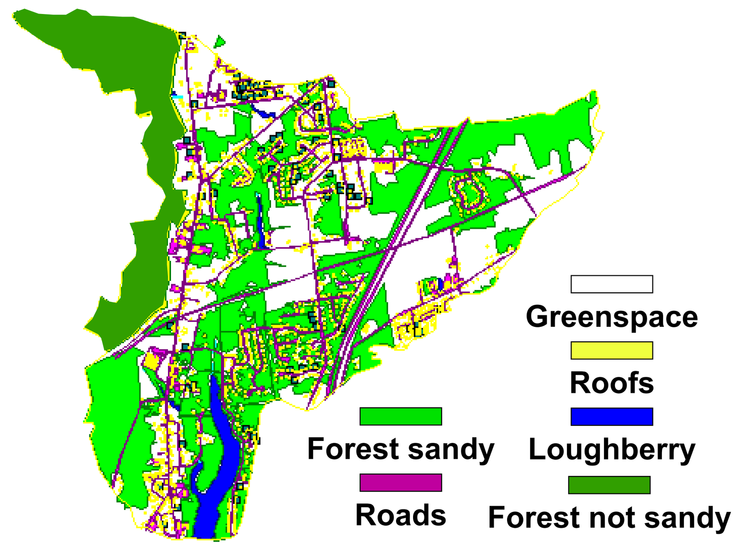
1968 aerial photo of Loughberry Lake
Notice minimal development north of lake

2001 aerial photo of Loughberry Lake watershed

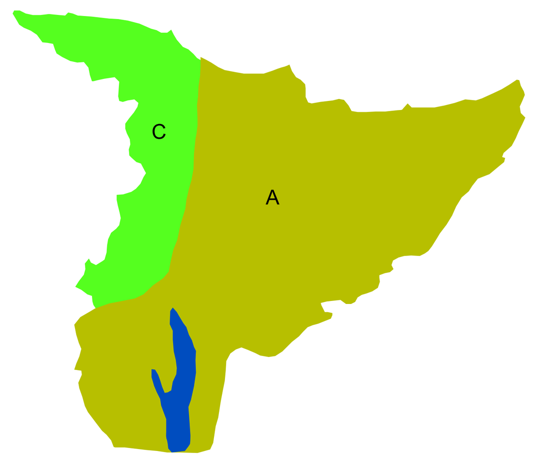
October 2003 development in Loughberry Lake watershed



1980 Earth Resources Observation Systems Data Center land use classification for Loughberry Lake watershed



2001 land cover delineation in Loughberry Lake watershed



Loughberry Lake watershed soil types
Hydrology group A: loamy sand (mud, silt, clay and sand mixture) - low runoff potential
Hydrology Group C: rolling, rocky - high runoff potential

*North is to the top of the poster in each map, Loughberry Lake is ~1.5 km long

IMPLICATIONS

- Best results, for small basins, are obtained from high resolution aerial photographs compared to "generalized" EROS land use data (trade time for accuracy)
- Development in the neighboring town of Wilton significantly increases runoff volume (26 to 58%) and peak discharge (54%) for 10-year storms
- Greater surface runoff volumes and peak discharges increase pollutant transport to the lake
- More runoff and less infiltration exasperates water shortage during drought due to less groundwater recharge into Loughberry Lake
- Continued development will further diminish water quantity and quality
- Effects of development on Loughberry Lake necessitate either 1) water conservation and better watershed management or 2) a new water supply for Saratoga Springs

NEXT STEP

- Saratoga Springs is looking to use Saratoga Lake or the Upper Hudson River as a new water source
- We will perform similar hydrologic analyses for the Saratoga Lake watershed
- We will evaluate projected development in the Saratoga Lake watershed for the next 20 to 30 years (based on zoning and population data) to see how runoff and peak discharge will change and influence Saratoga Lake water quantity and water quality

REFERENCES

Dunne, Thomas and Leopold, Luna B., 1978. Water In Environmental Planning: W.H. Freeman and Co., New York, 718 p.
Soil Conservation Service, 1972. National engineering handbook section 4: Hydrology. Washington, D.C., USA: United States Department of Agriculture.

ACKNOWLEDGMENTS

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