CONF-770209--4

LAKE JACKSON WATERSHED STUDY: DESCRIPTION OF SITES, METHODOLOGY AND SCOPE OF RESEARCH[1]

R. R. Turner, T. M. Burton[2] and R. C. Harriss[3]
Environmental Sciences Division
Oak Ridge National Laboratory[4]
Oak Ridge, Tennessee 37830

ABSTRACT--The Lake Jackson watershed study was undertaken to quantify changes in water quality and geochemical exports resulting from urbanization within the 11,900 hectare watershed of a recreational lake in north Florida. Three subbasins of 430, 611 and 792 hectares in size and otherwise similar in all respects except land-use were instrumented for intensive hydrologic and chemical monitoring during a two-year period (June 1973—May 1976). Two of these subbasins offered considerable contrast in major land use: (1) rapidly developing urban, versus (2) stable forested-agricultural. The third subbasin was intermediate between these extremes of land use. The streams draining the subbasins were generally intermittent with respect to flow and thus major emphasis was placed on characterizing storm events. Hydrologic records for each water sampling station were provided through a cooperative arrangement with the U.S. Geological Survey. Water samples were collected both manually and by automatic discrete samplers. Constituents measured included suspended solids, dissolved solids, chloride, dissolved silicon and dissolved nutrients (nitrogen and phosphorus). The data obtained in this study are being used to identify and explore the hydrochemical consequences of urbanization on a small drainage basin scale.

---

[1]Publication No. 1030, Environmental Sciences Division, ORNL.

[2]Institute of Water Research, Michigan State University, East Lansing, Michigan 48824.

[3]Department of Oceanography, Florida State University, Tallahassee, Florida 32306.

[4]Operated by Union Carbide Corporation for the Energy Research and Development Administration.

DISCLAIMER

Introduction

Foresters, water supply hydrologists, agricultural scientists and ecologists have long recognized the importance of understanding the physical, chemical and biological functioning of small drainage basins prior to developing management strategies for these basins. In general, objectives of these strategies have included the maximization or optimization of a single characteristic or quality of a drainage basin, such as water yield, marketable timber production or soil fertility. With the increasing public demand for, and governmental regulation of, environmental quality it is not surprising that in recent years we have begun to consider strategies for the management of our drainage basins which are designed to simultaneously optimize many qualities of a drainage basin.

Urbanization is one process affecting many qualities of a drainage basin which fortunately has been getting comprehensive management. However, this has occurred slowly and has obviously not been directed entirely at maximizing overall environmental quality. It has been said by Leopold (1968) that "of all land use changes affecting the hydrology of an area, urbanization is by far the most forceful". The statement can certainly be safely broadened by replacing the word "hydrology" with "ecology".

Whereas the effects of most man-generated perturbations of watersheds, such as clear-cutting, can be accurately discerned using the experimental watershed approach, the economics and logistics of applying this approach to urbanization are prohibitive. We simply cannot afford to hydrologically calibrate adjoining undisturbed basins and then urbanize one of them in order to rigorously identify and explore effects. On the other hand, it is sometimes possible to compare pre-urbanization and post-urbanization studies conducted on the same basin. This has been done in several cases (e.g., Sawyer 1963), although successful examples of this approach are rare and obviously the result of afterthought. Another method, involving more uncertainty but being highly feasible both economically and logistically, is to identify adjacent basins which are as similar as possible in all respects except land-use and to conduct reasonably short-term comparative studies. The latter method has the distinct advantage of providing information over wide ranges of climate and geology without consuming especially large research budgets. The inherent disadvantage is, of course, the uncertainty over the actual comparability of adjacent basins even under the most ideal conditions. Unknown subtle differences in geomorphology, pedology or subsurface geology could conceivably result in data which are subject to misinterpretation. A further problem associated with this method may be unavailability of representing "control" basins adjacent to some urban areas. Obviously reducing the minimal acceptable size of candidate basins would increase the number of candidates and thus the chance of finding a comparable pair of basins, but also would increase the changes of occurrence of subtle differences in one basin which could strongly influence results.

The Lake Jackson watershed study employed adjacent basins differing markedly in land use to identify and explore some effects of urbanization on hydrology and water quality. The available information on meteorology, surficial and subsurface geology, topography and pedology of each watershed (Hendry and Sproul 1966; Hughes 1967; Bridges et al. 1972) strongly suggested that these watersheds were nearly comparable in these respects.

The study began as a documentation of the effects of land-use changes (mostly urbanization) on the water quality and primary productivity of a recreational lake in north Florida. However, the study evolved into an investigation of the hydrology and water quality of several streams draining into the lake from watersheds contrasting markedly in land use. This was a very natural evolution in view of the intimate connection between a lake and its watershed and represented an interfacing of aquatic and terrestrial research.

Lake Jackson, located immediately north of Tallahassee, Florida, occupies a large (1960 ha.) closed depression in an area of rapidly expanding population. The lake has been a valuable asset to the residents of Leon County, Florida, providing a convenient recreational area for boating, fishing, and bird hunting. In the past decade the lake has gained national prominence for the large number of trophy largemouth bass caught by sport fishermen (Underwood 1973). Concurrent with this rise in popularity of the lake as a recreational resource, urban land development has increased markedly in the southern part of its watershed. Specifically this urban expansion has been stimulated by construction of two large shopping malls (built in 1968 and 1969), an interstate highway link (started in 1972), and a major highway interchange within the southern watershed.

The objectives of both the lake and watershed portions of the research are:

1. Identify major trends in the response of Lake Jackson to urban encroachment as manifested in hydrology, water chemistry, sediment facies distribution, phytoplankton productivity and fishery biology.
2. Characterize spatial and temporal differences in selected material flux rates from representative tributary watersheds.
3. Determine relative significance of stormflow and baseflow as transport agents for selected dissolved and suspended materials into the lake.
4. Develop material input budget for Lake Jackson with emphasis on sediments and dissolved nutrients.

Results of research directed at the first of these objectives have been reported by Harriss and Turner (1974), Smith (1974), and Schamel et al. (1974). Results related to the second and third objectives are given in Turner et al. (1975), in Turner and Burton (1975), in Burton et al. (1976) and elsewhere in this symposium volume (e.g., Turner et al., this symposium; Burton et al., this symposium). Results related to the fourth objective will be published in the near future.

Study Sites

The three watersheds (Fig. 1) selected for intensive hydrochemical study are located in the physiographic province known as the Tallahassee Hills. The terrain is characterized as gently rolling (average slopes 4.5%) with topographic relief up to 36 m (120 ft.) and elevations up to 79 m (260 ft., m.s.l.). The hills are composed of a heterogeneous mixture of yellow-orange clays, silts and sands (Miccosukee Formation, a Miocene deltaic deposit) that are weakly cemented and characterized by low permeability except in thin, discontinuous sand lenses (Hendry and Sproul 1966). Soils developed on the hills are well-drained loamy soils of the Dothan-Orangeburg and Faceville-Tifton-Greenville Associations and support a lush natural vegetation of mixed hardwoods and pines.

Rainfall in the study area varies considerably both temporally and spatially, but averages 146 cm per year. February, March, June and July are typically the wettest months, with April, May, October and November typically

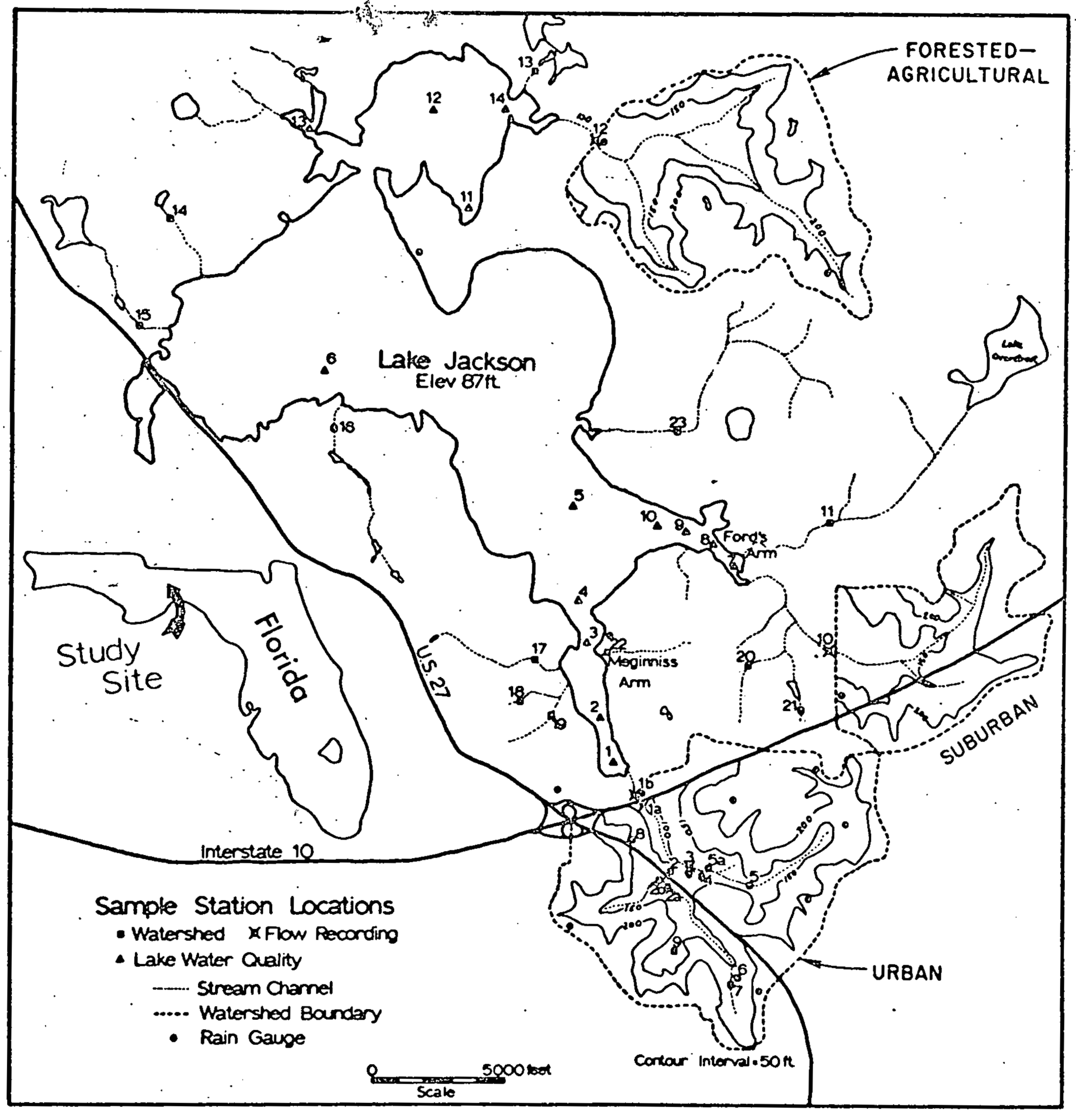


Figure 1. Location of study watersheds in Florida and in relationship to Lake Jackson.

the driest. Average annual temperature is 19.4°C with an average high of 27.2°C in July and an average low of 12°C in January (Hendry and Sproul 1966). Fig. 2 illustrates a calculated average annual water budget (Thornwaite method) for the study area. Potential evapotranspiration is 105 cm centimeters per year and thus the water surplus, or runoff, should be about 40 cm annually. Total rainfall over the study period (July 1973 to June 1975) was 250 cm and was thus about 40 cm below that normally expected over two years from the long-term annual average rainfall.

Land-use distribution in each study watershed during the study period is given in Table 1. The forested-agricultural watershed is almost entirely within a single large private estate with restricted access. Over 50% of this 611 hectare watershed is forested, the remainder being in old field and light agricultural use (corn and cattle grazing). Most of the forested portion is located along the stream channel, the farmland being on higher land toward the periphery of the basin. Fig. 3 illustrates the spatial distribution of the forested land within the watershed.

Table 1. Distribution of land use in the three study watersheds July 1973—June 1975.

Land use	Forested-Agricultural	Suburban	Urban
Woodland	318 ha (52%)	361 ha (84%)	95 ha (12%)
Agriculture	293 ha (48%)	30 ha (7%)	63 ha (8%)
Residential	0	9 ha (2%)	531 ha (67%)
Commercial	0	0	103 (13%)
Interstate Highway	0	30 ha (7%)	0
Total:	611 ha	430 ha	792

The urban watershed is drained by Meginniss Arm Creek and has been undergoing rapid urban development in the past decade. This basin is now about 80% in urban land use. During our study period, land use in this 792 hectare basin consisted of low-density single-family housing, several apartment complexes, office parks, commercial areas (including two large shopping malls) and two schools. Sanitary-sewer facilities exported wastes from this watershed to the watershed of another lake. Thus sewage effluents were never deliber-

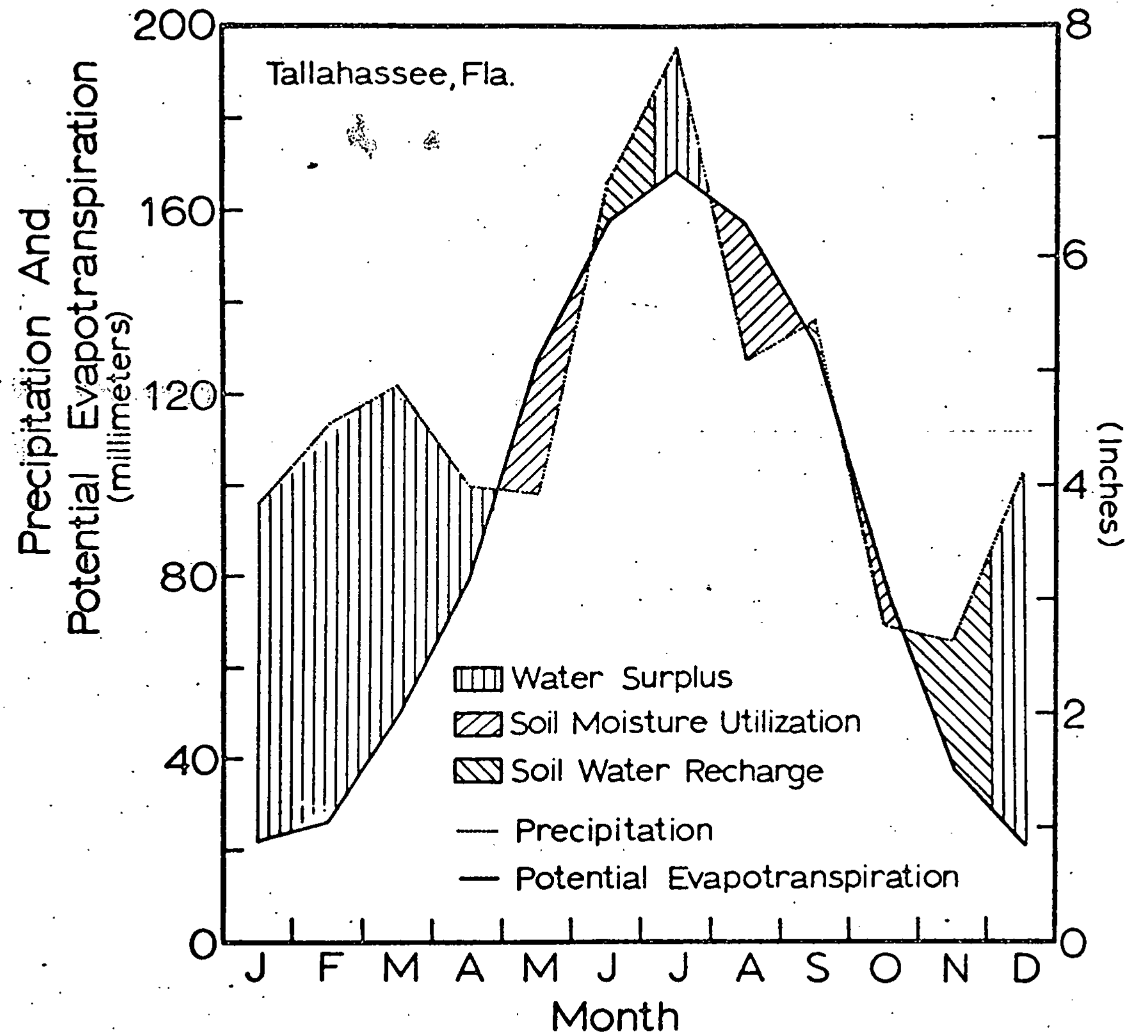
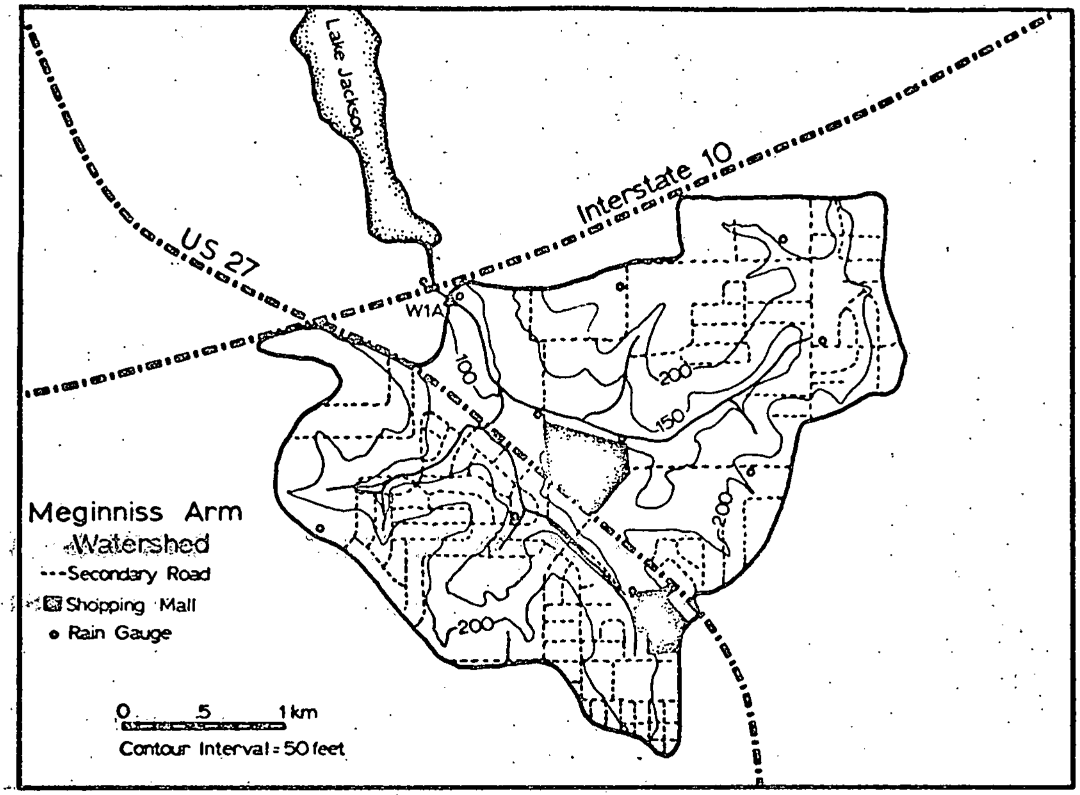


Figure 2. Annual water budget for Tallahassee, Florida, calculated from long-term average monthly rainfall and potential evapotranspiration (Thornwaite method).



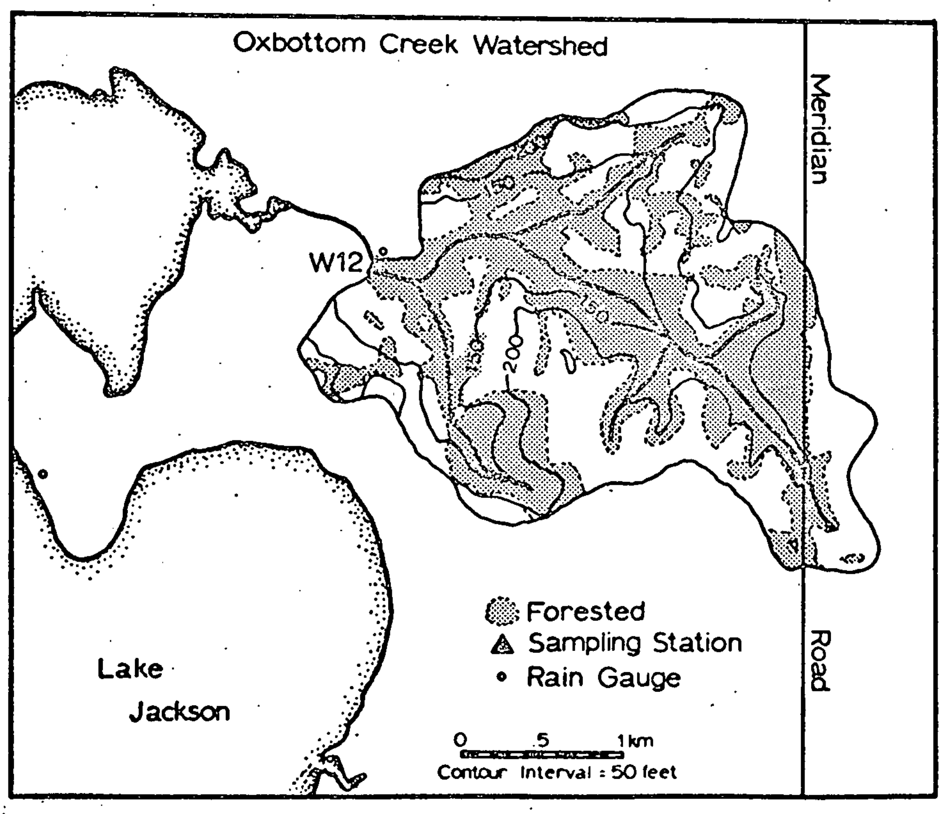


Figure 3. Detailed maps of urban (top figure) and forested-agricultural (bottom figure) watersheds.

ately a component of streamflow, although we observed occasional failures of the collection system which allowed leakage into streams. Fig. 3 illustrates the spatial distribution of roads and major shopping malls within the urban watershed.

The suburban watershed is somewhat smaller (430 ha.) than either of the other two basins and is not truly representative of typical suburban land use. This basin is mostly forested (84%) but has some features of typical suburban basins, i.e., residential subdivision with septic tanks, a school with a package sewage treatment plant, and an interstate highway.

Methods

Because of the often intermittent nature of streamflow in the study watersheds, major emphasis was placed on sampling stormflow. Automatic water samplers (Sigmamotor Model WM-4-24) were installed at suitable downstream sites to adequately sample runoff from storm events. These samplers were either activated manually prior to the start of a storm or pre-set to activate automatically with a rise in the stream water level. Generally it was preferable to activate the samplers manually in order to obtain a pre-storm sample and to ensure proper operation of the sampler. Automatic activation was used primarily to sample storms that might otherwise have been missed if only manual activation were used. Discrete 500 ml samples were taken over storm hydroperiods at pre-set time intervals (20 or 30 minutes on the urban, 40 minutes on the suburban, and 1 hour on the forested-agricultural watershed), the time intervals being related to the duration of the storm peak. The sampler normally required 10 to 12 minutes to pump 500 ml, thus samples were actually time-integrated. Storm hydroperiods generally encompassed less than 8 hours at the urban watershed and often as long as 48 hours at the forested-agricultural watershed.

Turbidity and conductivity of each sample were determined within 24 hours of collection. To reduce the number of samples to be analyzed, some samples were composited on the basis of these measurements and stream discharge at the time of collection. Samples collected at peak discharge, during periods of rapidly changing discharge, or which differed greatly in turbidity or conductivity, were not composited. Baseflow, or low flow, samples were collected weekly or more frequently and processed without compositing in the same manner as stormflow samples. A Hach Model 2100A turbidimeter and Barnstead Model PM-70CB conductivity bridge were used for the turbidity and conductivity measurements respectively.

Sample aliquots for dissolved constituent analyses were filtered through prewashed 0.45μ Millipore membrane filters, preserved with $HgCl_2$, and refrigerated at 4°C. These samples were analyzed on a Technicon Auto Analyzer II system using the following Technicon Industrial Methodologies:

Ammonia-nitrogen (indophenol method)	154-71W
Nitrate+nitrite-nitrogen (Cd reduction and diazotization)	158-71W
Nitrite-nitrogen (diazotization)	161-71W
Ortho phosphate-phosphorus (molybdate reactive phosphorus, MRP)	155-71W
Dissolved silicon (molybdate reactive)	186-72W
Chloride (ferric thiocyanate)	99-70W

Total dissolved phosphorus was determined on filtered (0.45μ) sample aliquots by H_2SO_4–$HClO_4$ digestion followed by analysis for molybdate reactive phosphorus (Technicon Industrial Methodology 188-72W). Total phosphorus was determined on unfiltered aliquots using the same methodology. No interference from $HgCl_2$ in the phosphate analyses was observed. Analytical quality control was checked regularly using EPA nutrient reference samples and has been summarized elsewhere (Harriss and Turner 1974).

Suspended solids (non-filtrable residue), dissolved solids (filtrable residue), and the volatile fractions of each of these were determined according to sections 224-C and 224-E of <u>Standard Methods</u> (American Public Health Association 1971). It should be noted that 'dissolved' solids as used in this study may include some 'suspended' solids as the glass fiber filters used in this determination had a pore size too large (1–3μ) to exclude all of the smaller suspended solids.

Measurements of streamflow from the three watersheds were made by personnel of the Water Resources Division, Subdistrict Office, U.S. Geological Survey (USGS), Tallahassee, Florida, through a cooperative arrangement with Florida State University and the Florida Department of Transportation. Staff gauges and stage height recorders (Fisher-Porter) were installed on each stream in June 1973. Stage-discharge rating curves were developed from repeated flow measurements at appropriate stream cross-sections over the entire period of study. Changes in channel geometry and/or local base level at all three gauging stations during the study period necessitated use of several rating curves. Stage height was recorded on punch tape at 15-minute intervals at all three gauging stations. These tapes were processed completely by the USGS who ultimately published the data in the form of mean daily discharges (Water Resources Data for Florida, Water Year 1975, Volume 1, North Florida). Where required for water quality data analysis, the original 15-minute stage data was retrieved from the punch tapes or provisional listings provided by the USGS and converted to discharge using the appropriate rating curves. The hydrologic data are summarized in a companion paper (Turner et al.) in this symposium.

Rainfall amounts were measured at 12 to 15 sites, generally on an event basis, using plastic wedge-shaped rain gauges (Tru-Check). Vandalism at many rain gauge sites precluded continuous records at all sites and thus the number of operational gauges were highly variable. In general, at least two gauges were operational on both the forested-agricultural and suburban basin and at least ten on the urban basin. Additional rainfall data were available from continuous recording rain gauges, one located on the forested-agricultural watershed and one on the urban watershed.

In order to obtain estimates of the atmospheric input of several constituents to the study watersheds, bulk rainfall was collected intermittently for chemical analyses at two locations using a 11 cm plastic funnel and 2 liter polyethylene bottle. The locations were (1) in an open area on the forested-agricultural watershed, and (2) atop a 5-story building located ca. 5 km south of the urban watershed. The latter site also featured a Wong collector which permitted collection of wetfall only. Most of the rain samples were obtained from this location since birds and insects frequently contaminated the collector on the forested-agricultural watershed. Atmospheric inputs for the study period were calculated by multiplying precipitation (volume)-weighted mean concentrations by total rainfall input to each watershed.

Results reported in companion papers in this symposium (Burton et al.) were based on analyses performed on 1039 streamwater samples (423 from urban watershed, 245 from suburban and 371 from forested-agricultural) collected during the two-year study period. Included in the data set are data for 34 individual storm events on the urban watershed, 23 storms on the suburban watershed and 26 storms on the forested-agricultural watershed. To facilitate determination of the relative importance of stormflow export of each constituent, streamflow and concentration data were partitioned into two subsets, storm (quickflow) data and non-storm (delayed flow) data. Details of the method of flow partitioning are given in Turner et al. (this symposium). Watershed exports were then calculated using discharge-weighted mean concentrations and total streamflow for each subset.

In summary, the study described here and in the companion papers in this volume compared the hydrology, surface water quality and material export characteristics of three adjacent small (<10 km^2) watersheds in north Florida which were reasonably similar in all respects except land use. The study represented an economically and logistically feasible approach to improving our understanding of some of the hydrochemical consequences of urbanization on a small drainage basin scale.

ACKNOWLEDGMENTS--This research was funded in part by a grant from the Florida Department of Transportation to Florida State University. Associated research on Lake Jackson was funded by the Florida Game and Freshwater Fish Commission. We thank Trina Billingsley, Judith Dietrich, and several part-time student assistants for technical assistance. We also thank Edward A. Laws for computer programming assistance and for his helpful suggestions on this research. Hydrologic data were calculated from data supplied by the U.S. Geological Survey. John H. Phipps of Ayavalla Plantation generously provided access to his land for the conduct of a part of this study.

References

American Public Health Association. (1971) Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C.

Bridges, W. C. et al. (1972) Water Resources. In: Environmental Geology and Hydrology, Tallahassee Area, Florida. Spec. Pub. No. 16, Florida Dept. Natural Resources, Bureau of Geology, Tallahassee. 61 pp.

Burton, T. M., Turner, R. R. and Harriss, R. C. (1976) The impact of highway construction on a north Florida watershed. Water Resources Bull. 12, 529–538.

Burton, T. M., Turner, R. R. and Harriss, R. C. (1977) Suspended and dissolved solids exports from three north Florida watersheds in contrasting land use. In: Watershed Research in Eastern North America, Proc. Conf., Feb. 28–March 3, 1977, Edgewater, Maryland.

Burton, T. M., Turner, R. R. and Harriss, R. C. (1977). Nutrient export from three north Florida watersheds in contrasting land use. In: Watershed Research in Eastern North America, Proc. Conf., Feb. 28–March 3, 1977, Edgewater, Maryland.

Harriss, R. C. and Turner, R. R. (1974) Lake Jackson investigations. Florida Game and Freshwater Fish Commission, Dingell-Johnson Final Completion Report, Project F-12-15.

Hendry, C. W., Jr., and Sproul, C. R. (1966) Geology and groundwater resources of Leon County, Florida. Florida Geol. Surv. Bull. 47. 178 pp.

Hughes, G. H. (1967) Analysis of the water-level fluctuations of Lake Jackson near Tallahassee, Florida. Fla. Bd. Conserv., Div. Geol., Report of Investigations No. 48. 25 pp.

Leopold, L. B. (1968) Hydrology for urban land planning — a guidebook on the hydrologic effects of urban land use. U.S. Geol. Survey Circular 554.

Sawyer, R. M. (1963) Effect of urbanization on storm discharge and groundwater recharge in Massan County, New York. U.S. Geol. Surv. Prof. Paper 475C. pp. 185–187.

Schamel, S., Davidson, G. A., and Casey, T. J. (1974) "Urban" sediment in Lake Jackson, Florida — a case study in sediment pollution (abstract). Proc. Geol. Soc. Amer., Southeast Section Meet. April 4, 1974, Atlanta, Georgia. p. 396.

Smith, S. L. (1974) Lake management and research — Lake Jackson studies. Final Completion Report, Dingell-Johnson Project F-12-15, Florida Game and Freshwater Fish Commission, Tallahassee, Florida. 94 pp.

Turner, R. R. and Burton, T. M. (1975) The effects of land use on stormwater quality and nutrient and suspended solids exports from three north Florida watersheds. In: Proceedings Stormwater Management Workshop (edited by M. P. Wanielista). pp. 121–146. Publications Florida Technological University, College of Engineering, Orlando, Florida.

Turner, R. R., Harriss, R. C., Burton, T. M. and Laws, E. A. (1975) The effect of urban land use on nutrient and suspended exports from north Florida watersheds. In: Mineral Cycling in Southeastern Ecosystems, U.S. Energy Research and Development Administration Symposium Series, CONF-740513.

Turner, R. R., Burton, T. M. and Harriss, R. C. (1977) Descriptive hydrology of three north Florida watersheds in contrasting land use. In: Watershed Research in Eastern North America, Proc. Conf. Feb. 28–March 3, 1977, Edgewater, Maryland.

Underwood, R. (1973) "They're digging Jackson's grave". Bassmaster Magazine, September–October Issue, pp. 44–48.