1

Establishing the Marcell Experimental Forest: Threads in Time

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CONTENTS

Introduction

The Marcell Experimental Forest (MEF), carved out of northern Minnesota's aspen, pine, and swamp forests in 1959, turned 50 years old in 2009. Established to investigate the role of peatlands in the northern Lake States region, its instrumented watersheds (Figure 1.1) include nutrient-poor bogs and nutrient-rich fens (organic-soil wetlands) along with glacial-till moraines and deep sandy drift. Unlike most experimental watersheds in the eastern and western mountains of the United States, the MEF is flat, wet, and tied to the regional groundwater system.

The establishment of the MEF and watershed research by the USDA Forest Service in Minnesota parallels the first scientific assessments of forests and water and their interaction. These threads of understanding of this resource date to the mid-1800s when logging in Maine waned and logging in the Lake States supported the westward sweep of settlers into the Midwest and West following the Civil War.

By 1840, loggers were leaving the cutover lands of New England and Maine en route to the Lake States; Yankee farmers homesteaded the cleared areas. In 1864, George Perkins Marsh, President Lincoln's ambassador to Italy and designer of the Washington Monument, also chronicled how man's use of the land changed its water, soil, capacity to produce vegetation, wildlife, and fish. Before becoming a lawyer and diplomat, the versatile

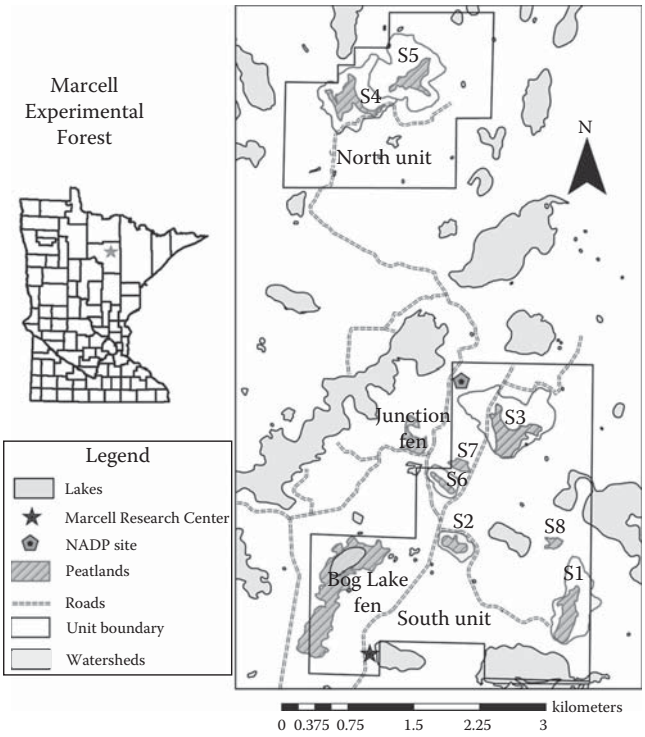

FIGURE 1.1
The MEF in north central Minnesota. The North and South Units are in the Marcell Hills Moraine in central Itasca County, Minnesota. The map shows the six research watersheds (S1–S6), other long-term research sites, and the Marcell Research Center.

Vermonter had many occupations, including logger, lumber dealer, and woolen manufacturer.

Marsh was the first to chronicle the destructive impact of human activities on the environment. Until he published *Man and Nature: Physical Geography as Modified by Human Action*, scientists held that the physical aspects of the Earth were entirely the result of natural phenomena. Marsh suggested that humans were the primary agents of change in the environment. His work, revised in 1874 as *The Earth as Modified by Human Action*, sparked the establishment of forest reserves (1891) that became the national forests (1905).

In the same year that Marsh published *The Earth as Modified by Human Action*, a man who would be instrumental to watershed research in the Lake States and the nation was born in Simbirsk (now Ulyanovsk), Russia. Raphael Zon (Figure 1.2) immigrated to the United States in 1896, studied forestry at Cornell University, and, in 1901, joined Gifford Pinchot, the first chief of the Forest Service, as a forester in the Bureau of Forestry in Washington. While in this post, Zon became interested in the relationship between forests and water. From 1907 to 1920, he was chief of Silvics and Forest Investigation.

FIGURE 1.2
Raphael Zon (1944) and Carlos Bates (1949). Raphael Zon (left) was the first director of the Lake States Forest Experiment Station in St. Paul, Minnesota from 1923 to 1944. In 1927, Bates (right) joined with Zon in St. Paul.

From 1907 to 1912, Zon compiled 1200 references concerning the relationship between forests and water. These references, dating to 1801 (with observations from 1789), represented work in North America, Europe, Russia, India, China, and Africa. Zon's conclusions mirrored those of Marsh. One conclusion was that man and his impact on forest cover and soils changes the quantity and timing of streamflow. In 1923, Zon left Washington to become the first director of the Forest Service's Lake States Forest Experiment Station (LSFES) in St. Paul, Minnesota.

St. Paul was the home of Adolf Meyer, another pioneer in hydrology. A consulting engineer and professor of hydraulic engineering at the University of Minnesota, Meyer published *The Elements of Hydrology* in 1917. A revised edition included precipitation and streamflow data from early U.S. Geological Survey (USGS) streamflow gaging sites in Minnesota and the Dakotas. Meyer concluded that cultural conditions (forest cover or agricultural land) had little impact on retarding the flow of floodwaters; he preferred streamworks of dams and levees to control floods. The grand debate between those who favored forest influences (watershed management), and supporters of hydraulic engineering (dams) began in the early 1900s and persisted into the twenty-first century.

While in Washington, Zon proposed a system of experimental forests and, in 1908, established the Fort Valley Experimental Forest in northern Arizona. A year later, the Fremont Experimental Forest was established near, Colorado Springs, Colorado. Carlos Bates, a graduate forester (University of Nebraska), spent 1907 through early 1909 in Zon's Silvics and Forest Investigations section (Figure 1.2). Like Zon, Bates excelled in both silviculture and forest influences. Zon sent Bates to Colorado in 1909 to open the Fremont Experimental Forest and establish a satellite watershed experiment 480 km away at Wagon Wheel Gap. Bates conducted the world's second

controlled (paired watershed) experiment at Wagon Wheel Gap. The first was in Czechoslovakia in 1867 at the upper reaches of the River Becva in Moravia (Nemec and Zeleny 1967).

Following 10 years of paired-watershed calibration at Wagon Wheel Gap, conifers were cut from one of the watershed pairs. The results of that experiment, published in 1927, only fueled the watershed management versus dam debate, which Sartz (1977) discussed in detail. Bates developed the first theories on the movement of water through the soil of mountain watersheds to maintain streamflow during droughts. In 1927, he joined Zon in St. Paul. Beginning in 1928, the Midwest and Great Plains experienced 10 years of consecutive drought as annual precipitation was 7.6–22.9 cm below average. Minnesota had experienced a similar drought from 1882 to 1891 with annual precipitation about 10.2 cm below average. During this period, much of the original white pine in Minnesota and Wisconsin was harvested and sent downstream via the many splash dams that captured the below-average snowmelt. Massive floods in 1892 ended the dry spell, smashed many splash dams, and left the floodplains full of stamped white pine logs released in the rogue log drives. A long summer of log retrieval followed.

During a period of massive soil erosion and dust bowls (1929–1934), Bates focused on the cause and prevention of erosion in southeastern Minnesota and southwestern Wisconsin in an area known as the Driftless Area. In this unglaciated landscape, early farming on steep slopes led to intense gully erosion. In 1934, Bates turned his attention to the dust bowls of the Great Plains as head of the Great Lakes Shelterbelt Project in St. Paul. This was 2 years before multiple, massive floods wiped out the town of Beaver in the Whitewater River basin in southeastern Minnesota. In that flooding, the floodplain was covered with 2 m of fine sand that eroded from Driftless Area gullies. Landscape change, flooding, erosion, and deposition were the norm in 1936 and 1937 even though annual precipitation at St. Paul was 15.2 cm below average.

The Coon Creek basin in southwestern Wisconsin experienced the same erosion and deposition that occurred in the Whitewater River basin. These and other basins that drain into the Mississippi River sent massive amounts of sand into the nation's central transport system; long islands formed in the Mississippi behind dams and locks built for barge transport. It was Coon Creek where Aldo Leopold, considered the father of wildlife management and the U.S. wilderness system, began to apply lessons for healing the land that were developed on his "Sand County" farm near Baraboo, Wisconsin. Coon Creek also was where Hugh Hamond Bennett, known widely as the father of soil conservation, began to incorporate field terraces, contour strip-cropping, and riparian revegetation into farm-management practices in the Midwest.

During the 1920s and 1930s, the public concern grew after Bennett and other environmentalists pointed out the profound relationship between land abuse and the loss of soil, recurrence of floods, and adverse effects on

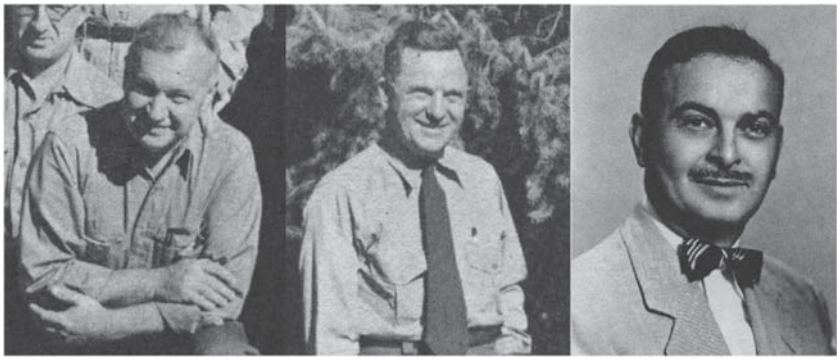

FIGURE 1.3
In 1956, Zig Zasada (left) was enlisted by Station Director Dick Dickerman (center) to head a station-wide effort to establish experimental forests for the purpose of watershed research (the MEF in Minnesota, Coulee in Wisconsin, and the Udell in Michigan). Sid Weitzman (right) became the first Chief of the Division of Watershed Management in 1956 in St. Paul.

the quality of the nation's rivers and streams. The landmark *Soil Erosion: A National Menace*, authored by Bennett and Ridgely Chapline and published in 1928, was instrumental in the creation of the U.S. Soil Conservation Service in 1935.

In 1933, Zigmond "Zig" Zasada (Figure 1.3) arrived in the tiny town of Bena in north-central Minnesota as foreman of the St. Louis (Missouri) crew in one of the many newly established Civilian Conservation Corps camps. A recent forestry graduate from Syracuse University, Zasada and his crew laid out roads, planted red pine, tended and released pine, and, as the timber sale official on the Chippewa National Forest, conducted the first thinnings in a large area of jack pine and red pine near Cutfoot Sioux Lake and the Winnibigoshish Reservoir on the Mississippi River. Following the removal of jack pine, numerous thinnings, and accelerated growth of red pine, this area was designated as the scenic "Avenue of Pines" on State Highway 46 northwest of Deer River, Minnesota. In 1945, Zasada left the Chippewa and became a forest utilization specialist with the LSFES at St. Paul, where he shared an office with Carlos Bates.

Ralphael Zon retired as director of the LSFES in 1944 and was succeeded by Elwood Demmon. At that time, the Station was located on the third floor of Green Hall at the University of Minnesota. For the next 2 years, silviculture, utilization, soil erosion, and forest influences merged again at Green Hall. A contemporary of Bates was Joe Stoeckeler, a soil scientist who worked with Bates on erosion research in Wisconsin and later was one the first members of the watershed project at Grand Rapids.

Demmon campaigned strongly for research centers outside of St. Paul and established centers in Grand Rapids, Minnesota; Marquette and East Lansing, Michigan; and Rhinelander, Wisconsin. In 1946, Zasada succeeded

Larry Neft as head of the center at Grand Rapids. Zasada directed research on forest economics, entomology, utilization, and silviculture, leaving the center for 2 years to direct the center at Marquette. He returned to Grand Rapids in 1953 and remained there as the center's leader until 1961. It was during this period that Zasada set about adding watershed-management projects at the LSFES.

Murlyn "Dick" B. Dickerman (Figure 1.3), the new station director in St. Paul, added a host of disciplines, including pathology, genetics, engineering, wildlife habitat, recreation, and watershed management, along with office buildings at outlying research centers to house the new staff. The 1957 launching of Sputnik shocked the nation and resulted in an increase in funding for a variety of Federal programs, including basic research in the physical sciences. This favorable development benefited Dickerman, who, since 1954, had backed the development of the Udell Experimental Forest in Cadillac, Michigan; the Coulee Experimental Forest in Lacrosse, Wisconsin; and the MEF near Grand Rapids for watershed research. Zasada was chosen to lead this effort.

Zasada organized a local committee in Grand Rapids that included Wes Libbey of the Izaak Walton League; Charlie Godfrey, the Itasca County land commissioner; H.M. Sword, county commissioner and chairman of the Itasca County Farm Bureau; Buck Hedman, leader of the local realtors association; and George Rossman, publisher of the *Grand Rapids Herald Review*. Local support also was obtained from C.K. Andrews, president of Blandin Paper Co. as well as from Minnesota and Ontario Paper, Sartell Paper Mill, and Northwest Paper Co.

Not everyone saw new knowledge as a need in forestry, but members of the Grand Rapids committee learned how advances in silviculture and watershed management meant real stewardship for Lake States forests and subsequently championed the three watershed research projects. Their efforts paid off when Representative John Blatnik and Senators Edward Thye and Hubert Humphrey (Box 1.1) appropriated $70,000 to hire project leaders for each watershed site (Roger Bay at the MEF, Dave Striffler at the Udell, and Richard Sartz at the Coulee). The funding also enabled the LSFES to establish the position of division director for Watershed Management at St. Paul. In 1956, Sid Weitzman (Figure 1.3), who had been with the Fernow Experimental Forest near Parsons, West Virginia, became the first director of that division. Watershed-management research had been conducted on the Fernow since 1948, and so Weitzman proved an effective mentor to Bay (Figure 1.4), Striffler, Starz, and Stoeckeler, accompanying them on a tour of USDA Forest Service watersheds in Arizona, Colorado, and Utah in 1958.

In 1956, Bay and Weitzman joined the LSFES at St. Paul only days apart. Previously with the National Forest system in Montana, Bay had met Dickerman while earning a Master of Science degree in Forestry from the University of Minnesota. Following discussions with Weitzman, Bay accepted a watershed-research position at Grand Rapids, Minnesota.

BOX 1.1

Working with the local community was one of Zig Zasada's many talents. In 1958, he secured funding for a Forestry Sciences Laboratory in Grand Rapids. The building was dedicated in 1960 with speeches by Richard McArdle, Chief of the USDA Forest Service, and Minnesota Senator Hubert H. Humphrey. While Zasada was driving them to the airport following the ceremony, Humphrey casually inquired if there was anything he could do for the USDA Forest Service when he returned to Washington. McArdle told Humphrey his support would be needed to enact legislation on multiple-use sustained yield that currently was before Congress. A week later, the bill became law, directing that the National Forests be managed for a variety of uses and values, including watershed protection as well as timber, wildlife, rangeland grazing, and recreation. Zasada left Grand Rapids in 1966 to become a staff assistant to the deputy chief of the USDA Forest Service. During the next 3 years, he was instrumental in the establishment of 17 USDA Forest Service research laboratories following numerous, wide-ranging discussions with congressional delegations and university and local officials.

At St. Paul, Stoeckeler had developed a program to study snow accumulation and melt and soil freezing for several forest types and density levels. He also conducted road surveys in northern Minnesota to determine the most effective drainage across roads in swamp areas. In addition to suggesting study areas, Stoeckeler helped Bay set up a small laboratory in Grand Rapids for the collection of soil-moisture data. Study plots were established on the Cutfoot and Pike Bay Experimental Forests on the Chippewa National Forest and on the Big Falls Experimental Forest (State of Minnesota) in large, black spruce peatlands north of Grand Rapids. Bay collected and analyzed the data from snow and soil-freezing measurements and reported results in several publications. Stoeckeler remained in St. Paul working on special projects.

In 1957, Clarence Hawkinson (Figure 1.4) left the Chippewa National Forest to join the staff at Grand Rapids as a forestry technician. He later became the first "Master of the Marcell" as principal field technician. In 1958, Don Boelter, a soil scientist, joined the staff to research the physical properties of organic soils (Figure 1.4).

The Search for Potential Study Watersheds

In 1959, Boelter and Bay began hunting for a site on which to locate an experimental forest for watershed studies. In the relatively flat or rolling landscapes

FIGURE 1.4
Early work at the MEF (clockwise from upper left): Don Boelter preparing organic soil cores for determination of water retention curves; Roger Bay with a local Rotary group; and Clarence Hawkinson changing the chart on an H-type flume at the outlet of S1 watershed and changing the chart on the recording upland well in S3. (Upper left: Roger Bay photographer; upper right: unknown; lower left: Sandy Verry photographer; lower right: Roger Bay photographer.)

of northern Minnesota, it was difficult to determine watershed boundaries. To locate watercourses, Boelter and Bay studied National Forest and county maps and also consulted USGS topographical maps. Upon selecting a potential site, they visited county land offices and studied aerial photographs. On the photos, it was possible to distinguish black spruce stands in swamplands from aspen and other upland forests and thus potential sites on State, county, and National Forest lands. The final test was hiking into areas with small watersheds that contained both a significant amount of peatland and streams suitable for the construction of weirs or flumes for measuring water yield.

Because it was difficult to delineate watershed boundaries and access the large peatlands north of the Chippewa National Forest and within the glacial Lake Agassiz area, Boelter and Bay redirected their efforts north of Grand Rapids in the glacial moraine and outwash area known as the Marcell Hills. This area also had the advantage of short travel times from Grand Rapids and was mostly National Forest land to the south and mostly Itasca County land to the north. In 1959, they settled on a 925 ha area that would formally be established as the North and South Units of the MEF in 1962 (Bay 1962).

In 1960, the first permanent streamflow gage at the MEF was constructed on the outlet stream of the S2 watershed. Unlike other USDA Forest Service experimental watersheds, which used the designation WS, watersheds on the MEF were identified as S1–S8 (S stands for swamp, the common term for wetland forest in the Lake States). Almost immediately, attention was directed toward defining what the Scandinavian terms "bog" and "fen" meant at the MEF with respect to wetland vegetation and water chemistry and to calibrating watersheds for future studies of forest harvesting.

Building a Watershed Research Program in Northern Minnesota

After Dickerman obtained funding to expand the watershed program, the LSFES contracted with Robert Dils, a professor at Michigan State University, to produce a problem analysis for watershed-management research in the Lake States. This was a cooperative effort among the LSFES, Michigan State University, and the Michigan Agricultural Experiment Station. He completed the problem analysis in April 1956. At that time, Stoeckeler reviewed the recommended areas for research and proposed the initiation of various watershed projects.

Several years earlier, the Marcell Ranger District on the Chippewa had constructed an all-weather access road for potential timber sales. The short road led to the future S1 watershed, providing access to most of the South Unit. Access to the North Unit posed a different problem. A rough road had been developed by landowners to access the area during deer-hunting season. Four-wheel drive and luck were needed to drive through mud and snow in the early years. The owners and Itasca County signed a cooperative agreement that allowed use by the experimental forest so long as access during deer hunting season was limited.

Beginning Work on MEF Watersheds

One of the first projects was generating a contour map of the MEF. A survey line was run from a USGS benchmark several miles from the area to establish local benchmarks for the mapping process. Mark Hurd, a private contractor, took aerial photos of the forest and produced a 1.2 m contour map of the area. In the first several years, considerable time was spent constructing flumes and weirs for streamflow measurements and drilling groundwater wells in the bogs and uplands. In the latter, a portable,

gas-powered drill was used to auger through the soil and drive a pipe and well point. For the wet peat soil in the bogs, a length of steel pipe (3.2 cm in diameter) was used. A steel circle (with a hole of the pipe diameter), cut on the radius and twisted to form an auger screw, was attached to the end of the well pipe. The well was simply screwed down 6.1–10.7 m by Bay and Boelter.

Streamflow measurements were made with a concrete cutoff V-notch weir that could be placed in solid mineral soil; at other outlets, metal flumes that could be transported on poor forest roads were used. It was believed that the flumes would not pond like the V-notch weir and thus increase the accuracy of measurements. At Lacrosse, Wisconsin, Richard Sartz had been working with a local sheet metal shop to fabricate flumes for use on the Coulee Experimental Forest. The flumes were manufactured in sections and shipped to Grand Rapids. Clarence Hawkinson (Figure 1.4) supervised the manual assembly of the flumes, caulking each section, installing cutoff walls of steel, and placing the flumes in the outlets. Over time, the flumes proved less accurate than V-notch weirs with concrete cutoff walls. In the flat and cold terrain of northern Minnesota, the flumes, supported on large screw rods set in concrete footings, twisted and turned, requiring weekly adjustments to ensure that the flumes and their sheet metal approaches remained level.

Don Boelter developed a series of field and laboratory instruments for measuring the physical properties of organic soils. These included caissons to isolate organic soil in the field where deformation could be avoided in extracting peat samples, and special adaptations of tension plates and pressure chambers in the laboratory to measure water retention in organic soils that are sensitive to changes in hydraulic head. Both auger-hole and piezometer pumping methods adapted to organic soils were used to measure hydraulic conductivity.

Initial research at the MEF emphasized peatland hydrology and ecology and the physical properties of organic soils. It then was expanded to include traditional paired-watershed experiments, with studies of the impact of forest harvest or forest-type conversion on streamflow. Every aspect of the water cycle also has been investigated with respect to water quantity and quality. Table 1.1 provides a timeline of major events on the MEF and Figure 1.4 pictures of early laboratory and field work. In 2004, the MEF increased by an additional 202 ha (total of 1141 ha) following approval of the forest plan for the Chippewa National Forest by the chief of the USDA Forest Service.

Of the three original watershed projects administered by the LSFES, only the MEF maintains an active, wide-reaching research program with fully instrumented watersheds including two control watersheds and four treatment watersheds modeled after the paired-watershed treatments at Wagon Wheel Gap and the Fernow Experimental Forest.

From the beginning, the MEF has fostered cooperative research programs with various universities. Many of the USDA Forest Service scientists

TABLE 1.1

Timeline of Major Events at the MEF

Year	Event
1959	Site selection of the MEF
1961	First routine monitoring of hydrology and climate begins
1961	Field laboratory built
1961	Studies begin to understand peat soil properties, peatland hydrology, and ecosystem energy budgets
1962	Formal establishment of the MEF
1966	First water chemistry samples collected
1967	Ditching experiment in S7 bog initiated
1968	Studies begin to develop the first electric analog model of groundwater flow at S3 fen (Sander 1971)
1969	First stripcutting the S1 bog
1969	Establishment of first upland runoff collectors
1969	Research begins assessing the influence of various canopies on interception
1972	Upland harvest in the S4 watershed
1972	Harvest of the S3 fen
1974	Strips left from first harvest cut in S1 bog
1977	Establishment of atmospheric chemistry sampling that became part of the NADP program in 1978
1978	PHIM (Peatland Hydrologic Impact Model) development begins
1980	Harvest of the S6 upland
1980–1982	Trials of cattle grazing and herbicide applications to convert S6 upland from a deciduous to conifer system
1981	Major research on sulfur, DOC, and nitrogen cycles begins
1983	Gas flux measurements of methane begin
1989	Soil temperature monitoring begins
1990	Establishment of pilot Long-Term Soil Productivity (LTSP) study
1991	Eddy covariance measurement of both carbon dioxide and methane
1993	Mercury studies begin
1993	Establishment of the Mercury Deposition Network (MDN) site
2001	Sulfate deposition experiment on the S6 bog begins
2006	Reestablishment of eddy covariance measurements for carbon dioxide at bog Lake fen
2006	Opening of the Marcell Research Center
2006	Addition of 200 ha to the South Unit of the MEF
2009	Reestablishment of eddy covariance measurements for methane at bog Lake fen
2009	Establishment of study assessing upland forest harvesting effects on mercury cycling
2009	Symposium on 50 years of Research at the MEF
2010	Book produced: *Peatland Biogeochemistry and Watershed Hydrology at the Marcell Experimental Forest: Results from 50 Years of Scientific Research*

at the MEF have been appointed as adjunct professors. The University of Minnesota leads the list in the number of cooperative studies. There are also cooperative programs with the Science Museum of Minnesota's St. Croix Watershed Laboratory, Michigan State University, University of Michigan, Michigan Technological University, University of Wisconsin, North Dakota State University, University of Nebraska, University of New Hampshire, University of Toronto, and Lakehead University, and universities and institutions in Finland, Germany, the Netherlands, Norway, and Russia.

Seeing the potential of new research directions has kept the MEF on the forefront of water research. In 1969, upland runoff plots were established as part of watershed research. During this time, studies were initiated on interception for amount and water chemistry and microclimate. In 1975, work began in cooperation with the Minnesota Agricultural Experiment Station to develop what would become the National Atmospheric Deposition Program. Researchers found an unequivocal link between emissions from coal power plants and acid precipitation and explored the effects of acid rain on lakes in the Lake States region. In 1980, Sandy Verry started worked with researchers at the National Oceanic and Atmospheric Administration to measure greenhouse gases and atmospheric deposition. In 1991, as an MDN test site, the MEF investigated the cycling of total and methylmercury through forest and wetland ecosystems. That same year, it was the first site for studies of soil compaction in the Lake States. During the mid-1980s, the MEF initiated research on carbon pools and cycling that included the major anions and cations, heavy metals, and organic toxins as part of a long-term NSF research program. The MEF also has been the site of one of the most intensive studies of the interaction of mercury and sulfate deposition in North America and has been called the "climate change" experimental forest.

Each year, students prowl the mosquito-infested swamps and forests of the MEF. They now number in the hundreds and hail from numerous states as well as Canada, Finland, Germany, Israel, Korea, the Netherlands, and Taiwan. Housing for students at the MEF, once rudimentary, is critical to study progression, as is the new Marcell Research Center with its modern facilities and living quarters.

The MEF serves as an anchor for water and climate research in the Lake States, a valued partner for research comparing watershed streamflow results in the eastern United States (Hornbeck et al. 1993) as well as for studies of atmospheric chemistry, carbon cycling, mercury in the environment, and climate change. Research at the MEF has settled a significant portion of the debate on forest influences versus engineering: land-use change can affect flows of up to at least the 30 year flood. More importantly, the cycle of erosion and deposition in stream channels is accelerated as they adjust to changes in land use.

Raphael Zon would be pleased that his pioneering efforts to understand the interactions of forests and water continue at the MEF thanks in large part to Zig Zasada, who spearheaded the effort to establish watershed projects

in the Lake States. Zig and Marie Zasada spread Zon's ashes in the Cutfoot Experimental Forest in 1956, 3 years before the MEF was established.

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