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Great Lakes Update

Snowpack Contributions to Great Lakes Water Levels

Anyone familiar with the Great Lakes knows that one of the key components of the hydrologic cycle that effect water levels is the magnitude of snowmelt supplies received on the upper lakes. Fortunately, the snowmelt process is not so rapid. On occasion rapid snowmelt can result in localized ponding of water and a few swollen streams. Much of the water becomes overland runoff and harmlessly ends up in the local streams, eventually flowing into one of the Great Lakes.

During the last three winters, the northern Great Lakes have seen dramatic changes in snowfall accumulations. The winter of 1995-96 had significantly higher than normal snowpack across the Lake Superior watershed.

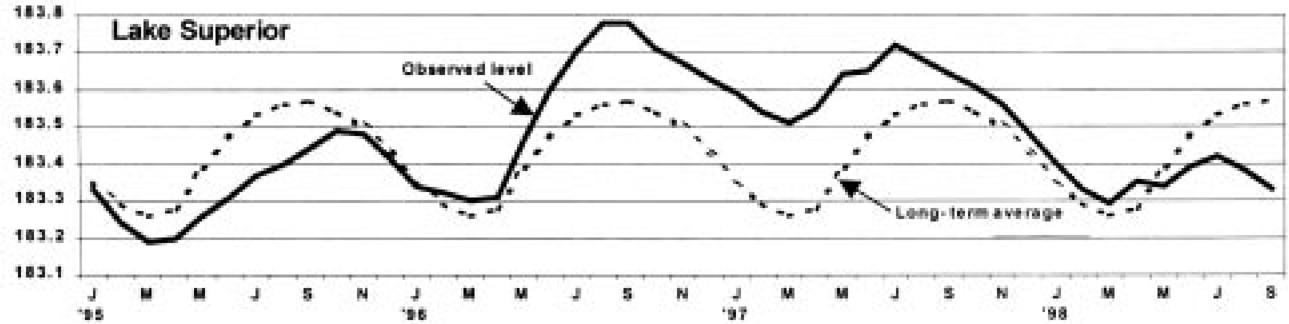
During the winter of 1996-97, snowpack magnitudes were even more extreme. Having back-to-back winters with significantly higher than normal precipitation led to pronounced increases in water levels in each of the Great Lakes. The effects of snowmelt supply on Great Lakes levels are shown graphically on the next page.

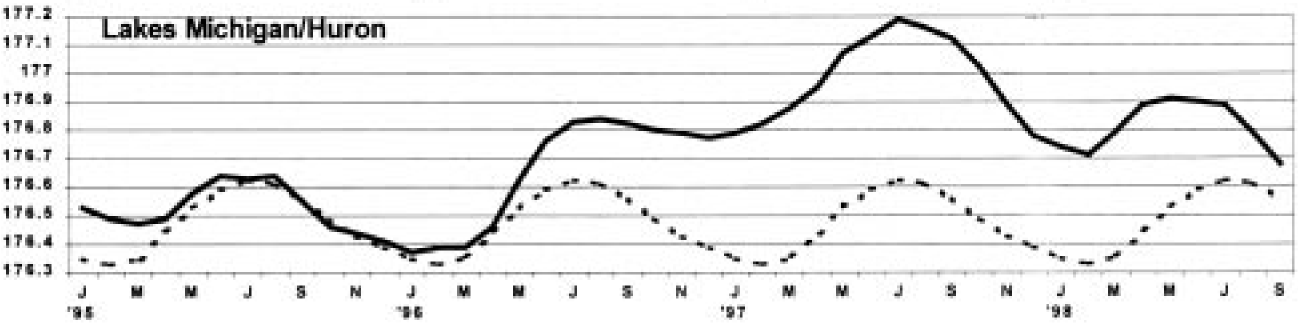
A cold winter's day at Marquette Bay, Michigan
(Courtesy National Weather Service, Marquette, MI)

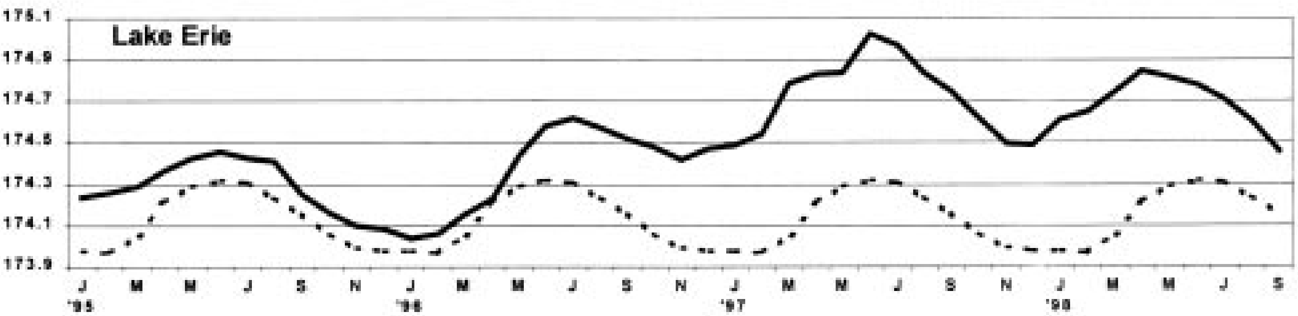
Last winter (1997-98), the Lake Superior basin as a whole received lower than normal snowfall; more importantly, temperatures regularly rose to above freezing during the daytime which allowed some reduction in the snowpack to occur through evaporation and melt. The ensuing spring runoff was so insignificant on the northern Great Lakes basins that the Lake Superior level rose only 1/4 of its average increase. The effects of this lack of water replenishment on Lake Superior continue to ripple through the Great Lakes as the downstream lake levels continue to fall at a faster-than-average pace.

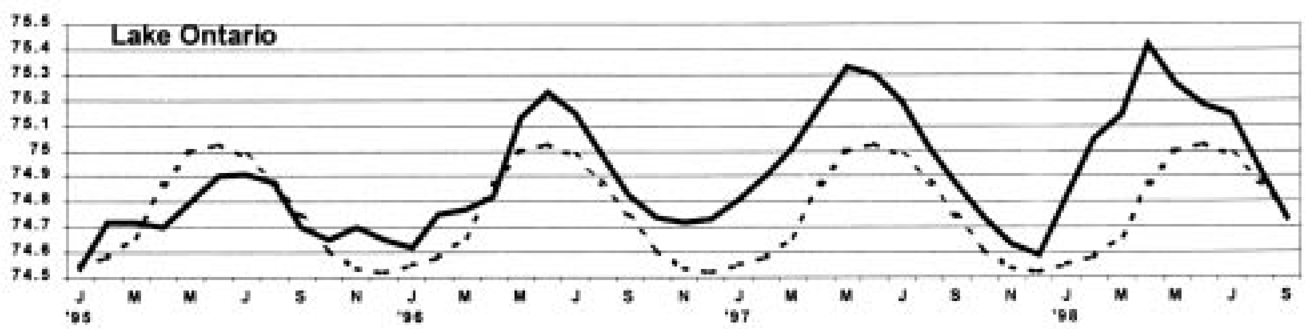
The agency in charge of monitoring the snowpack conditions across the continental U.S. is the National Operational Hydrology Remote Sensing Center (NOHRSC), located in Chanhassen, Minnesota. NOHRSC is part of the National Oceanic and Atmospheric Administration's National Weather Service (NWS). NOHRSC is primarily interested in determining how much water (snow water equivalent or *SWE*) is "locked up" in the frozen snowpack.

The NOHRSC began using airborne snow survey technologies in 1982 in order to estimate the SWE over large areas in just a few days of measurements. The Corps of Engineers has been funding the NWS to conduct airborne snow surveys over the Lake Superior watershed generally every year since 1985. A specially equipped Shrike twin engine aircraft uses a downward-looking sensor to measure the amount of naturally occurring gamma radiation that is emitting through the

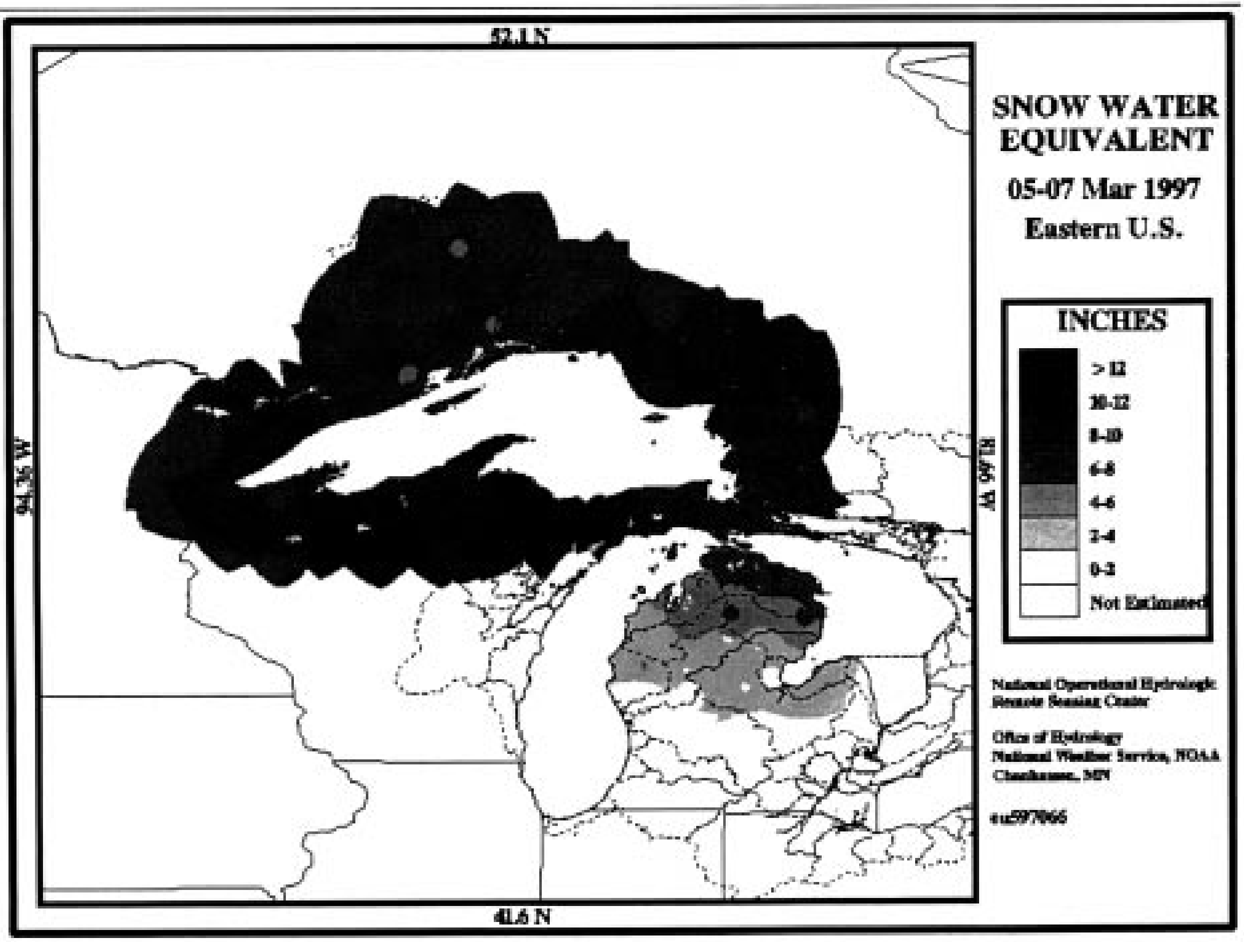








The above graphs are of (top to bottom) Lake Superior, Lakes Michigan/Huron, Lake Erie and Lake Ontario, and span a 42 month period from January 1995 through September 1998. In the spring of 1996, snowpack (containing 7-12+ inches of estimated SWE on the northern lake watersheds) melted during a wetter than normal April. This set the stage for a two-year period of higher than average Great Lakes water levels. The winter of 1996-97 provided record snowpack across the upper Midwest and into the Great Lakes. The rapid thaw in the spring of 1997 resulted in Red River of the North flooding and a continued trend of well above normal lake levels. However, near drought conditions across parts of the Great Lakes for much of late 1997 and most of 1998 has resulted in a significant decline in lake levels. Note that the long-term average (dashed line) peak is later in the spring on Lake Superior (top) and gets progressively earlier through Lake Ontario (bottom).



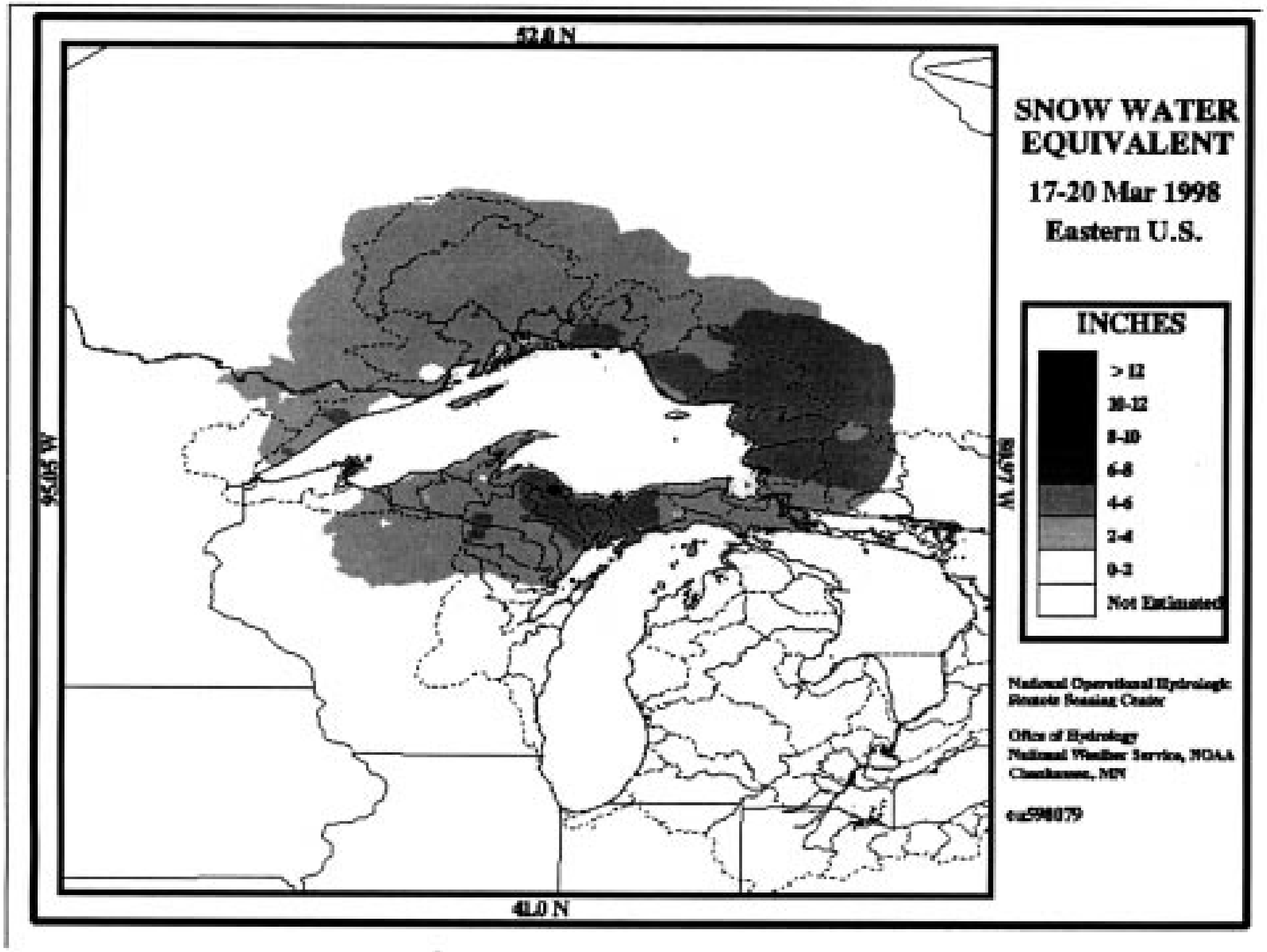
The above figure for March 5-7, 1997 shows the widespread distribution of greater than six inches of SWE, with greater than 12 inches across the central Upper Peninsula of Michigan. Significant snowmelt runoff did occur, along with minor flooding and damage, but no widespread problems were reported across any of the Great Lakes watersheds. (Courtesy NOHRSC)

snow from the ground below. The water in the snow reduces the radiation emitting through the snowpack, and measurably less radiation is sensed by the aircraft. The final SWE measurements are calculated by an onboard computer and the data are transmitted back to the NOHRSC. The flight lines are also videotaped to supplement the data collection performed by the sensor.

The snow data is then checked and converted to tabular and graphic formats (such as above) by NOHRSC. The information is then disseminated to the NWS's River Forecast Centers across the country for use in developing public information statements. The airborne measurements are very important to forecasters who determine the potential severity of spring snowmelt runoff and flooding that would occur. This technology was used to prepare for one of the worst floods ever experienced on the Red River of the North in 1997.

The massive volume of this stored water was exemplified during the spring of 1997 when the Red River of the North inundated Fargo, North Dakota under several feet of melt water when stubborn cold weather relented to an advance of 70-degree warm air. The rapid warmup unleashed all of the stored water simultaneously with disastrous results.

Dr. Thomas Carroll, Director of the NOHRSC says, that his agency flew approximately 100 surveys across the Red River basin in early February 1997. The findings were staggering - almost eight inches of water was stored in the snowpack within the basin; only four



This figure for March 17-20, 1998 displays the relatively minor snowpack that was a direct result of a near-record warm El-Nino winter. NOHRSC publishes these maps in color on their web site at http://www.nohrsc.nws.gov

inches of SWE caused severe flooding in the same area in the late 1970's.

NOHRSC issued its annual Spring Snowmelt Flood Outlook on February 13, 1997 and predicted that "...severe, at or above record flooding on every forecast point (in the basin) on record" would occur on the Red River. The approximately three months of lead time this report provided allowed federal, state and local agencies, as well as the public, to organize and prepare for the pending disaster.

Although the flooding could not be prevented, hundreds of thousands of dollars in property was saved due to the accurate and advance information NOHRSC provided.

The Detroit District of the U.S. Army Corps of Engineers has contracted with Michigan Technological University (MTU) in Houghton, Michigan to collect, digitize, analyze and map past SWE data in order to improve knowledge of the seasonal characteristics and historic ranges of snowpack conditions over the Lake Superior basin. Many of the paper station records of SWE predate the aerial surveys, however, and must be converted into digital (computer) format.

Once completed, a Geographic Information System can quickly produce a SWE basin-average map that will be compared to each seasonally observed SWE file to determine relation to average for each sub-basin. The derived information will be used for forecasting the water levels of the Great Lakes through routing models.

Winter Weather Patterns and La Niña

It seems fitting that the drainage basin of the headwater lake for the Great Lakes system - Lake Superior - normally receives the most copious amounts of snow annually. An average storm track, which often places the basin in the path of the heaviest snowfalls, usually is accompanied by the Arctic front.

Once a low pressure system has spread its snow across the terrain, bitter cold air from the Arctic is ushered in on north winds in the low's wake. Due to terrain differences and lake shore proximity, snow amounts vary greatly around the basin. The often relentless lake-effect snow machine produces an average of 12-15 feet of snow annually along the south shore of Lake Superior.

The Great Lakes region and, "especially locations downwind of Lake Superior, could possibly see greater than average lake effect snows this winter" says Warning Coordination Meteorologist **Jack Pellett**. Mr. Pellett works for the National Weather Service Forecast Office (NWSFO) in Marquette, Michigan. The Lake effect snow machine is primarily fed by evaporation from the relatively warm lake surfaces. The NWS reported that July Lake Superior water temperatures were in the unheard-of low to mid 70's nearshore and near 60 degrees offshore. However, by mid October, lake temperatures had tumbled back to more seasonal norms.

Mr. Pellet also pointed out that near-surface wind trajectories and other meteorological factors play a significant role in the occurrence of lake effect snow. Add in the apparent development of a *La Niña*-influenced weather pattern, the Great Lakes may be in for a colder, snowier winter. "A weak-to-moderate *La Niña* would keep the active (storm-producing) jet stream to our west in the central plains, while a stronger *La Niña* would develop more active weather further east (closer to the Great Lakes). In either case, we would be on the colder side of the jet stream".

The term *La Niña* (Spanish for "little girl") refers to an unusually cold pool of surface water off the Peruvian coast in the Equatorial Pacific region within 600 miles of the Equator. Sea-surface temperatures along the equator can fall as much as 7 degrees (F) below normal. This cold pool can extend from the West Coast of South America to as far west as the International Date Line. However, each *La Niña* is different.

The NWS Grand Rapids (MI) advises "A high amplitude or more snake-like jet stream pattern is expected to cause periods of unusually mild weather followed by significant outbreaks of Arctic air... especially in January. As a result, there is an increased likelihood of more frequent and stronger storm systems affecting the region..."

As of late October, water temperatures in this region were below normal at the time of year and are getting colder. This cooling trend is expected to continue into February 1999. Correspondingly, the NWS anticipates that monthly average temperatures for the Great Lakes region will be colder than the previous month through the winter with the greatest departure from average actually occurring in March 1999. Precipitation is expected to be greater than normal across the northern Great Lakes this fall, before the pattern shifts south and east through March 1999.

Temperatures are expected to be below normal through the winter across the Lake Superior, northern Michigan, Huron and Ontario basins, while near normal temperatures are expected across the Lake Erie, southern Michigan and St. Clair basins.

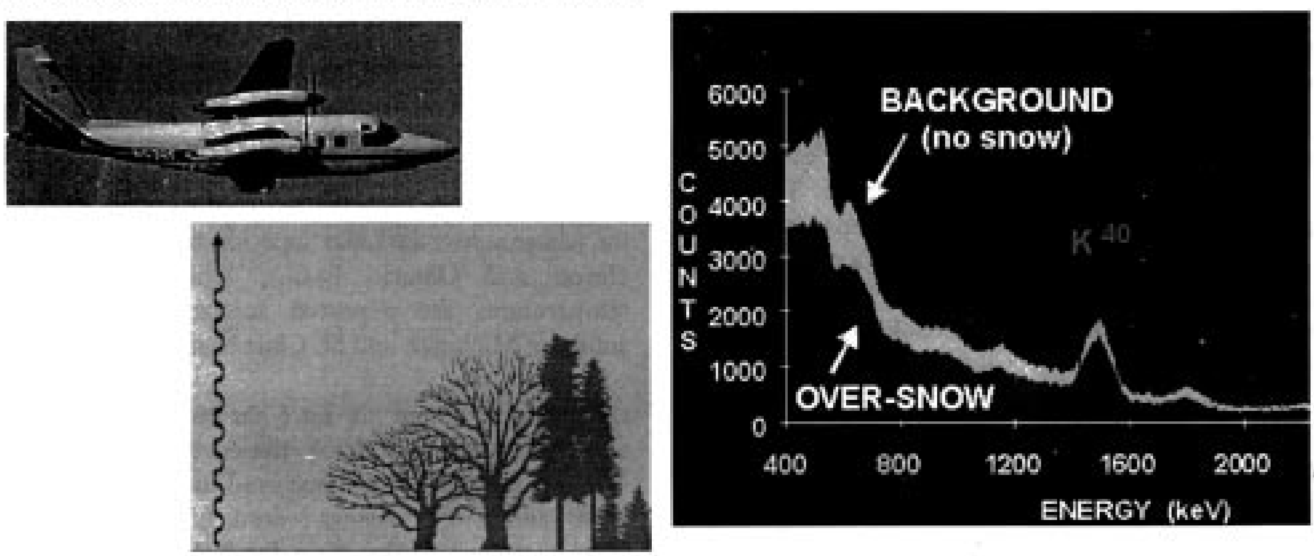
Of the most recent six *La Niña* episodes, four were snowier than normal across the northern Great Lakes. The last *La Niña* winter occurred in 1995-96. In early 1996 and 1997, a near-record high snowfall and persistent spring rains kept the Lake Superior water level near a record high. However, *El Niño* kept snowfall minimal in 1998, resulting in seasonal peaks in water levels on Lakes Michigan, Huron and Superior that were a month earlier and several inches lower than in previous years. This can be directly attributed to the lack of snowmelt entering these watersheds.

If the *La Niña* pattern develops across North America as anticipated, above normal snowfall could aid in reversing the 1.5 foot fall in Lake Superior water levels that recently occurred. This is due to the nearly year-long semi-drought that the central and northern Great Lakes have had to endure. The Lake Superior elevation fell below its long-term average (LTA) on May 5, 1998; the last time the level was below its LTA was January, 1996. As of October, 1998, the Lake Superior water level was almost 1 foot below its LTA. The lake level has steadily fallen since it seasonal peak in mid July, a peak some 13 inches lower than that of July 1997.

The latest monthly lake levels forecast published by the Detroit District, Corps of Engineers, shows a continuing decline in Lake Superior water levels until March 1999. The lake level is expected to remain almost one foot below its LTA through the upcoming winter.

The Science Behind Airborne Snow Water Equivalent Surveys

The ability to make reliable airborne gamma radiation SWE measurements is based on the fact that naturally occurring terrestrial radiation is emitted from the potassium, uranium, and thorium radioisotopes in the upper 8 inches of soil. The radiation is sensed from a low-flying aircraft flying 500 feet above the ground. In simple terms, the water mass in the snow cover blocks the terrestrial radiation signal; the greater the amount of water in the snow, the less radiation is sensed by the aircraft. Consequently, the difference between airborne radiation measurements made over bare ground in summer months and snow-covered ground in the winter months is used to calculate SWE values within ½ inch accuracy. The airborne snow data collected in the late winter and early spring are used by hydrologists from the NWS and other federal and state agencies when creating water supply outlooks, river and flood forecasts, and Great Lakes water level forecasts.



The NOHRSC uses a dedicated Shrike twin-engine aircraft to make aerial snow water equivalent measurements (top left), from naturally-occurring gamma radiation that is emitted from the soil under the snowcover (lower left). The arrows on the graph (above right) indicate a higher amount of gamma energy sensed by the survey over bare ground ("BACKGROUND"), and the lower amount of radiation sensed near the lower (OVER-SNOW) arrow. (Graphics courtesy NOHRSC.)

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