The New Vermont Inland Lake Score Card

What is the Vermont Inland Lakes Score Card?

The Vermont Inland Lake Score Card is a user-friendly interface developed by the Vermont Lakes and Ponds Management and Protection Program (VLPP) to share available data on overall lake health with lake users. Using Google Earth, viewers can select from more than 800 lakes in the state and learn about four key aspects of lake health: nutrients, aquatic invasive species, shoreland and lake habitat, and mercury pollution. Links embedded in the Score Card open deeper views into the underlying data and point to steps Vermonters can take to protect their lakes.

New and Improved

The new Vermont Inland Lake Score Card is the first comprehensive update since the Score Card was launched in 2010. With this update, several significant changes were made:

- More lakes are represented (n=823).
- New available data is included.
- Shoreland and Habitat scores are available for an additional 200 lakes.
- Previous metrics were modified and/or new metrics have been developed to capture:
  - Nutrient Trend
  - Watershed Disturbance
  - Water Quality Standards Status
- Mercury Fish Tissue Contamination, one of the most widespread stressors to Vermont lakes, is now scored separately from acid sensitivity (now captured in the Water Quality Standards Status).
- Lakes with insufficient data are clearly distinguished from those with data. In the original scorecard, lakes without data defaulted to good condition. The new Score Card defaults to 'no score' if there is insufficient data to calculate a score.
- Data are limited to Vermont's inland lakes. Lake Champlain is not included.

The new Vermont Inland Lake Score Card, like the original Vermont Lake Score Card, aims to answer the question "how is a lake doing?" with easy-to-interpret graphics and images. The Lake Scores are based on the best available data and information the VLPP has currently. While the data upon which a score is based is empirically derived, the actual thresholds differentiating lake scores were based on the best professional judgement. Final scores were reviewed by VLPP scientists.

Those wishing to better understand the scoring process are encouraged to read the 'How Lakes Are Scored' sections that follow below. Those wishing to protect a lake's 'good' score, or wishing to restore a lake with a 'fair' or 'poor' score can find best management practices here.

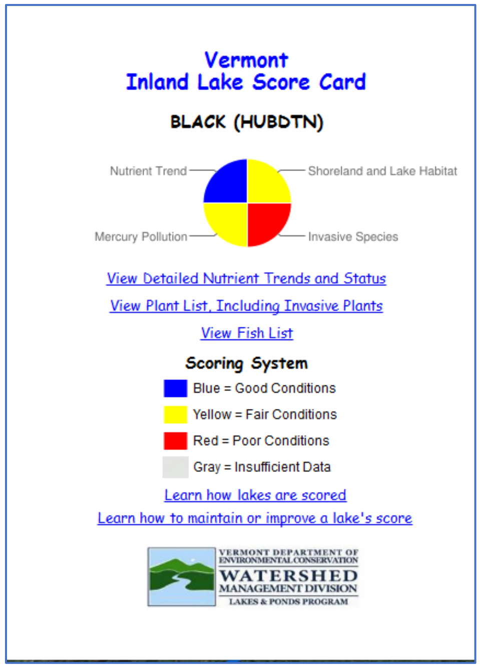

Figure 1. The Vermont Inland Lake Score Card

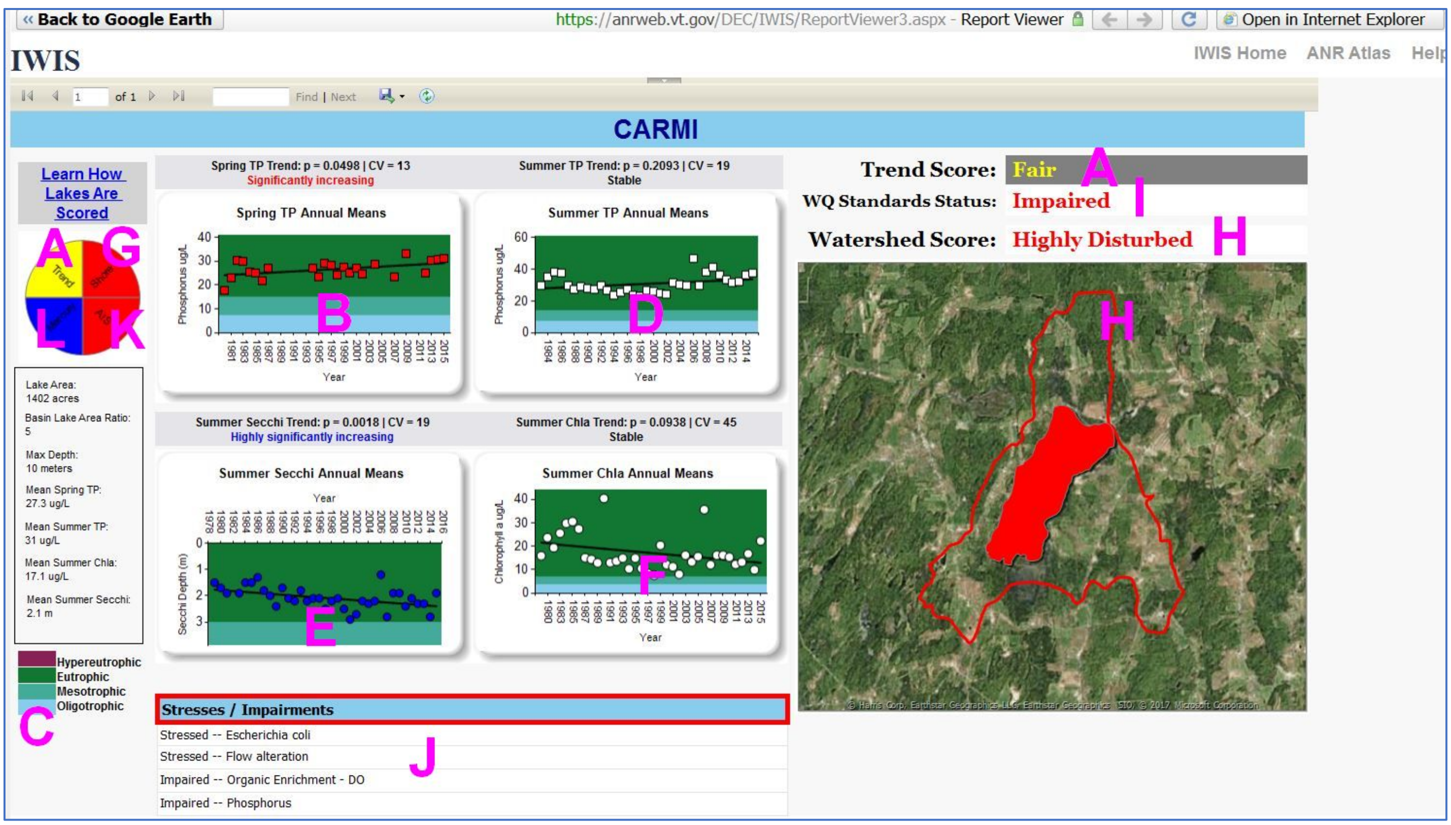

Figure 2. Pop-up displayed when selecting the 'View Detailed Trends and Status' link on the Score Card. Letters denote specific references from the text below. *Note: to save or print, click on the 'Open in Default Web Browser' button in the top right corner of the page.*

How Lakes are Scored: Nutrient Trend

The nutrient trend score captured in the top left quadrant of the Secchi disk icon on the Score Card (Figure 1) and in the Detailed Trends and Status pop-up (Figure 2). The score for a lake's nutrient trend comes from two lake monitoring programs within the VLPP - the Spring Phosphorus program and the citizen Lay Monitoring Program. Both data sets are used when available, however, often there is only one. Selecting the 'View Detailed Trends and Status' link opens a lake-specific display (Figure 2) showing actual data used to calculate the score as well as the lake's water quality standards status, and watershed status.

Spring TP Annual Means

Total phosphorus (TP) concentrations at spring turnover represent the potential available phosphorus that will feed primary producers like aquatic plants and planktonic algae during the following summer. Since 1977, VLPP scientists have collected phosphorus samples at spring turnover in Vermont lakes as part of the Spring Phosphorus Program. The 'Spring TP Annual Means' graph (B in Figure 2) shows the change in mean spring phosphorus from all sampling stations over time. The background colors denote the trophic state corresponding to a range of phosphorus concentrations (C in Figure 2).

Above the 'Spring TP Annual Means' graph, the *p* value and coefficient of variation (CV) for the trend is displayed. At least 5 data points are required to calculate a trend. Individual trend scores are determined by the statistical probability outcome from a Kendall's Tau rank correlation test, where a *p* value of less than 0.05 denotes a statistically significant trend. Larger CV values indicate higher variability within the data set.

Lakes with increasing phosphorus trends and/or big swings in TP concentrations over time, are cause for concern. An increasing trend suggests something is changing in the lake, along the shoreline or in the watershed that is causing phosphorus concentrations to rise. Caught early, intervention may stop or abate the source. Lakes with big swings in phosphorus, and therefore high CV values, may be experiencing episodic phosphorus pollution. Like increasing trends, episodic increases in phosphorus suggest that intervention may stop or abate the source.

Summer TP, Secchi and Chl*a* Annual Means

Summer TP, Secchi and chlorophyll *a* (Chl*a*) means reflect phosphorus concentrations and how the lake's phytoplankton (water column algae) are responding to those concentrations. These three parameters (D,E, and F in Figure 2) are a measure of the water column's productivity and are collected by volunteers from a central location in the lake as part of the Vermont Lay Monitoring Program. Like the Spring TP graph, the background colors denote the trophic state.

Each year, volunteer monitors sample the phosphorus in the lake's euphotic zone on a weekly basis over the summer. At least eight samples are needed to calculate the annual summer mean phosphorus concentration shown in the graph (D in Figure 2). Above the graph, the *p* value and coefficient of variation (CV) for the trend are displayed. At least five annual means are needed to determine a trend. A *p* value of less than 0.05 denotes a statistically significant trend. Individual trend scores are determined by the statistical probability outcome from a Kendall's Tau rank correlation test. Larger CV values indicate higher variability within the data set. Like Spring TP, increasing trends or concentration swings may point to a pollution source of concern.

Chl*a* , a photosynthetic pigment found in planktonic algae, serves as a good approximation for algal abundance in a lake. At least eight weekly chl*a* samples are needed to calculate the annual mean and at least five annual means are needed to determine a trend. A *p* value of less than 0.05 denotes a statistically significant trend. Individual trend scores are determined by the statistical probability outcome from a Kendall's Tau rank correlation test. Larger CV values indicate higher variability within the data set. Like spring and summer total phosphorus, increasing trends and concentration swings are of concern.

Secchi disk measurements are routinely used to quantify the clarity of the water, which can be influenced by turbidity and the presence of planktonic algae. The deeper the Secchi depth, the better the water clarity. At least eight weekly Secchi depth readings are needed to calculate the annual mean and at least five annual means are needed to determine a trend. A *p* value of less than 0.05 denotes a statistically significant trend. Individual trend scores are determined by the statistical probability outcome from a Kendall's Tau rank correlation test. Larger CV values indicate higher variability within the data set. Like the other water quality parameters measured by Vermont's Lay Monitors, a decreasing trend in Secchi depth is of concern.

Final Nutrient Trend Score

The final nutrient trend score, which determines the color of the Nutrient quadrant on the Score Card, combines the individual scores from the spring TP, summer TP, summer Chl*a* and summer Secchi. First, each parameter received an individual score based on the outcome of the Kendall Tau test (Table 1), with non-signficant, stable or improving trends receiving more points.

Table 1. Individual Trend Scores for Spring TP, Summer TP, Summer Chla, and Summer Secchi

Statistical Probability	**Trend Indication**	**Program Score** 2 = good, 1= fair, 0=poor
> 0.05	Not significant	2
Between 0.01 and 0.05	Significant -with improving slope -with declining slope	 2 1
< 0.01	Significant -with improving slope -with declining slope	 2 0

The summer scores were then added together. If a score was missing for a summer parameter, a value of two was used as a default.

Table 2. The individual summer TP, Chl a and Secchi scores from Table 1 were added together to create the summer final score.

Summer Individual Score	**Summer Final Score**
6	2
4 or 5	1
< 4	0

For the final nutrient trend score, the Spring TP score was added to the Summer final score. If only spring TP data was available, the final nutrient trend equaled two times the spring TP score. Table 3 shows how the final nutrient score is set and the corresponding color used in the Score Card.

Table 3. Final numeric nutrient trend score and corresponding color in the Score Card.

Nutrient Trend Final Numeric Score	**Vermont Inland Lake Nutrient Trend Condition Score**
4	Good
2 or 3	Fair
< 2	Poor

The final score represents an overall trend for each lake, but should be evaluated using the data shown in the Score Card pop-up (B – D in Figure 2). As an example, consider a lake which does not have an increasing nutrient trend and therefore scores a 'good' or blue. However, spring and summer graphs shown in the pop-up have wide swings in phosphorus concentrations from year to year. For this lake, the lack of trend may be due to the "noisiness" of the data. So, while the final nutrient score is important, we encourage users to look at the graphs for the whole story describing each lake.

The nutrient trend score relates directly to lake protection and restoration efforts in Vermont. 'Blue' lakes with stable low nutrient concentrations are a valuable resource for Vermont and efforts there should focus on protecting that good quality. 'Yellow' lakes offer opportunity for watershed residents to reduce nutrient inputs and improve conditions in the lake. To find out what you can do to protect a lake with a good score and restore a lake with a fair or poor nutrient trend, click on the 'how to improve or maintain a lake's score' link shown on the Score Card.

How Lakes are Scored: Shoreland and Habitat

The Vermont Lake Score Card uses the same thresholds used by the USEPA National Lake Assessment (NLA) to score a lake as good, fair or poor for lakeshore disturbance whenever possible (see Next Generation Lake Assessment). The majority of the 2017 Vermont Inland Lake Score Card lakes were scored using this index. However, there are some lake shoreland habitat scores based on maps of lakeshore disturbance generated from 2003 'leaf-on' and 'leaf-off' aerial imagery. This method likely underestimates lakeshore disturbance and these lakes will be re-evaluated in the next few years using the USEPA NLA Lakeshore Disturbance Index. The discussion below outlines the NLA methodology used to evaluate most lakes for the 2017 Score Card.

VLPP scientists randomly selected one site along the shoreline using GIS. Starting from this location, an additional nine sites are placed equidistant from each other around the lake for a total of ten sites. All ten sites are visited by a field crew, usually as part of the Spring Phosphorus monitoring program. At each site, various types of human disturbance are noted within a 15m by 15m plot on the shore immediately adjacent to the water (the 'main' plot). Types of disturbances recorded include buildings, lawn, commercial activity, roads/railroads, powerlines, docks, dams or seawalls, trash or landfill, and agricultural activities. In addition to disturbances in the main plot, observations are made of disturbances in 15m by 15m plots on either side of the main plot, and 'behind' the main plot in the riparian area extending away from shore.

The Lakeshore Disturbance Index captures both the intensity and extent of development around a lake. It is calculated from the observations described above. Each disturbance at each of the 10 random sites receives a score, assigning 1 for a disturbance in the main plot and 0.5 for a disturbance in the additional areas outside the main plot. These proximity-weighted disturbances are divided into two groups, agricultural and non-agricultural. An average is calculated for each group, which represents the intensity of development. To that is added a factor for the proportion of sites that have at least one disturbance, which is a measure of the extent of development around the lake. The final Lakeshore Disturbance Index is the average of the intensity and extent of development around the lake, and is calculated as follows:

$$\frac{1 - \{ 1 / [1 + \text{hiiNonAg} + (5 \times \text{hiiAg})]\} + \text{hifpAnyCirca}}{2}$$

Where;

hiiNonAg = mean proximity weighted non-agricultural disturbances (e.g. intensity of non-agricultural development)

hiiAg = mean proximity-weighted agricultural disturbances (e.g. intensity of agricultural development)

hifpAnyCirca = the proportion of 10 random sites around the lake that have any disturbance.

The Lakeshore Disturbance Score is shown by the color of the upper right quadrat of the Secchi icon (see G in Figure 2). A lake with a Lakeshore Disturbance Index value of 0.2 or less is considered in good condition. A lake with a Lakeshore Disturbance Index value between 0.2 and 0.75 is considered in fair condition. A lake with a Lakeshore Disturbance Index value of greater than 0.75 is considered in poor condition (Table 4).

Table 4. How the USEPA Lakeshore Disturbance Index is used to score Lake Shoreland and Habitat Condition in the 2017 Vermont Inland Lake Score Card

Lakeshore Disturbance Metric Value	Vermont Inland Lake Shoreland and Habitat Score/ USEPA National Lake Assessment Score
≤0.2	Good
0.2 – 0.75	Fair
≥0.75	Poor

Because the Lakeshore Disturbance Index is a measure of the human activity within 15m of the lake's shoreline at ten random sites around a lake, it reflects how intensively and extensively a lake's shore is being used. Numerous studies in the literature and conducted by VLPP scientists have shown that as lakeshores are disturbed, shallow water habitat and water quality are degraded, in conflict with Vermont's water quality standards (learn more). Ultimately, such degradations negatively impact the aesthetic value of the lake as well as the communities of aquatic organisms that live in or near the water - fish, insects, amphibians, birds, and mammals. For this reason, the Vermont Legislature passed the Vermont Shoreland Protection Act in 2014, which limits the amount of human disturbance within 100 feet (30 m) of Vermont lakeshores.

Lakes with a Good Lakeshore Disturbance score can maintain that condition by complying with the Shoreland Protection Act requirements for new projects in the protected lakeshore zone. For lakes that score Fair or Poor, any new development must also comply with the Shoreland Protection Act, however, lakeshore residents and owners can reduce the impacts from existing development by revegetating their shorelines and instituting the best management practices promoted by Vermont's Lake Wise Program, to offset the stress that nearshore human disturbance is having on a lake's habitat, aquatic life and water quality.

How Lakes are Scored: Watershed Disturbance

The Watershed Disturbance Score is derived from a landscape development intensity index (LDI) developed by Brown and Vivas (2005). The LDI is a measure of human-induced alterations to the biological, chemical and physical processes of a watershed's lands that impact the receiving water, in this case a lake. Watershed delineations and corresponding land use intensity data used to calculate the LDI for the 2017 Vermont Inland Lake Score Card came from The Nature Conservancy's Northeast Lake Classification System. Coefficients used in the LDI come from the Ohio EPA Division of Surface Water Wetland Ecology Group and are shown in Table 5.

Table 5. LDI Coefficients used in the development of the Vermont Inland Lake Watershed Disturbance Index from the Ohio EPA Division of Surface Water Wetland Ecology Group

NLCD Land Class	Description	Landscape Development Intensity (LDI) Coefficient
11	Open water	1
21	Developed, open space	6.92
22	Developed, low intensity	7.47
23	Developed, medium intensity	7.55
24	Developed, high intensity	9.42
31	Barren land	8.32
41	Deciduous forest	1
42	Evergreen forest	1

NLCD Land Class	Description	Landscape Development Intensity (LDI) Coefficient
43	Mixed forest	1
52	Shrub/scrub	2.02
71	Grassland/herbaceous	3.41
81	Pasture/hay	3.74
82	Cultivated crops	4.54
90	Woody wetlands	1
95	Emergent herbaceous wetlands	1

Land uses within each Vermont lake watershed were assigned an land class from Table 5. The LDI was calculated as an area weighted average as follows:

$$LDI_{total} = \sum \%LU_i \cdot LDI_i$$

Where;

LDI total = LDI ranking for the entire lake watershed

$\%LU_i$ = percent of the total area of influence in land class i

LDI_i = landscape development intensity coefficient for land use i

Thresholds for scoring Vermont lake watersheds were determined using the best professional judgement of VLPP scientists (Table 6). The final Watershed Disturbance Score is denoted by text and the color of the watershed outline in the pop-up (see H in Figure 2).

Table 6. Lake Watershed Disturbance Score LDI Thresholds

Lakeshore Disturbance Index(LDI)	Vermont Inland Lake Watershed Score
< 1.3	Minimally Disturbed
$\geq$ 1.3 & $\leq$ 1.7	Moderately Disturbed
> 1.7	Highly Disturbed

The Watershed Disturbance Score is strongly dependent on the accuracy and age of the underlying land use data set. The Nature Conservancy's watershed delineations were mathematically derived using the U.S. Geological Survey's National Hydrography Dataset stream flow network tools. These tools do not include a mapped visualization of the watersheds. Therefore, to provide a visual display of each lake's watershed score, VLLP derived a separate map layer derived from elevation data. Some discrepancies may exist between the visual representation of a watershed in the Lake Score Card pop-up when compared to the National Hydrography data set. Users are cautioned to keep these limitations in mind when viewing the colored watershed outlines. VLPP scientists will periodically incorporate new data layers and improve tools for lake watershed analysis and display.

How Lakes are Scored: Water Quality Standards Status

The Water Quality Standards Status reflects a lake's current condition based on the uses protected by the Vermont Water Quality Standards and the Vermont Surface Water Assessment and Listing Methodology. The status is shown in text and by the color of the lake itself (see I in Figure 2). As outlined in Table 7, lakes identified as good are meeting Vermont Water Quality Standards. Stressed lakes are impacted to a small degree by pollutants or other stressors, and the associated lake acreage is identified as 'stressed' in the 2016 Vermont Water Quality Integrated Assessment (305b) Report. Impaired or altered lakes are highly impacted by pollutants or other stressors, and the associated acres are identified as 'impaired' or ‘altered’ in the 2016 Vermont 305b Report as well as the 2016 Vermont Priority Waters List. Impaired lakes may be subject to a TMDL plan. The cause of the stress or impairment is noted at the bottom of the pop-up (see J in Figure 2). For lakes with good Water Quality Standards Status, no text will be displayed.

Table 7. How the Water Quality Standards Status is scored

Water Quality Standards Status	Water Quality Standards Status Score
Lake does not exceed the criteria outlined below	Meets Standards
Total phosphorus concentrations periodically exceed criterion (generally 18 ug/L), unless due to natural influences	Stressed due to phosphorus/nutrients
Dissolved oxygen in hypolimnion periodically falls to/near 0 mg/L or 0% saturation during summer, unless due to natural influences	Stressed due to organic enrichment – dissolved oxygen
Alkalinity less than 12.5 but greater than 2.5 mg/L $CaCo_3$	Stressed due to acid sensitivity (pH)
Chloride concentration exceeds 230 mg/L but is below 860 mg/L	Stressed due to chloride
E. coli from public swim beach areas occasionally exceed 235 organisms/100 mL	Stressed due to *E. coli*
Artificial water level fluctuations	Stressed due to flow alteration
Total phosphorus concentrations consistently exceed criterion (generally 18 ug/L), unless due to natural influences	Impaired due to phosphorus/nutrients
Dissolved oxygen in hypolimnion consistently falls to/near 0 mg/L or 0% saturation during summer (unless due to natural condition)	Impaired due to organic enrichment - dissolved oxygen
Alkalinity less than or equal to 2.5 mg/L $CaCo_3$	Impaired due to acid extreme acid sensitivity (pH)
Chloride concentrations exceed 860 mg/L	Impaired due to chloride
E. coli from public swim beach areas exceed geometric mean of 126 organisms/100 mL and/or 10% of samples exceed 235 organisms/100 mL over a representative period of 60 days	Impaired due to *E. coli*
Flow alteration from artificial drawdown and on the Vermont List of Priority Waters Part F: Waters Altered by Flow Regulation	Altered due to flow alteration

How Lakes are Scored: Aquatic Invasive Species

The Aquatic Invasive Species (AIS) score is based on the presence of one or more invasive animal or plant species (see K in Figure 2). A good score indicates there are no known invasive species present. Poor indicates that there is at least one invasive species present, regardless of its abundance or ‘nuisance’ level. Species evaluated to determine the AIS Score card are:

- Eurasian watermilfoil
- Variable leaf watermilfoil
- Water chestnut
- Zebra mussel
- Alewife
- Rusty crayfish
- Spiny water flea
- Asian clam

Table 8. Aquatic Invasive Species Scores

AIS Status	AIS Score
No known invasive species in lake	Good
At least one invasive species confirmed in lake	Poor

To learn which aquatic plants, native and invasive, are known in your lake, click on the ’View Plant List, Including Invasive Plants’ link in the Score Card (see Figure 1). A handful of Vermont inland lakes have known infestations of invasive animals. These are listed in Table 9.

Table 9. Known Infestations of Invasive Animals in Vermont Inland Lakes

Lake	Known Invasive Animals
Bomoseen	Zebra mussel, Asian clam
Carmi	Rusty crayfish
Morey	Rusty crayfish
St. Catherine	Alewife

Aquatic Invasive Species Management DOES Matter!

The **Vermont Aquatic Invasive Species Program** works with lake associations and volunteer groups to manage invasive species populations around the state. For simplicity, these efforts were not included in the AIS Score but they are integral to controlling the spread of AIS from waterbody to waterbody. Future editions of the Score Card may include management activities, but the 2017 Score Card is limited to presence/absence.

How Lakes are Scored: Mercury Fish Tissue Contamination

The Mercury Fish Tissue Contamination Score reflects the most recent data that VLPP has regarding the presence of mercury (Hg) in the food web of Vermont lakes. Mercury pollution is a serious environmental problem, contaminating forests, soils, rivers and lakes in Vermont and throughout the world. Much of the Hg reaching Vermont comes through air pollution originating outside the state.

Vermont used information from an intensive study of 93 randomly selected lakes in VT and NH to determine how much Hg may be accumulating in lake food webs. As part of this study, several types of lake organisms, including yellow perch, were tested for the presence of Hg. Results indicated that 40% of lakes in Vermont were likely to have fish exceeding EPA limits for allowable fish tissue Hg concentrations. The resulting model and fish test results are incorporated into the Score Card as noted in Table 10 and shown in the Secchi icon (see L in Figure 2).

Table 10. How lakes are scored for Mercury Contamination

Mercury Thresholds	Mercury Fish Tissue Contamination Score
Study results indicate low probability of Hg accumulation in fish tissue	Good
Study results indicate that Hg accumulation in fish tissue is likely	Fair
Study confirmed that Hg in fish tissue exceeds EPA guidelines	Poor