USGS
science for a changing world

Prepared in cooperation with the Swinomish Indian Tribal Community

Thermal Profiles for Reaches of Snee-Oosh and Fornsby Creeks, Swinomish Indian Reservation, Northwestern Washington, July 2013

Data Series 807

U.S. Department of the Interior
U.S. Geological Survey

Thermal Profiles for Reaches of Snee-Oosh and Fornsby Creeks, Swinomish Indian Reservation, Northwestern Washington, July 2013

By Andrew S. Gendaszek and Chad C. Opatz

Prepared in cooperation with the Swinomish Indian Tribal Community

Data Series 807

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2013

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this information product, for the most part, is in the public domain, it also may contain copyrighted materials as noted in the text. Permission to reproduce copyrighted items must be secured from the copyright owner.

Suggested citation:
Gendaszek, A.S., and Opatz, C.C., 2013, Thermal profiles for reaches of Snee-Oosh and Fornsby Creeks, Swinomish Indian Reservation, northwestern Washington, July 2013: U.S. Geological Survey Data Series 807, 6 p., *http://dx.doi.org/10.3133/ds807*.

ISSN 2327-638X

Contents

Figures

Tables

Conversion Factors and Datum

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.2808	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (m^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32.$$

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Thermal Profiles for Reaches of Snee-Oosh and Fornsby Creeks, Swinomish Indian Reservation, Northwestern Washington, July 2013

By Andrew S. Gendaszek and Chad C. Opatz

Abstract

Longitudinal profiles of streambed temperatures were measured in approximately 225-m-long reaches of the Snee-Oosh and Fornsby Creeks in the Swinomish Indian Reservation, northwestern Washington, during July 2013, to provide information about areas of groundwater discharge to streams. During summer, groundwater discharge is a source of cold water to streams and typically cools the surface water into which it discharges and buffers diurnal temperature fluctuations. Near-streambed temperatures were averaged over 1-m-long sections of cable during 1-minute periods every 30 minutes for 1-week periods using a fiber-optic distributed temperature sensor positioned on top of the streambed. The position of the fiber-optic cable was surveyed with a Global Positioning System. Stream temperatures and survey data are presented as Microsoft Excel® files consisting of date and time, water temperature, and geographical coordinates.

Introduction

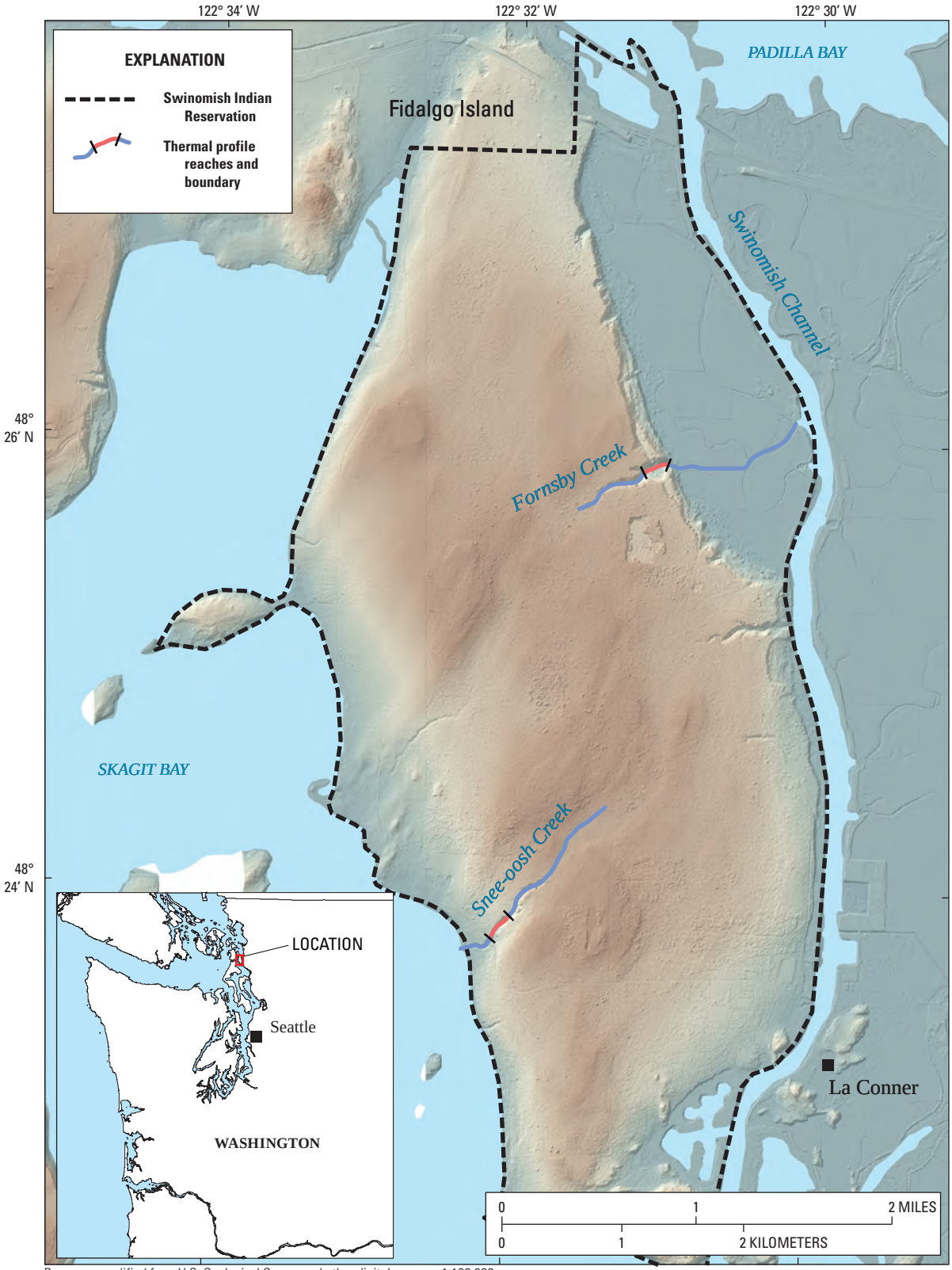
Creeks of the Swinomish Indian Reservation primarily are fed by groundwater contributions from springs and seeps during the summer dry season (Drost, 1979). Groundwater discharge to streams influences streambed temperature (Stonestrom and Constantz, 2003) in such a way that stream reaches gaining groundwater during the summer are characterized by cool temperatures at the streambed/water interface and are buffered from the diurnal temperature fluctuations. Longitudinal profiles of near-streambed temperature have been used widely to identify the location of groundwater discharge to streams based on the difference in temperature between groundwater and surface water (*for example*, Lowry and others, 2007; Briggs and others, 2012; Mwakanyamale and others, 2012). In recent years, fiber-optic distributed temperature sensing, which is capable of measuring temperatures over 1-m intervals over distances of 10^2–10^3 m has been applied to hydrological applications, including groundwater/surface-water investigations (Selker and others, 2006).

Purpose and Scope

The purpose of this report is to present longitudinal thermal profiles of stream temperatures for reaches of Snee-Oosh and Fornsby Creeks. These data complement groundwater-flow and watershed modeling efforts by the Swinomish Office of Planning and Community Development to inform management of water resources within the Swinomish Indian Reservation by elucidating the relation between its groundwater and surface-water systems.

Description of Study Area

The Swinomish Indian Reservation comprises approximately 31 km^2 of Fidalgo Island between the Swinomish Channel, Skagit Bay, and Padilla Bay (fig. 1), and is underlain primarily by Pleistocene glacial sediments (Dragovich and others, 2000). The temperate marine climate of the Swinomish Indian Reservation is characterized by cool, wet winters and warm, dry summers. Several perennial and intermittent streams drain the uplands that approach 100 m above sea level and follow deep ravines that have been incised through the glacial sediments. The glacial sediments were deposited during the last major advance of the Puget Lobe of the Cordilleran Ice Sheet during the Vashon Stade of the Fraser Glaciation. These sediments include low-permeability Vashon till deposits, which mantle most of the Swinomish Indian Reservation, and the high-permeability Vashon advance outwash, which forms an important aquifer that supplies groundwater to the Reservation and is largely confined by Vashon till (Embrey and Jones, 1998). Vashon advance outwash generally overlies low-permeability stratified sediments deposited before the Vashon Stade during the Olympia Interglaciation (Dragovich and others, 2000). Drost (1979) identified the contact between the Vashon advance outwash and the underlying low-permeability sediments as the primary location of springs and seeps that discharge into creeks within the Swinomish Indian Reservation. Streamflow within Snee-Oosh Creek originates from a large wetland complex perched upon Vashon till.



Base map modified from U.S. Geological Survey and other digital sources, 1:100,000.
Hillshade modified from 6-foot Digital Elevation data, 1:24,000, Puget Sound LIDAR Consortium.
Projection: Washington State Plane North FIPS Zone 4061. Horizontal datum: North American Datum of 1983.

Figure 1. Location of the study area and longitudinal thermal profiles of Snee-Oosh and Fornsby Creeks, Swinomish Indian Reservation, northwestern Washington.

Thermal Profile Survey

Near-streambed water temperature was measured every 30-minutes over 1-m intervals using a fiber-optic distributed temperature sensing (FO-DTS) installed on the streambed of Fornsby Creek from July 18 to 25, 2013, and Snee-Oosh Creek from July 1 to 9, 2013. The FO-DTS was deployed across the mapped geologic contacts between the Vashon advance outwash and the underlying low-permeability sediments that were identified by Drost (1979) as the primary location of springs and seeps into Snee-Oosh and Fornsby Creeks. The FO-DTS emits a pulse of laser light through a fiber-optic cable, part of which returns to the sensor as Raman-backscattered light at a higher (Stokes) and lower (anti-Stokes) wavelength relative to the incident light wavelength (Selker and others, 2006). Unlike the Stokes wavelength intensity, the anti-Stokes wavelength intensity is strongly affected by temperature; the temperature at a given section of the fiber-optic cable may be determined by measuring the ratio of the Stokes and anti-Stokes intensities together with information about the time-of-travel of the laser pulse propagation.

The FO-DTS was initially calibrated for temperature by placing the ends of the fiber-optic cable in a constant-temperature ice bath (0.0°C) verified with a National Institute of Standards and Technology (NIST) certified thermistor with an accuracy of ±0.1°C. The FO-DTS was programmed to average stream temperatures over 1-m-long sections of cable during 1-minute periods every 30 minutes. During the survey, data-logging thermistors were placed in the streambed adjacent to the calibration points on the fiber-optic cable to enable fully dynamic calibration of the FO-DTS (Hausner and others, 2011). The fiber-optic cable was deployed along approximately 225-m-long sections of Snee-Oosh and Fornsby Creeks and was secured to the streambed with small cobbles. The fiber-optic cable was mostly submerged in the stream, but low, dispersed streamflow and large logs in several locations precluded complete submergence of the fiber-optic cable. Locations of individual meter marks on the fiber-optic cable were surveyed with a Garmin® 60Csx global positioning system (GPS); the position of meter marks between surveyed points (referred to as stations) was linearly interpolated.

The FO-DTS was deployed in Snee-Oosh Creek at 14:45 on July 1, 2013, and was retrieved at 10:45 on July 9, 2013. Water temperature data for the Snee-Oosh Creek is presented in table 1, and GPS-surveyed locations of the water temperature measurement stations are presented in table 2. The time series of stream temperature shows the diurnal heating and cooling of the Snee-Oosh Creek along the measured profile (fig. 2). High temperatures were recorded during the afternoon at locations where the fiber-optic cable was not submerged (for example, near 30 and 110 m). Water temperatures were coolest and temporally constant where groundwater emerged from seeps (for example, near 200 m). The FO-DTS was deployed in Fornsby Creek at 14:45 on July 18, 2013, and was retrieved at 8:45 on July 25, 2013. Water temperature data for the Fornsby Creek is presented in table 3, and GPS-surveyed locations of the water temperature measurement stations are presented in table 4. Diurnal heating and cooling of Fornsby Creek and the non-submerged fiber-optic cable (for example, near 10 and 25 m) also are evident from the time series of Fornsby Creek stream temperature (fig. 3). Water temperatures were coolest and temporally constant where groundwater emerged from seeps (for example, distance upstream of 170 m). Water temperature measurement stations where the fiber-optic cable was placed above the wetted channel because of an obstruction also are identified in tables 2 and 4.

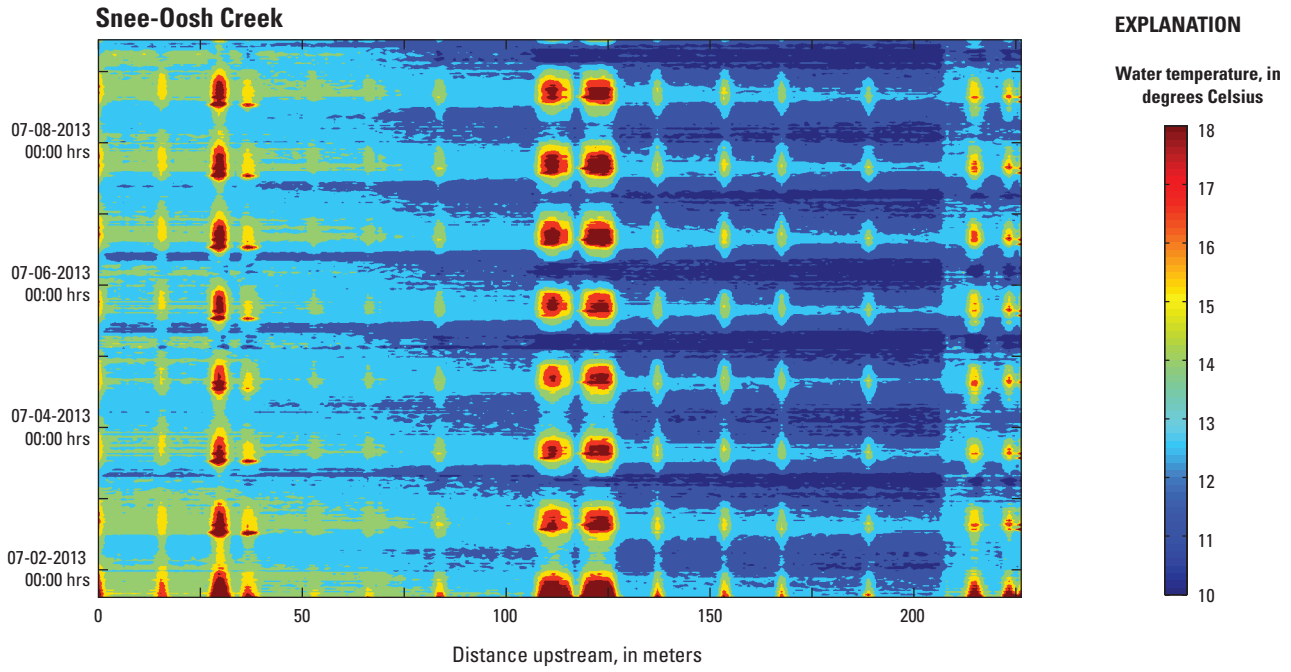


Figure 2. Longitudinal thermal profile of a 224-meter-long reach of Snee-Oosh Creek measured by fiber-optic distributed temperature sensor, Swinomish Indian Reservation, northwestern Washington, July 2013.

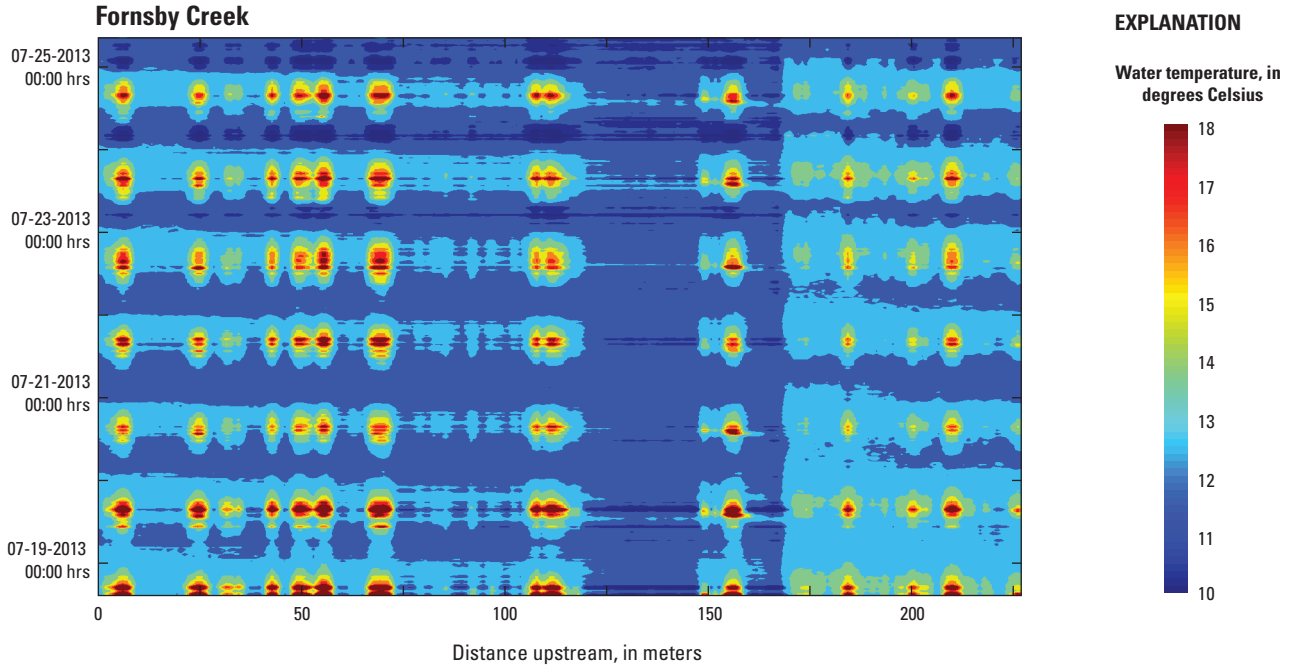


Figure 3. Longitudinal thermal profile of a 225-meter-long reach of Fornsby Creek measured by fiber-optic distributed temperature sensor, Swinomish Indian Reservation, northwestern Washington, July 2013.

Distribution of Information

A Microsoft Excel® file of tables 1–4 that include the thermal profile data for each longitudinal thermal profile is available at http://pubs.usgs.gov/ds/807/.

Table 1. Water temperature data for Snee-Oosh Creek, Swinomish Indian Reservation, northwestern Washington, July 1–9, 2013.

Table 2. Global positioning system location data for water temperature measurement stations for Snee-Oosh Creek, northwestern Swinomish Indian Reservation, northwestern Washington.

Table 3. Water temperature data at Fornsby Creek, Swinomish Indian Reservation, northwestern Washington, July 18–25, 2013.

Table 4. Global positioning system location data for water temperature measurement stations for Fornsby Creek, Swinomish Indian Reservation, northwestern Washington.

Acknowledgments

The authors would like to thank Jason Thompson, Lexton Adams-Lett, and Ryan Day of the Swinomish Office of Planning and Community Development for assistance in collecting longitudinal temperature profiles.

References Cited

Briggs, M.A., Lautz, L.K., and McKenzie, J.M., 2012, A comparison of fibre-optic distributed temperature sensing to traditional methods of evaluating groundwater inflow to streams: Hydrological Processes, v. 26, p. 1,277–1,290.

Dragovich, J.D., Troost, M.L., Norman, D.K., Anderson, G., Cass, J., Gilbertson, L.A., and McKay, D.T., Jr., 2000, Geologic map of the Anacortes South and La Conner 7.5-minute quadrangles, western Skagit and Island Counties, Washington: Washington Division of Geology and Earth Resources Open-File Report 2000-6, 4 sheets, scale 1:24,000.

Drost, B.W., 1979, Water resources of the Swinomish Indian Reservation, Washington: U.S. Geological Survey Water-Resources Investigations Report 79-12, 83 p., http://pubs.er.usgs.gov/publication/wri7912.

Embrey, S.S., and Jones, J.L., 1998, Reconnaissance hydrogeology and water quality of the Swinomish Indian Reservation, Skagit County, Washington: U.S. Geological Survey Water-Resources Investigations Report 96-4031, 28 p., http://pubs.er.usgs.gov/publication/wri964031.

Hausner, M.B., Suárez, F., Glander, K.E., Giesen, N., Selker, J.S., and Tyler, S.W., 2011, Calibrating single-ended fiber-optic raman spectra distributed temperature sensing data: Sensors, v. 11, p. 10,859–10,879.

Lowry, C.S., Walker, J.F., Hunt, R.J., and Anderson, M.P., 2007, Identifying spatial variability of groundwater discharge in a wetland stream using a distributed temperature sensor: Water Resources Research, v. 43, no. 10., doi:10.1029/2007WR006145.

Mwakanyamale, K., Slater, L., Day-Lewis, F., Elwaseif, M., and Johnson, C., 2012, Spatially variable stage-driven groundwater-surface water interaction inferred from time-frequency analysis of distributed temperature sensing data: Geophysical Research Letters, v. 39, no. 6, 6 p. doi:10.1029/2011GL050824.

Selker, J.S., Thévenaz, L., Huwald, H., Mallet, A., Luxemburg, W., van de Giesen, N., Stejskal, M., Zeman, J., Westhoff, M., and Parlange, M.B., 2006, Distributed fiber-optic temperature sensing for hydrologic systems: Water Resources Research, v. 42, no. 12, W12202, 8 p., doi:10.1029/2006WR005326.

Stonestrom, D.A., and Constantz, J., eds., 2003, Heat as a tool for studying the movement of ground water near streams: U.S. Geological Survey Circular 1260, 96 p., http://pubs.usgs.gov/circ/2003/circ1260.

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Washington Water Science Center
U.S. Geological Survey
934 Broadway, Suite 300
Tacoma, Washington 98402
http://wa.water.usgs.gov

ISSN 2327-638X (online)
http://dx.doi.org/10.3133/ds807