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Publication No. 85-e23

WA-16-1020

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MEMORANDUM
July 24, 1985

To: Greg Sorlie

Through: Lynn Singleton LS

From: Will Kendra WK

Subject: North Fork Skokomish River Streamflow and Water Quality Survey

ABSTRACT

Runoff from the North Fork Skokomish River (North Fork) is impounded and ultimately diverted from the Skokomish River system (Segment 07-16-04) for power generation by the city of Tacoma's Cushman Hydroelectric Project. Hence, summer streamflows in the lower North Fork are minimal. The Water Quality Investigations Section (WQIS) of the Washington Department of Ecology (WDOE) surveyed streamflow and water quality conditions on the lower North Fork and analyzed data from an existing monitoring station. Flow at each sampling site measured less than 20 cfs. Water quality was generally good, except that high temperatures (17.3°C and 19.7°C) were recorded at two locations. Analysis of recent discharge and temperature data from USGS Gage No. 12059500 on the lower North Fork revealed that mean monthly flows from June through September were less than 25 cfs and that temperatures have reached 17.5 °C in both July and August. Flow enhancement would likely reduce stream temperatures, prevent de-watering and fish stranding, and increase the amount of habitat available to fish.

INTRODUCTION

The Skokomish River drains 240 square miles of the Olympic Peninsula adjacent to Hood Canal (Figure 1). The mainstem Skokomish is formed by the confluence of the North and South Forks at river mile (r.m.) 9.0. Streamflows in the South Fork and its major tributary, Vance Creek, are unregulated (Cummans, 1974). Runoff from the North Fork, however, is impounded and used for hydroelectric power generation by the city of Tacoma (Figure 2). The Cushman Hydroelectric Project, completed in 1930, consists of two dams and two powerhouses. Cushman Dam No. 1 and Powerhouse No. 1 are located at r.m. 19.6. Dam No. 1 forms Lake Cushman which extends upstream to r.m. 28.0. Powerhouse No. 1 discharges to Lower Lake Cushman, which is impounded by Cushman Dam No. 2 at r.m. 17.3. A penstock at Dam No. 2 diverts nearly the entire flow of the North Fork to Cushman Powerhouse No. 2, which discharges into Hood Canal near the town of Potlatch.

Annual streamflow in the lower North Fork (r.m. 9.0 to 17.3) is considerably smaller than in the upper North Fork and the South Fork (Table 1). Spillway releases at Dam No. 2 are infrequent and typically occur during prolonged periods of runoff when the hydraulic capacity of the penstock is exceeded. In summer months, flows in the lower North Fork are derived from seepage around Dam No. 2, leakage at the radial spillway gate, spring and ground water discharges, intermittent tributary streams, and McTaggert Creek (B. Caldwell and K. Slattery, WDOE, personal communication). McTaggert Creek (r.m. 13.3) is the only perennial tributary to the lower North Fork, although a portion of the creek is diverted for hydropower production (Figure 2). A dam on upper McTaggert Creek, constructed by the city of Tacoma in 1953, diverts water through Deer Meadow Creek and into Lower Lake Cushman.

License to operate the Cushman Hydroelectric Project is scheduled for Federal Energy Regulatory Commission renewal in the near future. To attain relicense, the city of Tacoma must first receive water quality certification from WDOE. Certification was granted in 1985, but was conditioned on the maintenance of minimum flows in the lower North Fork immediately below Cushman Dam No. 2. Based on Wampler's (1980) application of the in-stream flow incremental methodology (IFIM), WDOE recommended provision of the following minimum flows to protect water quality and fish life: November to January - 33 cfs; February to June - 70 cfs; July 1 to 31 - 70 cfs decreasing to 30 cfs; August - 30 cfs; September - 65 cfs; and October - 39 cfs (K. Slattery, WDOE, personal communication).

The city of Tacoma has appealed the conditioned certification to the Pollution Control Hearings Board. The Board has scheduled a pre-hearing conference for July 29, 1985. In preparation for that conference, Marc Horton of WDOE's Office of Operations and Enforcement requested WQIS to collect stream data in the North Fork below the dam (especially temperature) and to analyze information from existing monitoring stations. As a result, the following objectives were established:

1. Document present streamflow and water quality conditions in the lower North Fork Skokomish River and McTaggert Creek.
2. Analyze recent river discharge and temperature data collected at USGS Gage No. 12059500 located on the North Fork 7.2 miles downstream from Cushman Dam No. 2.

METHODS

Five sampling stations were selected on the lower North Fork and McTaggert Creek to typify flow and water quality conditions below the Cushman dams (Figure 2). Site 1 was located immediately below Cushman Dam No. 2. Sites 2 and 4 were situated on the North Fork above and below the McTaggert Creek confluence, respectively. Site 3 was located on McTaggert Creek approximately 20 m upstream of the mouth. Site 5 was originally chosen at the site of USGS Gage No. 12059500, 1.1 miles above the South Fork confluence. However, lack of access (through private property) necessitated the relocation of site 5 to the extreme lower North Fork 50 m above the South Fork confluence.

Sampling was conducted on July 9, 1985, with the assistance of Ken Slattery from WDOE's Water Resources Planning and Management Section. Several days of hot (90°F), dry weather preceeded July 9, hence flows were expected to be minimal and stream temperatures maximal. Parameters measured during the survey included discharge, temperature, dissolved oxygen, pH, and conductivity. Current velocities required for discharge estimation were measured with a Marsh-McBirney Model 201 Portable Water Current Meter. Discharges were calculated according to the procedures of Buchanan and Somers (1969). Temperature was measured using two ASTM thermometers, one providing a check against the other. Two dissolved oxygen samples were collected at each station using a one-liter, funnel-like apparatus that permitted over-filling of the sample bottles without aeration. Oxygen samples were chemically fixed in the field and titrated upon return to the laboratory using the azide modification of the Winkler technique (APHA, 1980). Percent saturation of oxygen was estimated using the computer program "DOSAT/UNION-NH3-N" on WQIS's Wang computer. An Orion Model 399A Ionalyzer was used to determine pH. Specific conductance was measured with a Beckman Solu Bridge Type RB-5 conductivity meter.

RESULTS

Present Survey

Cushman Dam No. 2 is located at the upper end of a steep, narrow canyon. The only access to the base of the dam is a stairway that is the property of the city of Tacoma. The stairway is posted with a sign warning against trespass. In light of the city's pending certification appeal, Ken Slattery believed the project operations manager would refuse us access to the base of the dam. As a result, sampling at site 1 was cancelled.

The radial spillway gate on Dam No. 2 was leaking an estimated 2 to 3 cfs (based on visual observation). The edge of the canyon wall obstructed visual inspection of the stream channel below the dam, but a large (10 to 20 m) pool could be seen approximately 50 m downstream of the dam. Brad Caldwell (WDOE, personal communication) walked the lower North Fork from the dam downstream to McTaggert Creek in June 1984. He reported that seepage in the vicinity of the dam amounted to 1 to 2 cfs, which apparently percolated into the streambed just below the large pool. Flow remained subsurface for approximately one mile, except for occasional standing pools of water. Mr. Caldwell noted that the substrate in this reach was predominantly boulders, which he attributes to tremendous surges in discharge during spillage (see Table 1: streamflow has exceeded 5,000 cfs in the North Fork in recent years). A small creek forms about one mile below the dam, presumably fed by the subsurface flow described above. From this point to the McTaggert Creek confluence, discharge slowly increases as a result of several small spring seeps. In addition, gravel and rubble become the predominant bed material. According to Wampler (1980), this segment of the North Fork is characterized by a moderate-to-steep gradient, mostly well-vegetated banks, and a mixed deciduous-conifer canopy. The steep canyon continues downstream nearly two miles below the dam, at which point the valley broadens and side hills become increasingly forested.

A network of beaver ponds extends from McTaggert Creek upstream approximately 400 to 500 m. Depth of the ponds ranged from 0.2 to 1.0 m. We located site 2 upstream of the beaver ponds, and sampling commenced shortly after noon (Table 2). Apparently 30 to 50 percent of the streamflow observed at this station originated as leakage from the spillway gate at Dam No. 2. If leakage from the spillway gate was stopped, the North Fork would be virtually dry upstream from McTaggert Creek. Except for high temperature (17.3°C), water quality at this site was good. While walking downstream to site 3, I paused to measure temperature several meters below the beaver ponds. Water temperature had climbed to 19.7°C, an increase of 2.4°C. At that time (1300) about 90 percent of the surface area of the ponds was exposed to direct sunlight.

Streamflow in McTaggert Creek (site 3) was 1.6 cfs higher than flow in the North Fork (site 2). Water quality at site 3 was good; the low stream temperature (13.0°C) was expected to cool the warmer North Fork considerably. Extensive deposits of gravel were evident at the mouth of McTaggert Creek. Below the McTaggert Creek confluence, the North Fork assumes a moderate stream gradient for nearly three miles (Wampler, 1980). The floodplain in this reach is characterized by a predominantly deciduous overhead canopy, and the valley walls appear from the ridge to be well-forested.

Sampling station 4 was located just upstream of the point where the access road (Stevens Road) crosses the North Fork. The site was selected a sufficient distance downstream of the McTaggert Creek confluence (0.5 mile) to ensure complete mixing of McTaggert Creek and North Fork waters. The following relationship was used to calculate the expected temperature of the North Fork after complete mixing with McTaggert Creek:

$$T = \frac{(T_2)\ (Q_2) + (T_3)(Q_3)}{Q_2 + Q_3}$$

where: T = Expected complete mix temperature at sampling site 4,
T_n = Observed temperature at sampling site n,
Q_n = Observed discharge at sampling site n.

Since temperature below the beaver ponds was known, I used T_2 = 19.7 °C instead of T_2 = 17.3 °C in the equation. Expected temperature at sampling site 4 was calculated to be 16.0°C; the actual temperature was 15.8°C (Table 2). However, flow was expected to be 13.8 cfs below the confluence, but was actually measured at 15.9 cfs, a difference of 2.1 cfs. Assuming minimal sampling error, discrepancies between expected and observed temperatures and flows may be explained by the porous nature of the stream bed in the vicinity of the confluence. Specifically, a portion of upstream surface flow may pass under or through the extensive gravel deposits at the confluence, escaping measurement until it surfaces where the substrate changes above sampling site 4.

The North Fork river valley broadens to a mostly flat condition in its final 1.5 miles (Wampler, 1980). Stream gradient in this reach is moderate and the overhead canopy sparse. Temperature at station 5 (50 m above the mouth of the North Fork) was 1.0°C cooler than at station 4 (Table 2). A temperature decrease was unexpected, especially as site 5 was downstream of 200 m of low-velocity, slough-like water. The temperature drop may be the result of cool spring and ground water inflows (there are no perennial tributaries in this reach). A flow increase of 2.6 cfs between sites 4 and 5 supports this explanation, as does the slight change in specific conductance between the two stations.

Historic Flows and Temperatures

Flows at USGS Gage No. 12059500, located 1.1 miles upstream of the mouth of the North Fork, have been recorded daily since 1950. Published data are available through September 1982. For the period October 1972 to September 1982, discharge peaked in December and was lowest in August (Figure 3). Flows were highly variable from October through April, but summer flows were consistently low. Mean monthly discharges from June through September were less than 25 cfs; in August, mean streamflow was 11.2 cfs. During the ten-year period, discharge at this gage was recorded as low as 5.0 cfs.

Daily temperatures were recorded at USGS Gage No. 12059500 from March 1965 through September 1982. For the period October 1975 to September 1982, minimum temperatures occurred in January and February while temperatures peaked in August (Figure 4). During the same seven-year period, temperatures reached 17.5°C in both July and August. The maximum temperature measured during the period of daily record was 19.0°C on July 8, 1968.

DISCUSSION

The Skokomish River and its tributaries are classified as "Class AA" waters (WDOE, 1982). The water quality standard for temperature in Class AA freshwaters reads as follows: "Temperature shall not exceed 16.0°C...due to human activities." Further, "When natural conditions exceed 16.0°C...no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C" (omitted segments address marine waters). Clearly, temperatures above the 16.0°C standard have occurred in the North Fork in the recent past (Figure 4) and continue to occur at present (Table 2). The temperature of 19.7°C I observed immediately downstream of the beaver ponds (but above McTaggert Creek) exceeded the highest temperature on record at USGS Gage No. 12059500.

On July 18, 1985, Ken Slattery and Fred Hahn, head of WDOE's Water Resources Management Division, measured stream temperatures throughout the North Fork (Table 3). Temperature upstream of Lake Cushman was 12.5°C. Temperatures in the North Fork below the Cushman dams ranged from 16.5°C to 21.0°C, the latter being recorded below the beaver ponds located immediately upstream of the

McTaggert Creek confluence. Weather since the earlier survey (July 9) had remained hot and dry, hence the observed increases in stream temperature were not unexpected.

Results of the field surveys and analysis of gage data indicate that flow enhancement should decrease temperatures in the lower North Fork. Stream temperatures are governed primarily by solar processes. Warming occurs through direct absorption of solar radiation by water, or through the transfer of heat from the atmosphere or stream bed to water. The lower North Fork is well-shaded, hence the heat gain from direct absorption is small. Similarly, shading inhibits solar heating of the stream bed and thus reduces heat transfer from substrate to water. As a result, heat exchange at the air-water interface plays an important role in regulating temperatures in the lower North Fork. Higher streamflows are less subject to the influence of ambient air temperatures because of decreased travel times and increased water volumes (i.e., less heat transfer potential at the air-water interface). In addition, higher streamflows will discourage construction of beaver dams which increase time of travel and thus encourage stream warming.

Low flows resulting from the Cushman diversion contribute not only to elevated stream temperatures, but also reduce the quantity and diversity of aquatic habitat. The North Fork presently occupies a limited portion of the floodplain and vegetation is encroaching upon the area formerly occupied by the river channel. Wampler (1980) reported that beaver dams exist in nearly all portions of the lower North Fork. Beaver dams impound and obstruct river flow, changing lotic (flowing water) habitat to lentic (still water) habitat. Wampler also noted that combined low flow and low water table conditions caused a 200 m reach of the North Fork 0.8 mile above the mouth to de-water in August 1979. He estimated that this particular reach de-waters at discharges below 10 cfs.

The North Fork formerly supported healthy runs of salmon and steelhead trout (Williams, et al., 1975; Wampler, 1980). Completion of the Cushman Project eliminated runs of spring-summer chinook and sockeye salmon, and significantly impacted runs of fall chinook, coho and chum salmon, and steelhead trout. As a result of flow manipulation, the North Fork above McTaggert Creek is either virtually dry or experiencing a flood and hence is largely unsuitable for use by anadromous salmonids. According to Wampler (1980), all species of salmon are limited in their upstream migration to the lower one mile of the North Fork during low-flow years. Juvenile salmonids were present in moderate abundance at all stations sampled during the survey of July 9. However, at station 5 I observed juvenile salmonids in small pools of water which were isolated from the main river channel. As flows decrease and the river level drops, these fish become stranded; as summer progresses, they will likely perish. Over time, juvenile mortalities translate into decreased adult harvests in sport, commercial, and tribal fisheries. Enhanced flows will likely benefit anadromous salmonids by reducing stream temperatures, increasing spawning and rearing habitat, and preventing channel de-watering and associated fish stranding.

Memo to Greg Sorlie
North Fork Skokomish River Streamflow and Water Quality Survey
July 24, 1985

SUMMARY

A survey of streamflow and water quality conditions on the lower North Fork Skokomish River, in conjunction with an analysis of USGS gage data, demonstrated that:

- Extreme summer low flows and winter flood flows are a historic and recurrent problem on the North Fork.
- Temperatures above the 16.0°C standard for Class AA freshwaters have occurred in the recent past and continue to occur at present.
- Extreme low flows result in fish stranding.
- Flow enhancement would likely reduce stream temperatures, increase anadromous salmonid spawning and rearing habitat, and reduce juvenile mortality.

WK:cp

Attachments

cc: Dick Cunningham
Jay Manning
Ken Slattery

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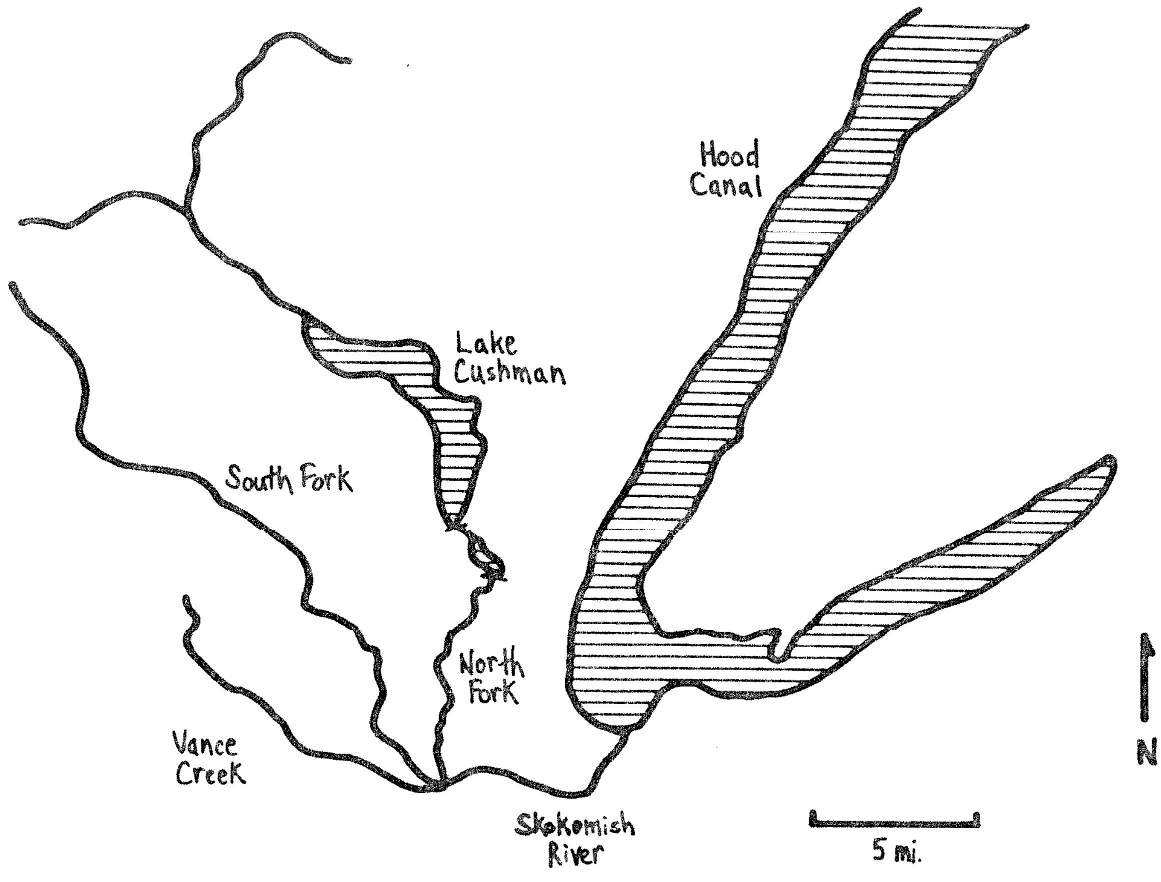

Figure 1. Map of Skokomish River system, located on the Olympic Peninsula, Washington (adapted from Wampler, 1980).

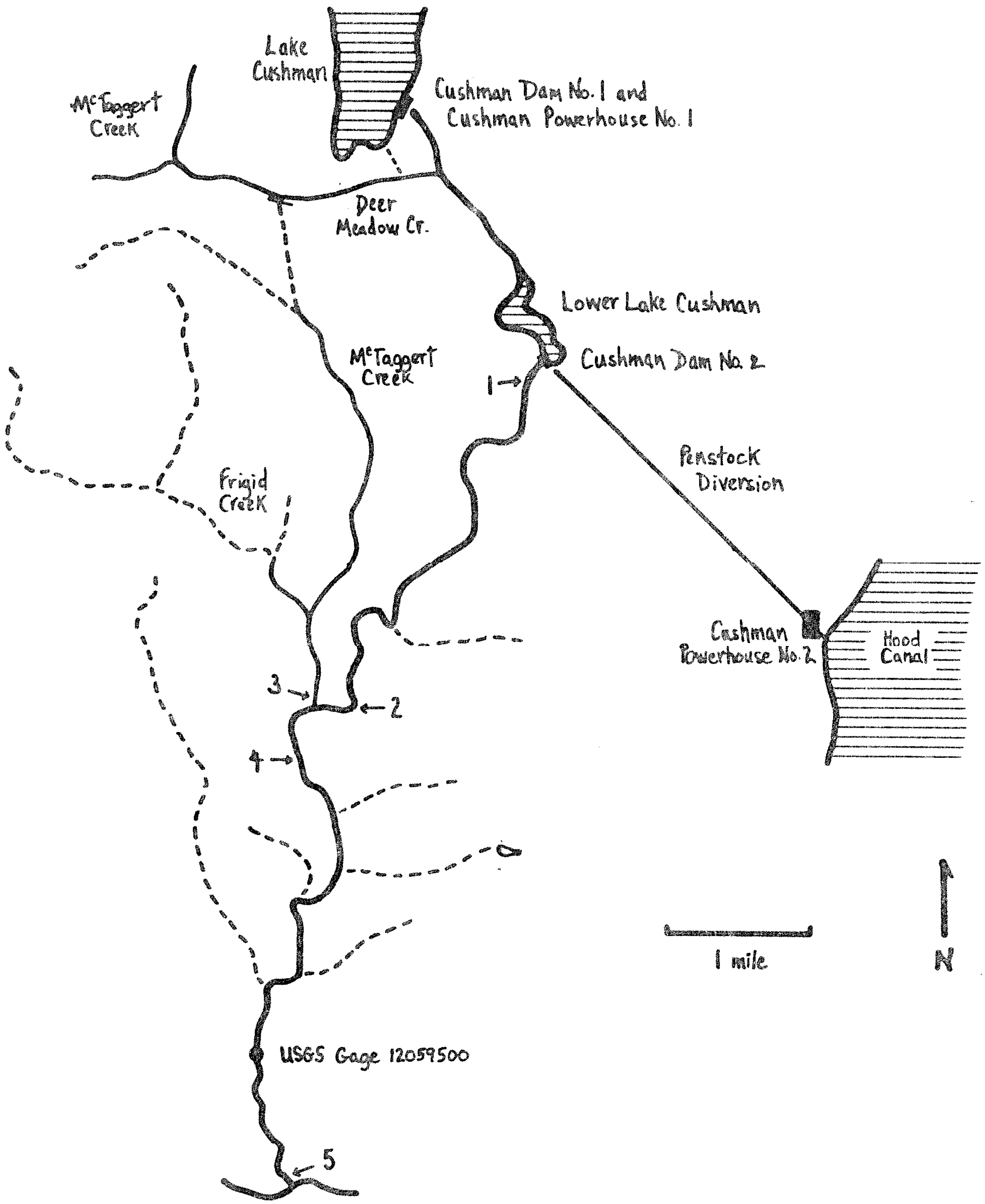

Figure 2. Map of North Fork Skokomish River showing the city of Tacoma's Cushman Dam Project and location of samping sites on the lower North Fork (1 - 5).

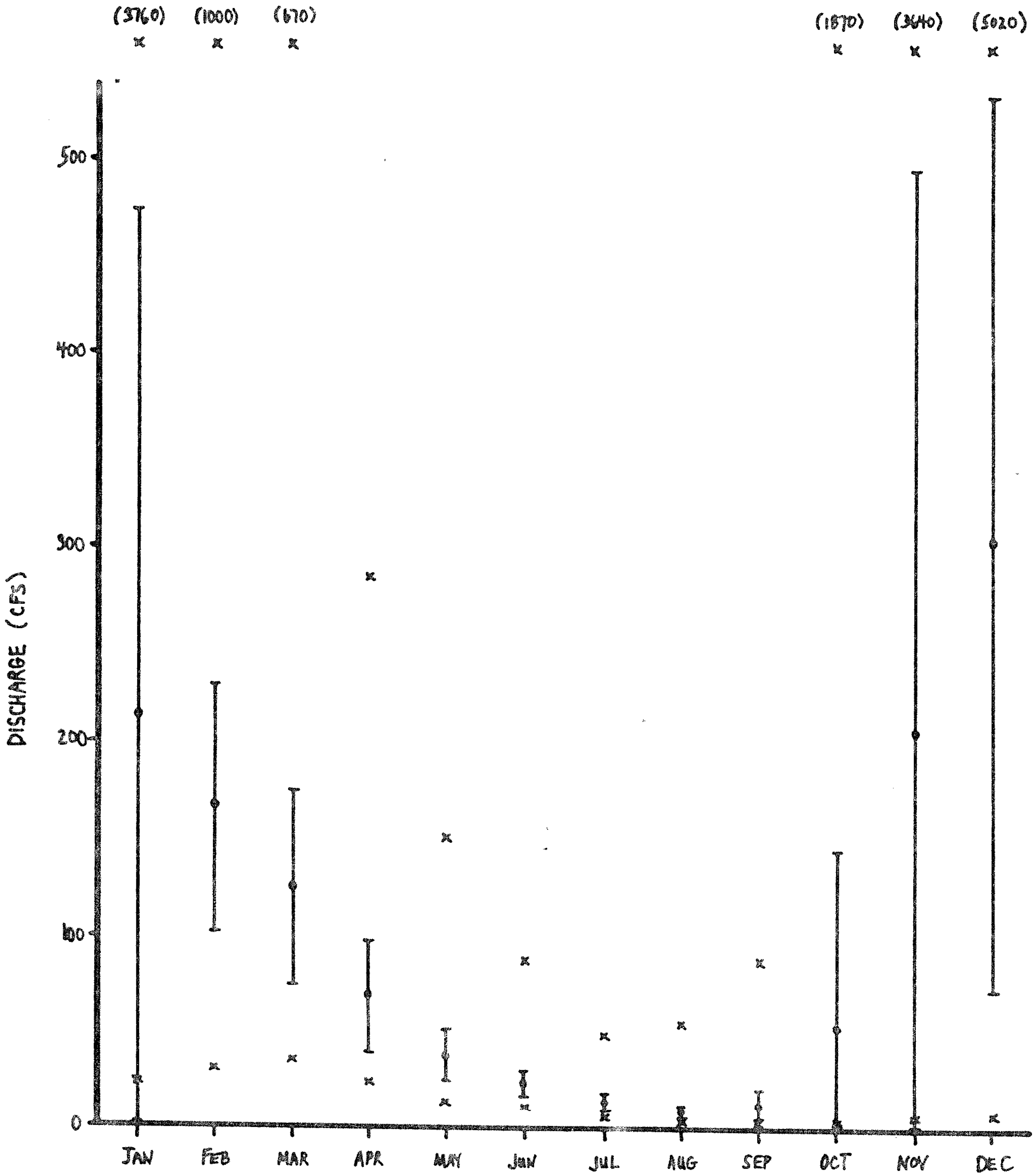

Figure 3. Mean monthly stream discharge at USGS Gage No. 12059500, located on the North Fork Skokomish River, 7.2 miles downstream from Cushman Dam No. 2. Each mean (●) was calculated by averaging the mean monthly flows reported by the USGS (1974-1980, 1982, 1983, 1985) for the period October 1972 to September 1982. Error bars denote ± 1 standard deviation; x's denote daily flow extremes during the 10-year period.

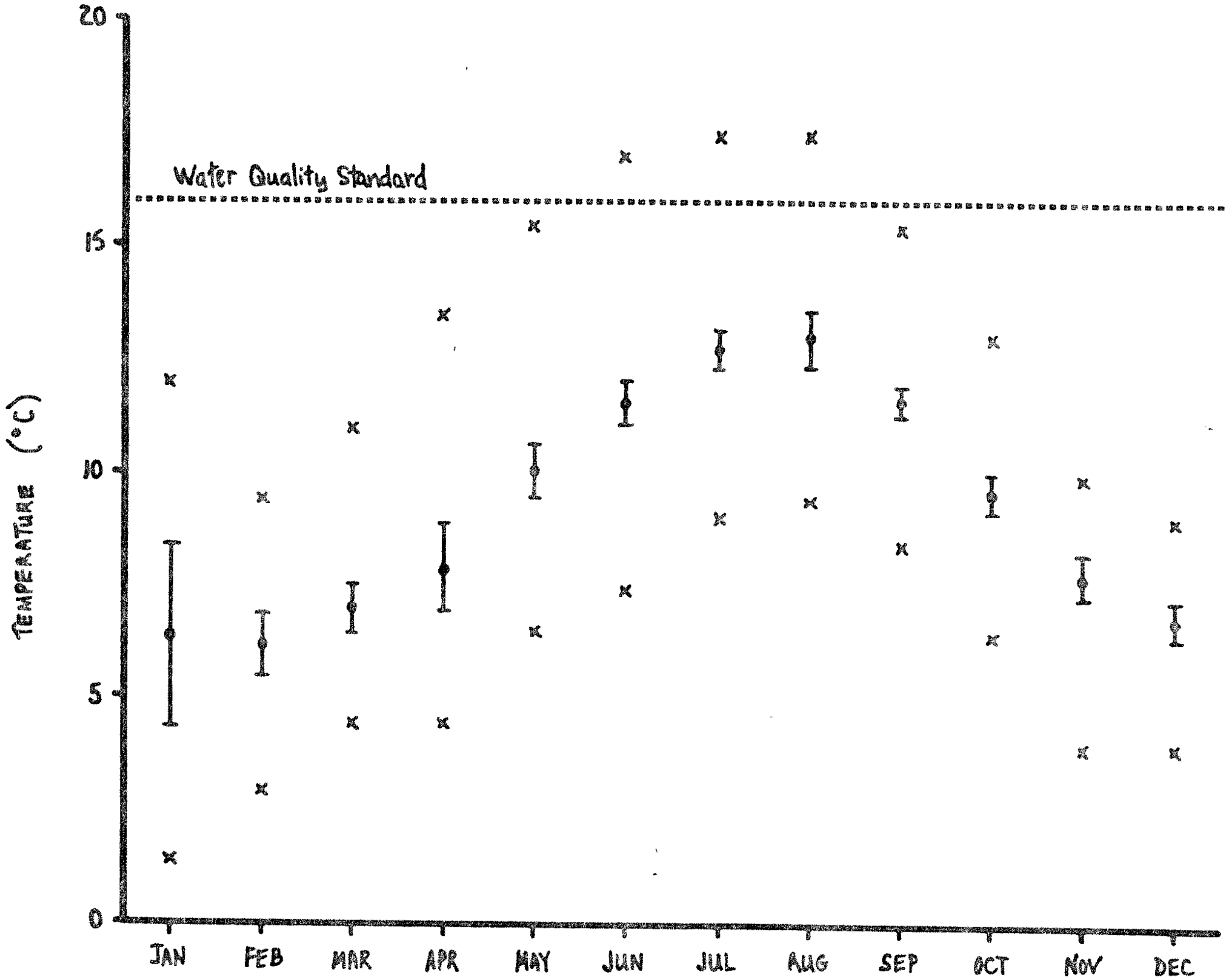

Figure 4. Mean monthly stream temperature at USGS Gage No. 12059500, located on the North Fork Skokomish River, 7.2 miles downstream from Cushman Dam No. 2. Each mean (●) was calculated by averaging the mean monthly temperatures reported by the USGS (1977-1980, 1982, 1983, 1985) for the period October 1975 to September 1982. Error bars denote ± 1 standard deviation; x's denote daily temperature extremes during the 7-year period.

Table 1. Streamflow and drainage characteristics at several USGS gage stations located on the Skokomish River and its tributaries (SF = South Fork; NF = North Fork). Mean annual discharge was calculated by averaging the mean calendar year flows reported by the USGS (1974-1980, 1982, 1983, 1985) for the years 1972 to 1981.

Gage Number	Gage Location	Drainage Area (mi^2)	Discharge (cfs)			
			Mean	Deviation	Maximum	Minimum
12056500	NF, 1.2 miles abv. Lake Cushman	57.2	536	95.8	7,780	48
12059500	NF, 1.1 miles abv. SF confluence	117*	106	50.3	5,020	5
12060500	SF, 2.3 miles abv. NF confluence	76.3	758	130.7	11,100	79
12061500	Mainstem, 3.7 miles blw. NF-SF confluence	227*	1,180	251.6	16,200	148

*Includes 99 mi^2 of non-contributing drainage above Cushman Dam No. 2 (except during spillage).

Table 2. Streamflow and water quality conditions at four sampling sites on the North Fork Skokomish River, July 9, 1985.

Sampling Site	Time	Discharge (cfs)	Temperature (°C) Air	Temperature (°C) Water	pH (S.U.)	Conductivity (umhos/cm)	Dissolved Oxygen mg/L	Dissolved Oxygen Percent Saturation
2	1230	6.1	24.4	17.3	7.0	80	10.0	103.9
3	1335	7.7	26.0	13.0	7.2	80	10.8	102.5
4	1425	15.9	29.5	15.8	7.1	80	10.0	100.6
5	1655	18.5	30.5	14.8	7.0	70	10.2	100.2

Table 3. Water temperatures at several locations on the North Fork Skokomish River, July 18, 1985 (data provided by K. Slattery, WDOE, personal communication).

Sampling Location	River Mile	Time	Temperature (°C)
Staircase Campground	29*	1030	12.5
North Fork, 1.5 miles above McTaggert Creek	14.8	1305	18.0
North Fork, 2 miles above McTaggert Creek	15.3	1420	16.5
North Fork at Stevens Road crossing (sampling site 4)	12.8	1630	17.0
North Fork above McTaggert Creek but below beaver ponds	13.3	1645	21.0
McTaggert Creek (sampling site 3)	13.3**	1650	15.0
North Fork mouth (sampling site 5)	9.0	1830	17.0

*Estimate.
**Confluence of McTaggert Creek and North Fork.