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COMPARISON OF UPSTREAM AND
DOWNSTREAM RIVER TEMPERATURES - 1964-1965

By

J. P. Corley

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COMPARISON OF UPSTREAM AND
DOWNSTREAM RIVER TEMPERATURES - 1964-1965

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COMPARISON OF UPSTREAM AND
DOWNSTREAM RIVER TEMPERATURES - 1964 AND 1965

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The President's Executive Order No. 11 258 of November, 1965 calls for a complete review of all pollution, including heat, arising in federal installations. This order has been implemented locally by letter^[1] with action required by the Pacific Northwest Laboratory.

Heat discharged to the Columbia River in reactor cooling water is one of the more important pollutants from Hanford operations. The effect of this heat on river temperatures has been studied for several years, primarily because of the potential effect on the Columbia River fisheries.

This document presents a summary of recent river temperature experience, with comparison data for a better perspective. A separate unclassified document^[2] by Battelle-Northwest evaluates the potential impact on the fisheries of the temperature changes shown here.

Base River Temperature

Reliable data on incoming temperature for the plant section of the river is available only since August of 1960 when a continuous temperature recorder was installed at the Priest Rapids gauge station about 10 miles upstream from the nearest reactor. Figure 1 shows, for the subsequent period, weekly mean river temperatures and the envelope of maximum and minimum weekly means. It is probable that in only one recent year, 1958, were the temperatures shown for the warm water months exceeded. However, the data shown is affected to a minor degree by special releases of water from Grand Coulee Dam during August and September of these years.

Downstream Temperatures

Downstream river temperatures have been measured continuously for several years at two locations, the 300 Area (below the plant boundary and within but near the head of the McNary reservoir) and Pasco (above the confluence with the Snake River and about 1/3 of the distance from the head of the reservoir to the dam).

-
- [1] Letter, P. G. Holsted to S. L. Fawcett, "Prevention, Control, and Abatement of Water Pollution by Federal Activities" Reference:H:CNZ January 14, 1966.
- [2] Nakatani, R. E. and R. F. Foster, "Hanford Temperature Effects on Columbia River Fish", BNWL-CC-591, April 5, 1966, Unclassified

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Table I shows measured river temperatures upstream and downstream from the reactors. The temperature stations are all shoreline locations; each downstream station record shows small differences from the mean river temperature at that location dependent on river flow, reactor operations and atmospheric conditions. All temperature data is given in degrees Centigrade.

The monthly averages shown are calculated from daily averages of each factor. The flow and temperature data are averaged from hourly readings of continuous recorder charts, with the hourly flow determined from the river elevation at the Priest Rapids gauge and the U.S.G.S. rating table for the gauge.

Reactor Heat Increments

Table I shows monthly average river temperature increases from reactor cooling water, calculated as follows:

$$\Delta T_q = 8.44 \times \frac{\Sigma P}{Q_R}$$

Where ΔT_q = average daily river temperature increment, in degrees Centigrade

ΣP = total reactor heat input, in megawatts

Q_R = average daily river flow rate, in cubic feet per second

Heat input is obtained from the sum of the daily average power levels at each reactor as reported by the Douglas-United Nuclear (formerly GE-IPD) Production Operation.

Table II shows summary tables for the same water years, together with data for the 1962-1963 water year previously published.^[3] No allowance is made in the tabulated values for heat losses of 3-8 percent which have been measured in the 107 retention basins, nor for some additional heat loss which occurs from the river from September to March.

Effects of the three old reactor shutdowns are less marked in the annual averages since two of the three occurred in the latter half of the water year. For comparison, if all three had been operating at an overall operating efficiency of 80 percent, ΔT_q for August, 1965 would have been 0.3°C higher and ΔT_3 about 0.4°C higher. For the same month, if N reactor had been operating at 95 percent efficiency instead of about 55 percent, its contribution to ΔT_q would have been about 0.3°C instead of about 0.2°C. Operation of the WPPSS generating station on NPR steam would not have measurably affected observed temperatures at the August, 1965 river flow, but at a low monthly average river flow of about 57,000

[3] Corley, J. P., "Effect of Hanford Operations on Columbia River Temperatures", Interim No. 2, HW-80888, Secret, December 3, 1964.

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cfs, steam generation could reduce river temperatures by as much as 0.2°C . With current reactor operations, the total reactor heat increment of river temperature is not apt to exceed 4.5°C during minimum flow periods, 2.5°C during the maximum temperature period, and 0.5°C during the peak of the flood season.

The residual $\Delta^2 T_3$ is equal to the observed temperature change across the plant boundaries minus the calculated reactor heat increment. Since shutdown of the three older reactors, this residual approximates the atmospheric effect in the plant reach of the river. Non-uniform mixing of the reactor effluents still exists for as much as 10 miles below the operating reactor furthest downstream. In addition, thin films of even higher temperature exist over very small areas at each location of seepage from cribs, trenches, and basin and piping leaks. Other than this local effect, no significant vertical stratification has been found in flowing water. Shallow shoreline areas generally show temperature increments of one to three degrees centigrade from solar heating during the summer months. Large sloughs may show even greater increments as vertical stratification occurs.

Lower Columbia Temperatures

For comparison, a tabulation of temperatures reported by the U.S. G.S. from downstream dams and tributaries is presented in Table III with the Priest Rapids gauge and Pasco data. The data covers the summer months of 1962-1965. Caution is in order on the U.S.G.S. data, in that the measurements are once-daily dip temperatures and do not necessarily reflect the mean temperatures. Nevertheless, the pattern seems reasonably clear. Temperatures at McNary Dam during the periods covered are routinely higher than at Pasco and appear to be influenced significantly by the Snake River which is warmer than the Columbia at McNary. Little change occurs in the river temperature below McNary as far as Bonneville. In all the reservoirs, there will be extended shallow areas in which temperatures several degrees higher than those shown will occur routinely from solar heating.

Notation

Q_r = river flow rate, in kcfs

T_{PR} = river temperature at the Priest Rapids gauge

T_3 = river temperature at the PRTR water intake, 300 Area

T_p = river temperature at the Pasco water intake

ΔT_q = reactor heat contribution to average river temperature

$\Delta T_3, \Delta T_p = (T_3 - T_{PR}), (T_p - T_{PR})$

$\Delta^2 T_3 = (\Delta T_3 - \Delta T_q)$

FIGURE 1
COLUMBIA RIVER TEMPERATURE AT PRIEST RAPIDS GAUGE
1960 -- 1966

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TABLE I

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MONTHLY AVERAGE TEMPERATURES AND DIFFERENCES

Month-Year	Q_R	T_{PR}	T_3	T_p	ΔT_q	ΔT_3	ΔT_p	$\Delta^2 T_3$	ΣQ_{MW}
September, 1963	71.1	18.3	20.4	19.8	2.6	2.1	1.5	0.5	11,350
October	61.7	16.3	17.6	17.0	1.8	1.3	0.7	-0.5	11,150
November	56.9	11.9	12.7	12.4	2.1	1.0	0.5	-1.1	14,150
December	60.7	7.7	9.0	8.5	2.2	1.3	0.8	-0.9	16,840
January, 1964	56.8	5.5	7.1	6.7	2.3	1.4	1.1	-0.9	16,500
February	75.3	4.7	6.2	6.1	1.5	1.5	1.4	0.0	13,550
March	63.9	4.7	7.1	6.8	2.2	2.4	2.1	0.2	14,700
April	65.3	7.2	9.7	9.4	1.8	2.5	2.3	0.7	13,900
May	168.8	9.7	11.5	11.5	1.0	1.9	1.8	0.8	20,100
June	388.0	12.8	13.8	13.6	0.4	1.0	0.7	0.6	18,450
July	295.8	15.3	16.5	16.3	0.5	1.2	1.0	0.7	17,550
August	131.1	17.1	18.6	18.2	1.0	1.5	1.1	0.6	16,600
Annual Average	124.6	10.9	12.6	12.2	1.5	1.6	1.3	0.1	22,300 ?
September, 1964	74.3	16.3	18.2	17.7	1.9	1.9	1.4	0.0	16,700
October	87.1	14.6	15.5	15.1	1.2	1.0	0.5	-0.2	12,400
November	70.1	10.8	12.1	11.4	2.4	1.3	0.7	-1.1	20,000
* ** December	68.5	6.3	7.7	7.0	2.5	1.4	0.7	-1.1	20,300
January, 1965	77.3	4.4	6.0	5.6	1.9	1.6	1.1	-0.3	17,400
February	99.2	3.3	5.2	-	1.4	1.8	-	0.4	16,500
March	88.3	4.1	5.6	-	1.4	1.5	-	0.1	14,700
*** April	111.5	6.6	8.5	-	1.3	1.8	-	0.5	17,400
May	235.4	10.0	11.0	11.3	0.6	0.9	1.2	0.3	16,700
**** June	311.4	13.3	14.0	14.4	0.4	0.8	1.1	0.4	14,800
July	218.4	16.1	17.1	17.5	0.5	1.1	1.5	0.6	12,900
August	127.8	18.4	19.6	19.7	0.9	1.2	1.3	0.3	13,700
Annual Average	130.8	10.3	11.7	-	1.4	1.4	1.2(est.)	0.0	21,700 ?

- * N Reactor reached nominal full power level
- ** DR Reactor out of service
- *** H Reactor out of service
- **** F Reactor out of service

~~8.44~~

$$\Sigma P = \frac{\Delta T_q Q_R}{8.44} = \frac{11,350}{8.44} \text{ MW Sep 63}$$

TABLE II

ANNUAL SUMMARIES
Averages, Maximums, and Minimums

	1962 - 1963			1963 - 1964			1964 - 1965		
	<u>Avg.</u>	<u>Max.</u>	<u>Min.</u>	<u>Avg.</u>	<u>Max.</u>	<u>Min.</u>	<u>Avg.</u>	<u>Max.</u>	<u>Min.</u>
Q	111.8	308.0 (6/16)	48.7 (9/16)	124.6	457.0 (6/17)	39.2 (4/5)	130.8	337.0 (6/21)	38.3 (12/13)
T _{PR}	11.0	19.5 (8/13)	3.0 (2/2)	10.9	19.3 (9/10)	4.1 (3/10)	10.3	19.1 (8/15)	2.9 (2/16)
T ₃	12.9	21.8 (8/11)	3.7 (1/31)	12.6	21.6 (9/8)	4.9 (2/25)	11.7	20.3 (8/8)	4.4 (3/4)
ΔT ₃	1.8	3.8 (3/24)	-1.0 (1/10)	1.6	3.2 (3/30)	-0.2 (11/21)	1.4	3.2 (1/31)	-0.7 (12/16)
ΔT _q	1.2	2.6 (9/16)	0.3 (6/20)	1.5	3.6 (1/1)	0.2 (6/14)	1.4	4.9 (11/22)	0.2 (6/24)
Δ ² T ₃	0.5	2.4 (5/21)	-2.1 (1/10)	0.1	1.7 (4/27)	-3.3 (1/12)	0.0	1.7 (4/14)	-3.0 (11/22)

() = Date of occurrence

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TABLE III

RIVER TEMPERATURE COMPARISON - JULY-SEPTEMBER
(All data to nearest half degree Centigrade)

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<u>Dates</u>	<u>Range of Daily Averages</u>		<u>Snake River</u> <u>Ice Harbor</u> <u>Dam</u>	<u>Columbia River Dams</u>		
	<u>Priest</u> <u>Rapids</u> <u>Gauge</u>	<u>Pasco</u>		<u>McNary</u>	<u>Dalles</u>	<u>Bonneville</u>
<u>1962</u>						
July 1-3	14.5-15	15-15.5	19	16 - 18	16.5 - 17	16.5 - 18
July 4-10	14.5-15.5	15.5-16.5	19-19.5	16.5-18	16.5-17	16.5-18
July 11-17	16	-	19.5-20.5	-	17-18	17-18
July 18-24	15.5-16.5	15.5-18.5	20.5-21	18-20	-	18-20
July 25-31	17-18	18.5-19	22-24.5	19.5-23	-	20-21
Aug. 1-7	17-18	-	23.5-24.5	20-22	-	20-21.5
Aug. 8-14	17	-	23-23.5	19-21.5	19-20	19.5-20.5
Aug. 15-21	17-17.5	19.5	23-23.5	20.5-21	20-21	20.5
Aug. 22-28	16.5-18	18.5-20	22-23.5	20-21.5	20-21	-
Aug. 29-Sept. 4	16.5-18	18.5-19.5	21-22	19.5-21	19-20	19-20
Sept. 5-11	16.5-18	18.5-19.5	20.5-21.5	19-21	12-20	19-20
Sept. 12-18	16.5	18.5-19	19-20.5	18.5-19	18.5-19	18-19
Sept. 19-25	17-18	18.5-20	19-20	19-19.5	18.5	18-18.5
Sept. 26-Oct. 2	16.5-18	17-19.5	19-20	19-19.5	17-19	18-18.5
<u>1963</u>						
June 26-July 2	14.5-15.5	15-16.5	16.5-17	16.5-17	16	16-16.5
July 3-9	15.5-16	16.5-17	17-20	16.5-18	16.5-17	16.5-18.5
July 10-16	15.5-16.5	16.5-18	20-21	18	17-18.5	18-19
July 17-23	16.5-18	17-18.5	21	18-19	18-19	18.5-19.5
July 24-30	17	18-19	21-21.5	19	18.5-19.5	19-19.5
July 31-Aug. 6	17-19	18.5-20	21-22	19-20	19-20	19-20
Aug. 7-13	19-19.5	19.5-20	21.5-24.5	20-21	20-21	19.5-21
Aug. 14-20	18.5-19.5	19.5-20.5	24-24.5	21-21.5	21-21.5	21
Aug. 21-27	18-18.5	19-19.5	22-24	20.5-21	19.5-20.5	20-21
Aug. 28-Sept. 3	18-18.5	19-20	21-22	20.5-21.5	20-20.5	20-20.5
Sept. 4-10	18.5-19.5	20-20.5	21-22	20.5-21.5	19.5-21	20-21
Sept. 11-17	18-19	19-20.5	21.5-22	21-21.5	19.5-21	20-21
Sept. 18-24	18-18.5	19-19.5	19.5-21	20-21	19-19.5	19-20
Sept. 25-Oct. 1	18-18.5	19-20	19	20	19-19.5	19-19.5

TABLE III (Continued)

RIVER TEMPERATURE COMPARISON - JULY-SEPTEMBER (Continued)
(All data to nearest half degree Centigrade)

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<u>Dates</u>	<u>Range of Daily Averages</u>		<u>Snake River</u>	<u>Columbia River Dams</u>		
	<u>Priest Rapids Gauge</u>	<u>Pasco</u>	<u>Ice Harbor Dam</u>	<u>McNary</u>	<u>Dalles</u>	<u>Bonneville</u>
<u>1964</u>						
July 1-7	14-14.5	14.5-15	15.5-16.5	15.5-16	15.5-16	15.5-16
July 8-14	14.5-15.5	15.5-16	17-20	16-17	16-18.5	16.5-18.5
July 15-21	15.5	16-16.5	20.5-21	17-18	18-18.5	18-18.5
July 22-28	15.5-16.5	16.5-18	20.5-22	18	18-19	18-19
July 29-Aug. 4	16.5-17	17-18.5	21.5-22	18.5-19	19	18.5-19.5
Aug. 5-11	16-17	17-19	21	19-19.5	19-19.5	19-20
Aug. 12-18	17	18.5-19	21-22	19.5-20	19.5	19-19.5
Aug. 19-25	16.5-18.5	18-19.5	20.5-22	20	19-20.5	19-20.5
Aug. 26-Sept 1	16-18	17-18.5	20-21	19-20	18-20.5	17-20
Sept. 2-8	16-16.5	17-19	18-19	18-18.5	-	17-18
Sept. 9-15	16-16.5	18-19	18	18-18.5	17-18	17-18
Sept. 16-22	15.5-16.5	18-18.5	18	18-18.5	17-18	16.5-18
Sept. 23-29	16-16.5	17-18.5	16-18	18-18.5	17-18	16.5-17
Sept. 30-Oct. 6	15-15.5	15.5-16.5	16-16.5	16.5-18	15-16.5	16-17
<u>1965</u>						
June 30-July 6	14.5-15.5	15.5-16.5	15.5-18.5	15.5-16.5	16-17	16-18
July 7-13	15.5-16	16.5-17	18.5-19.5	17-18	17-18.5	18
July 14-20	15.5-16.5	16.5-18	19-20	18-19	18.5-19	18.5-19
July 21-27	16-17	16.5-18.5	21	18.5-19	19-19.5	19-19.5
July 28-Aug. 3	17-18.5	19-20	17-21	19-20.5	19.5-21	19.5-20.5
Aug. 4-10	18-19	19.5-20.5	18.5-23	21.5	20.5-21.5	20-21.5
Aug. 11-17	19	19.5-20.5	24	21-21.5	21-21.5	21.5
Aug. 18-24	18.5	19.5-20.5	23-24	20.5-21	21.5	21-22
Aug. 25-31	17-18.5	18.5-20	20.5-22	20-21	19.5-21	19.5-21
Sept. 1-7	17-18	18.5-19.5	19.5-20	19.5-20	18.5-20	18.5-19
Sept. 8-14	18-18.5	19-20	19-19.5	19-19.5	18.5-19.5	18-19
Sept. 15-21	16.5-18	17-19	16-18.5	18.5-19.5	17-19	16.5-18
Sept. 22-28	16.5-17	17-19	15.5-16	18	17-18	16.5-17
Sept. 29-Oct. 5	16.5-17	17-18.5	15.5	17.5-18	16.5-18	16-16.5

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