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AUGUST 14, 1946

FINAL REPORT

COLUMBIA RIVER TEMPERATURE SURVEY

AT HANFORD ENGINEER WORKS

W. E. H. J.
W. E. H. J.
3-1-46
4. T. Hauff
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Prepared By:

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W. R. Lewis

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FINAL REPORT - COLUMBIA RIVER TEMPERATURE SURVEY AT HANFORD ENGINEER WORKS

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Introduction

It was agreed during a meeting on July 10, 1946 attended by Major A. A. White of the U. S. Army Engineers Manhattan District, L. R. Donaldson of the University of Washington, H. Thayer of the U. S. Army Engineers Seattle District, and R. F. Foster, M. H. Smith, S. T. Cantril and C. P. Kidder of the du Pont Company, that an investigation should be made to determine how fast and in what fashion the temperature of the effluent water from the 100 Areas is dissipated in the Columbia River. A preliminary report (Document No. 7-3684) on this investigation was issued March 1, 1946: it discussed the testing techniques developed and the results of a survey made at the 100-B Area. Following a review of the data and tentative conclusions presented therein, it was agreed to extend the survey using similar technique to the D and F Areas, and to determine if the tentative conclusions were substantiated.

Summary

The tentative conclusions presented in the preliminary report have been substantiated in all major respects. The quantities of heat added to the river by the three 100 Areas operating at the maximum rate experienced to date will heat the river less than 0.35°C at its minimum recorded flow, and less than 0.01°C at its maximum recorded flow, after complete mixing. Temperature traverses of the river made at each area, and representing a range of river flows and weather conditions, have indicated a general pattern in which the warm discharge water mixes with the river. At each area, all temperature effects due to plant water additions have leveled out to less than 0.2°C after the first 1500 feet of flow. At each area a broad band of water at ambient main channel temperature flows past the warm water addition point for at least 1500 feet, or until the effects of the warm water addition are dissipated to less than 0.2°C . No condition can be visualized whereby a temperature barrier across the river could be formed.

It was necessary to develop an elaborate technique involving precision temperature measurements made with extreme rapidity, to differentiate between solar heating effects and plant warm water effects. The temperature gradients caused by plant warm water additions were found to be definite and reproducible within the first 1500 feet of flow, but were found to be minor in comparison to the temperature variations occurring from hour to hour and from point to point due to solar heating effects. The sole exception to this generalization is the space within the immediate vicinity of the warm water discharge. Theoretically it is possible to obtain spot samples of water here 20°C above the river temperature, but these higher temperatures are reduced very rapidly by mixing with river water, and they could not form a temperature barrier across the river.

Discussion

The Columbia River derives most of its water from melting ice and snow. It normally is at its lowest stage during February, March and April. The spring rise starts in May and the crest is reached usually in June. The flow then drops off gradually for the remainder of the year.

The normal flow is about 75,000 cu.ft. per second. The lowest flow of which we have record was 25,300 cu.ft. per second on January 30, 1931. The highest crest on record was 750,000 cu.ft. per second in June 1894.

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The maximum operating rate for the three 100 Areas was experienced during July 1945. Under these conditions, the three areas returned to the river a total of 170,000 G.P.M. (378 cu.ft. per second) of water heated about 21°C above the river temperature. After complete mixing with the river, this quantity of returned warm water would heat the normal 75,000 cu.ft. per second flow of the river

$$\frac{378 \times 21}{75,000} = 0.11^{\circ}\text{C}$$

The minimum recorded flow would be heated about three times this amount or less than 0.35°C, and the maximum recorded flow would be heated 0.01°C. The maximum heating effect of any one area is less than 40% of the above total for the three areas.

At each of the three 100 Areas the warm water is introduced into the river through two parallel submerged 42 inch diameter pipes. These pipes are buried in the river bottom and extend out to discharge in the main channel of the river. At B Area, the discharge is about 400 feet out from the south bank; at D Area the pipes extend out beyond a small island to a point about 1500 feet from the south bank; at F Area the channel is close to the southwest bank, and the discharge is out only about 150 feet from the normal water line on that bank.

Under most conditions of river elevation and plant discharge rate, air is entrained with the warm water entering the discharge pipes. The water velocity in the pipes is not sufficient to keep this air dispersed as small bubbles, and as a result, huge air bubbles and surges of water are released alternately from the discharge end. Observations made when the discharge water had colored matter added to it, showed that the air bubbles came to the surface at a steep vertical angle, but that the inertia of the water surges carried the warm water 25 to 30 feet farther out into the river. The resultant alternating surges of warm water out of the discharge pipes result in rapid temperature fluctuations in the immediate vicinity of the discharge, but 200 feet or more downstream, conditions have evened out to such an extent that little fluctuation can be detected.

As discussed in the preliminary report, two general types of temperature measuring equipment were developed for surveying these conditions:

- A) For obtaining "spot" samples in the vicinity of the discharge, a 100 cc flask with insulated side-walls and quick-opening lid, mounted on a 20 foot pole was used. The temperature of samples taken with this equipment was read with a glass thermometer with an overall accuracy estimated as better than 1/2°C. The results of a survey made with these facilities at F Area are reported in Document No. 3-2401. Several samples as warm as 3.8°C above ambient main channel temperature were obtained 30 feet downstream from the discharge. It is difficult to maneuver the boat to stay immediately over the discharge, but it is reasonable to assume that if this were possible, "spot" samples 10 or 15°C above ambient river temperature might be obtained at the instant a surge of water 20°C above ambient temperature left the discharge.
- B) The special high-speed response resistance thermometer was developed to permit rapid explorations to be made over wide areas, where the temperature is stable for periods of five seconds or longer. The instrument developed for this purpose is described in more detail in the attached appendix B and is shown in photographs in Appendix C. Two preliminary designs were constructed and tested on this survey before the final instrument was perfected. The temperature feeling element is mounted in a torpedo shaped "fish" or parvane which maintains

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a constant depth of submergence while being towed at the high speeds necessary on this river. This instrument permits temperature readings with an accuracy of better than 0.1°C to be made with a time of response of 3 to 5 seconds. This response was sufficiently rapid that surveys could be made as fast as the boat location could be checked. However, when the instrument was used immediately downstream of the discharge, the indicator would oscillate up and back as frequently as 4 or 8 times in a 10 second period. When exposed to temperature fluctuations of this rapidity, the average of the temperatures indicated over a 10 second period probably is an accurate average of the true temperatures, but the maximum and minimum values indicated would not give the true width of variation being experienced. For this reason, the "spot" sample method is considered the more accurate method for determining the limits of temperature variation from second to second in the immediate vicinity of the discharge. The resistance thermometer is more accurate in locating bands of small temperature difference, and in differentiating solar heating effects from those of the warm water discharge.

In preparing to make a survey with the resistance thermometer, two range flags were set up on the river bank to mark each line along which traverses were to be made. After a certain amount of practice, the boat operator was able to vary his motor speed as necessary to compensate for changes in the river current, and was able to move at a uniform rate across the river always keeping in line with the two range flags. A transit was set up on the river bank in line with the flags, and was sighted on a stadia rod in the boat. The stadia rod man in the boat readjusted his target on the rod to correspond to each 100 foot increment as the boat progressed across the river. A flagman stationed along side the transit signalled to the boat as it came on to each target setting. In this manner it was possible to traverse across and back 1500 feet of river in ten minutes. However, when it was necessary to change boat operators, stadia men or transit men, it often required half a day to re-establish optimum coordination.

The data obtained at B Area during the survey of September 14, 1945 were presented in graphical form as Appendix B of the preliminary report, Document No. 7-3684 and are not repeated here. Data obtained at D and F Areas over the period April 17 to 25, 1946 are presented in graphical form as the attached Appendix A, Sheets 1, 2, 3 and 4.

A detailed description of the high-speed resistance thermometer is given as the attached Appendix B.

Photographs of the "fish" or parvane containing the resistance thermometer element and of the instrument and "fish" in operation on the boat are given as Appendix C, Sheet 1. Photographs illustrating the coordination between the boat crew and the transit man and flagman on the shore are presented as Appendix C, Sheets 2 and 3. Aerial views of the river illustrating its general configuration and the location of the various plants with respect to it are presented as Appendix D, sheets 1 to 5 inclusive.

W. E. JORDAN, CHIEF SUPERVISOR
100 - 300 TECHNICAL

R. H. Osterloh
R. H. Osterloh
100 Technical

W. R. Lewis
W. R. Lewis
100 Technical

RHO:WRL:jd

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Columbia River Temperature Survey

7-467f

100 D Area

April 25, 1946

Weather: Clear

Wind: 142, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225, 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345, 350, 355, 360, 365, 370, 375, 380, 385, 390, 395, 400, 405, 410, 415, 420, 425, 430, 435, 440, 445, 450, 455, 460, 465, 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525, 530, 535, 540, 545, 550, 555, 560, 565, 570, 575, 580, 585, 590, 595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700, 705, 710, 715, 720, 725, 730, 735, 740, 745, 750, 755, 760, 765, 770, 775, 780, 785, 790, 795, 800, 805, 810, 815, 820, 825, 830, 835, 840, 845, 850, 855, 860, 865, 870, 875, 880, 885, 890, 895, 900, 905, 910, 915, 920, 925, 930, 935, 940, 945, 950, 955, 960, 965, 970, 975, 980, 985, 990, 995, 1000

TEMPERATURE PROFILES

In line with warm water discharge pipe

353 feet downstream

887 feet downstream

2251 feet downstream

5703 feet downstream

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Continued from Page 1

7-4674

100 D.H.A.

April 12, 1946

Water Discharge Pipe
from the 100 D.H.A. Plant

Temperature Profile

In Line With Water
Discharge Pipe

353 Feet Downstream

667 Feet Downstream

2251 Feet
Downstream

4105 Feet
Downstream

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Boundary River Temperature Survey

7-4674

100 ft Area

April 23, 1943

Weather: Partly Cloudy

Wind: Light, 10-15 mph, S.W.

Temperature Profiles

In Line With Worm
Water Discharge
Pipes

150 Feet Downstream

300 Feet Downstream

600 Feet Downstream

1100 Feet Downstream

1400 Feet Downstream

South Bank

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Columbia River Temperature Survey 7-4674

160 F Area

April 12, 1945

Weather: B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL, BM, BN, BO, BP, BQ, BR, BS, BT, BU, BV, BW, BX, BY, BZ, CA, CB, CC, CD, CE, CF, CG, CH, CI, CJ, CK, CL, CM, CN, CO, CP, CQ, CR, CS, CT, CU, CV, CW, CX, CY, CZ, DA, DB, DC, DD, DE, DF, DG, DH, DI, DJ, DK, DL, DM, DN, DO, DP, DQ, DR, DS, DT, DU, DV, DW, DX, DY, DZ, EA, EB, EC, ED, EE, EF, EG, EH, EI, EJ, EK, EL, EM, EN, EO, EP, EQ, ER, ES, ET, EU, EV, EW, EX, EY, EZ, FA, FB, FC, FD, FE, FF, FG, FH, FI, FJ, FK, FL, FM, FN, FO, FP, FQ, FR, FS, FT, FU, FV, FW, FX, FY, FZ, GA, GB, GC, GD, GE, GF, GG, GH, GI, GJ, GK, GL, GM, GN, GO, GP, GQ, GR, GS, GT, GU, GV, GW, GX, GY, GZ, HA, HB, HC, HD, HE, HF, HG, HH, HI, HJ, HK, HL, HM, HN, HO, HP, HQ, HR, HS, HT, HU, HV, HW, HX, HY, HZ, IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN, IO, IP, IQ, IR, IS, IT, IU, IV, IW, IX, IY, IZ, JA, JB, JC, JD, JE, JF, JG, JH, JI, JJ, JK, JL, JM, JN, JO, JP, JQ, JR, JS, JT, JU, JV, JW, JX, JY, JZ, KA, KB, KC, KD, KE, KF, KG, KH, KI, KJ, KK, KL, KM, KN, KO, KP, KQ, KR, KS, KT, KU, KV, KW, KX, KY, KZ, LA, LB, LC, LD, LE, LF, LG, LH, LI, LJ, LK, LL, LM, LN, LO, LP, LQ, LR, LS, LT, LU, LV, LW, LX, LY, LZ, MA, MB, MC, MD, ME, MF, MG, MH, MI, MJ, MK, ML, MM, MN, MO, MP, MQ, MR, MS, MT, MU, MV, MW, MX, MY, MZ, NA, NB, NC, ND, NE, NF, NG, NH, NI, NJ, NK, NL, NM, NN, NO, NP, NQ, NR, NS, NT, NU, NV, NW, NX, NY, NZ, OA, OB, OC, OD, OE, OF, OG, OH, OI, OJ, OK, OL, OM, ON, OO, OP, OQ, OR, OS, OT, OU, OV, OW, OX, OY, OZ, PA, PB, PC, PD, PE, PF, PG, PH, PI, PJ, PK, PL, PM, PN, PO, PP, PQ, PR, PS, PT, PU, PV, PW, PX, PY, PZ, QA, QB, QC, QD, QE, QF, QG, QH, QI, QJ, QK, QL, QM, QN, QO, QP, QQ, QR, QS, QT, QU, QV, QW, QX, QY, QZ, RA, RB, RC, RD, RE, RF, RG, RH, RI, RJ, RK, RL, RM, RN, RO, RP, RQ, RR, RS, RT, RU, RV, RW, RX, RY, RZ, SA, SB, SC, SD, SE, SF, SG, SH, SI, SJ, SK, SL, SM, SN, SO, SP, SQ, SR, SS, ST, SU, SV, SW, SX, SY, SZ, TA, TB, TC, TD, TE, TF, TG, TH, TI, TJ, TK, TL, TM, TN, TO, TP, TQ, TR, TS, TT, TU, TV, TW, TX, TY, TZ, UA, UB, UC, UD, UE, UF, UG, UH, UI, UJ, UK, UL, UM, UN, UO, UP, UQ, UR, US, UT, UU, UV, UW, UX, UY, UZ, VA, VB, VC, VD, VE, VF, VG, VH, VI, VJ, VK, VL, VM, VN, VO, VP, VQ, VR, VS, VT, VU, VV, VW, VX, VY, VZ, WA, WB, WC, WD, WE, WF, WG, WH, WI, WJ, WK, WL, WM, WN, WO, WP, WQ, WR, WS, WT, WU, WV, WW, WX, WY, WZ, XA, XB, XC, XD, XE, XF, XG, XH, XI, XJ, XK, XL, XM, XN, XO, XP, XQ, XR, XS, XT, XU, XV, XW, XX, XY, XZ, YA, YB, YC, YD, YE, YF, YG, YH, YI, YJ, YK, YL, YM, YN, YO, YP, YQ, YR, YS, YT, YU, YV, YW, YX, YY, YZ, ZA, ZB, ZC, ZD, ZE, ZF, ZG, ZH, ZI, ZJ, ZK, ZL, ZM, ZN, ZO, ZP, ZQ, ZR, ZS, ZT, ZU, ZV, ZW, ZX, ZY, ZZ

Temperature Profiles

In-Line With Above
Water Discharge Pipes

150 Feet Downstream

300 Feet Downstream

600 Feet Downstream

1000 Feet Downstream

1500 Feet Downstream

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APPENDIX B

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RIVER WATER TEMPERATURE MEASUREMENTS

The Instrument Department was requested to make available, suitable equipment for the purpose of making a cross sectional temperature survey at the points of effluent from the various areas. It was desirable and necessary that the equipment have the following characteristics.

- 1) Accuracy - that the device be accurate to plus or minus $1/10$ of 1°C .
- 2) Portability - that the instrument be light in weight and self-powered, i.e. battery.
- 3) Response - that the speed of response be as great as possible consistent with stability.
- 4) Reliability - that the equipment be rugged enough to withstand the rigors of transportation and vibration of a small motor boat.

Accordingly, a Brown Round Chart Elecktronic Continuous Balance Pyrometer was chosen and converted to a Resistance Thermometer, as shown in Drawing H-4-353.

A sensitive thermal element was constructed of nickel wire and housed in a water proof cylindrical form with an outer wall thickness of 0.005. This element was coaxially mounted in a torpedo shaped lead and brass form thence referred to as the "fish".

The details of the "Fish" are shown in Drawing H-4-354. The "Fish" was connected to the recording two range Potentiometer ($0-20^{\circ}\text{C}$ and $10^{\circ} - 30^{\circ}\text{C}$) in the conventional three wire fully compensated circuit. The resistance thermometer element follows the Leeds and Northrup curve for Nickel Thermohms with a resistance of 100.6 ohms at 20°C . The fish was connected to the recorder by means of a 60 ft. length of #16-3 Super-service cable calibrated for length at one foot intervals by means of metallic clips. The recorder and a reel for easy cable handling were mounted on a suitable wooden platform that was clamped on the stern deck of the boat used. Calibration of the system was accomplished by means of a precision resistance decade box plus a water bath and accurate glass laboratory thermometers. Accuracy was well within plus or minus 0.05°C , the practical limit of readability by interpolation.

The power supply was an D.C. - A.C. Inverter of the vibrator type made by the American Radio & Television Co. Type R5B12, Capacity 125 Watts which was more than ample. Primary power was obtained from two 6 volt 85 ampere hour automobile storage batteries. Service life of the batteries in continuous operation appeared to be approximately 6 hours.

The response time of the equipment was approximately $1/10$ second per $1/10^{\circ}\text{C}$ with excellent stability. Two ranges were provided since the temperatures expected ran from 4°C to approximately 22°C . Both scales were readable directly to 0.1°C and by interpolation to 0.05°C .

The equipment stood up well under the rather severe boat vibration and truck transport shock. No difficulty was experienced from these conditions.

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APPENDIX C
Sheet 1

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The "fish" or parvane containing the
special resistance thermometric element

Print #7 C.4

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The temperature indicating instrument,
storage batteries, alternating current
generator and "fish" in operation.

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APPENDIX C
Sheet 2

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Print #5 C.4

Boat with temperature instrument, Stadia
Rod and crew about 50 ft. out from North
bank opposite D Area.

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Print #5 C.4

Penyan Boat, equipment and crew about
300 feet out from North bank opposite
D Area.

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Penyan boat and equipment at the instant readings were taken for 900 feet out from North Bank at D. Note spillway behind boat.

Point #4 C.4

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View looking upstream at transit set-up and boat during survey at D Area.

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APPENDIX D

Sheet 1

The river at B Area. The discharge is about 1/3 of the way out into the river and adjacent to the dark rectangular retention basin. The light island is about one and a half miles downstream. D Area may be seen to the left just before the bend in the river. F Area may be seen in the background just above B Area.

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APPENDIX D
Sheet 2

The river at D Area. The plant water discharge is opposite the retention basin and 1400 feet out in the river, in the channel beyond the island. These views were taken about a week after the survey was completed, and during that time the river has risen three feet. At the time of the survey, the island extended upstream to the indication of white water opposite the retention basin.

F Area may be seen in the background at the extreme right.

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APPENDIX D
Sheet 3

Close-up view of the river at D Area.

The spillway may be seen just upstream (right) of the retention basin. At the time of the survey, the river was lower and the island extended upstream as far as the indication of rough water. The discharge pipes run under the island out into the main channel on the side of the island closest to the camera. In making the survey at the area, the transit man and flag man were stationed on the side of the river closest to the camera.

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APPENDIX D

Sheet 4

F Area looking downstream. Photo taken one week after the survey. The river had risen three feet. At the time this view was taken, most of the plant discharge water probably was in the stream flowing to the right of the dark island, but at the time of the survey, very little water was flowing to the right of the dark island and warm water was found just to the left of this island.

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APPENDIX D
Sheet 5

Close-up view of the dark island about one and a half miles downstream from F Area discharge. At the time of the survey, very little water was flowing to the right of this dark island, and the larger adjacent island was connected to the right hand bank. The former construction camp at Hanford is five miles downstream from the dark island, and may be seen just beyond the peninsula on the right bank.

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