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DEPARTMENT OF THE INTERIOR

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August 25, 1948

MEMORANDUM

To: Arthur E. Gorman, Sanitary Engineer, Atomic Energy Commission
From: Arthur M. Piper, Staff Scientist, Geological Survey
Subject: Suggested hydrologic investigations at the Hanford Directed Operations.

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By TL BURSTIDE, 12-5-91

Verified By J.E. Savely 12-5-91

**SUGGESTED HYDROLOGIC INVESTIGATIONS
AT THE HANFORD DIRECTED OPERATIONS**

INTRODUCTION

1. This memorandum is submitted in response to your recent oral request for an outline of hydrologic investigations that seem desirable at the Hanford Directed Operations of the Atomic Energy Commission. In its present form, the outline is tentative and is intended as a basis for further consideration in the Commission, the Geological Survey, and other agencies concerned. In scope, it seeks to cover (1) advisory functions to the Atomic Energy Commission and its prime contractor with respect to an evaluation of the continuing hazards due to process wastes, also with respect to water-supply problems of the expanding operations at Hanford; also (2) civilian-protection aspects of possible emergencies, especially in the region adjacent to the Hanford reservation.

2. As background for the outline, it is understood that:

a. Ultimately, possibly within months, the process at Hanford will be so modified that substantially all radioactive and toxic waste products will be separated and will be reduced to relatively small volume or mass, so that they can be disposed of permanently and not accumulated within the reservation or the adjacent region. Once these modifications have been accomplished, the obligation for day-to-day disposal of waste products would rest with the prime contractor.

b. In the contingency of process failure or plant destruction, the Atomic Energy Commission would assume responsibility for decontamination and for protection of civilian population throughout the area affected. To evaluate the problems of such contingencies, also to program (and execute?) protective measures, the Weather Bureau would proceed with respect to aerologic features, the Geological Survey with respect to hydrologic features, and the Public Health Service with respect to water and food supplies. Intimate coordination of these three functional activities would be an obvious necessity in evaluating the problems; also, adequate plans for marshalling the personnel and equipment necessary to execute protective measures should be made as soon as practicable.

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Nature and scope of problems in
current operations
Water supplies in the south part of the reservation

3. Water requirements of operating and construction personnel are being met by three well fields, of which all are in the south part of the reservation and two are being developed currently. Additional fields may be necessary before the present construction program and plant expansion are complete. Because drafts are heavy and sustained, also because only a relatively thin water-bearing zone can be tapped, artificial replenishment is accomplished by an infiltration sump at each well field. This seems to be the most practicable means of developing the needed water, but requires that the over-all capacity of each field and infiltration sump be determined so that appropriate operating rules can be fixed.

4. In this connection, Mr. Clinton Hemming, in the prime contractor's engineering division, has recommended to his superiors that the tasks of evaluating the performance of the several well fields and developing rules for their operation, also of selecting promising areas for the development of additional fields as necessary, be delegated to the Geological Survey under an appropriate agreement. The Geological Survey has not been authorized to undertake these fundamental tasks. In a small way, however, it has sought to facilitate water-development activities through informal suggestions leading to a centralized file of pertinent reports and data from several divisions in the prime contractor's organization.

Radioactive and chemically toxic products in
the production areas
300 area

5. Fluid wastes of the 300 area include floor washings and coolant from the metallurgical operations, also washings and other products from the laboratory. Neither their quantities nor their composition is known to the writer, although it is understood that these wastes have radioactivity of low intensity but long life. They have been and are discharged into a sump east of the area and adjacent to the Columbia River; evidently the sump is underlain by material of low permeability, for it contains a pond which appears to be perennial and whose surface is above the highest level of the river.

6. Slight radioactive contamination is reported to have occurred intermittently in the water from one or more of the four wells within this area, presumably due to the waste products just cited. Samples

[REDACTED]

of water from the Columbia River, taken about half a mile downstream from the area, have shown intermittent radioactive contamination of low intensity 1/, although this contamination is not known to have been

1/ Radioactive contamination in the Columbia River.....at Hanford Works and vicinity: HW-9871, May 24, 1948.

derived from the 300 sump.

7. So far as is known to the writer, the extent and intensity of contamination below the land surface in and near the 300 area have not been explored. Periodic samples from the active wells are analyzed by the prime contractor so that use of the water can be discontinued whenever its radioactive intensity is excessive, but these analytical data do not indicate the extent of the contaminated zone. Also, because the water-bearing stratum tapped by the wells may not be contaminated uniformly, or from top to bottom, the radioactive intensity of the water sample taken from a well while it is being pumped may be decidedly less than that of the most highly contaminated water within the so-called zone of influence of that well at the time. It would seem prudent to explore the extent and intensity of subsurface contamination in this area, to take such remedial measures as are practicable, and to discontinue sump disposal of radioactive wastes as soon as is feasible.

100 areas

8. It is understood that (1) under normal operating conditions, radioactivity of low intensity and short life is induced in the cooling water which circulates through the three piles of the 100 areas; (2) effluent water is held in the detention basins for a sufficient time that its radioactivity diminishes to a harmless level through decay; however, (3) radioactivity concentrates to an excessive level in algae which grow in these basins; but (4) steps are being taken to kill the algae periodically by chlorination, to collect the destroyed algae by screens at the out-falls, and then to dispose of the radioactive screenings. When these latter steps have been taken, it seems assured that radioactivity of an intolerable level will not reach the river through the returned cooling water, under normal operating conditions.

9. However, in the event that a "can" ruptures within a pile (one such event is reported to have occurred thus far), the circulating cooling water would come into direct contact with irradiated uranium, whose contained fission products are intensely radioactive with half-life

[REDACTED]

ranging up to a few tens of years. The writer is not informed as to the extent that, until such rupture of a can would be detected and control measures could begin, the circulating water would dissolve or entrain material which would remain excessively radioactive after passing through the detention basin to the Columbia River.

10. In the single occurrence of can failure thus far, it is understood that, after the rupture was detected, washings were diverted into a sump excavated for the purpose and ultimately backfilled. The volume or radioactivity of these washings has not been reported to the writer. However, the several 100 areas are adjacent to the Columbia River, where the water table is no more than a few tens of feet beneath the land surface. Accordingly, it is quite possible that radioactive washings percolated to the water table and ultimately may seep, or already have seeped, into the river. It seems prudent that the extent and intensity of contamination beneath the temporary sump, also between the sump and the river, should be determined by adequate exploratory drilling and other pertinent methods. Also, that consideration be given to fully effective means for permanent disposal of radioactive products that might be released owing to can failures in the future.

200 areas

11. In normal operations, the 200 areas pose the major problems of waste disposal with which this memorandum is concerned. Very briefly, the wastes and their respective problems are as follows:

a. From the first stages of the separation process, highly concentrated and intensely radioactive liquids which are jetted through pipes to buried, concrete-encased, stainless-steel tanks. Some of the radioactive constituents have half-lives of many years. The procedure assumes that all such wastes reach the tanks and there will be held permanently (or possibly until withdrawn for re-processing by methods not yet in effect). It has been reported to the writer, but not confirmed, that jet pipes have broken a few times; such failure could have allowed some waste liquid to seep into the ground. For tank farms now under construction, jet pipes are being enclosed in a concrete conduit; this construction should minimize such seepage in the future. The tanks are constructed in series of three, the wastes being jetted to the first tank of the series, then cascading to the second tank when the first has filled, and so on. Inter-connections between the tanks of a series is by relatively short

[REDACTED]

pipes, understood to be rigidly attached. Because tanks are filled in succession, it seems conceivable that this differential loading might cause an interconnecting pipe to shear off at one end or the other. Further, during exothermic reactions that go on in the wastes for a considerable time, volume expansion would maintain a slow circulation through the interconnecting pipes. Accordingly, should a pipe shear off or fracture, waste fluid could seep into the ground. Finally, because the particular waste fluid is understood to be corrosive, it seems conceivable that a tank might ultimately fail, with a large volume of fluid being lost to the ground. These conceivable losses of intensely radioactive wastes involve no appreciable hazard to operating personnel on the land surface. However, they would augment hazards such as are outlined in paragraph 16.

b. From the intermediate and final stages of the separation process, fluid wastes of low concentration, with moderate radioactivity caused by constituents with half-lives ranging up to centuries. During the war, these wastes were infiltrated into the ground, largely into the zone of aeration from cribs a few tens of feet beneath the land surface, but in part into "reverse wells" reaching to the water table, or nearly so. (The water table beneath the 200 areas is in the order of from 200 to 250 feet below the land surface.) Beginning in 1947, infiltration by "reverse wells" has been discontinued. The nature of the hazard created by this method of waste disposal is contingent on the degree to which radioactive components of the waste become fixed on the earth materials adjacent to the points of disposal. If the fixation is complete and permanent, no regional hazard exists; if the fixation is neither complete nor permanent, radioactive components ultimately must percolate to the water table and, well within their half-lives, become extensively dispersed in the ground water beneath, and possibly even beyond, the reservation. This general problem is explored at greater length in paragraphs 16 and 22-24.

c. From various stages of the separation process, washings which are radioactively inert and which have been discharged onto the land surface in the west part of the 200-W area. These are not hazardous in themselves

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but, as is brought out beyond, the locus of their disposal complicates the hazard that may be created by the infiltrated radioactive wastes just discussed.

d. From each of the three holding basins in which irradiated slugs are detained in advance of the separation process, cooling water overflows into a surface outfall ditch several hundred feet long, from which it infiltrates the ground. In normal operation, this water has an induced radioactivity of low intensity and short half-life, analogous to the water which has been circulated through the piles of the 100 areas. If it is possible for a "can" to rupture during this detention, the circulating water doubtless would dissolve or entrain radioactive fission products of high intensity and half-lives ranging up to decades. The writer is not informed as to whether the radioactivity of water in the outfall ditches is monitored, and understands that no subsurface exploration has been carried on to prove or disprove the existence of radioactive contamination beneath and near these basins. The chance of such contamination may be remote, but definitely should not be overlooked.

12. With respect to the 200 areas, the essential problem considered by this outline is the behavior of radioactive components in fluid wastes which infiltrate below the land surface, either purposely as covered in paragraph 11b, or otherwise. As practised thus far, the two successive prime contractors at Hanford seemingly have been convinced that infiltration into the zone of aeration by cribbing has not involved any substantial hazard, now or in the foreseeable future. This conviction has been predicated in part on somewhat sketchy tests, reported by Kay and by Healy in 1946 2/ and interpreted to indicate that radioactive components

2/ Healy, J. W., Adsorption and retention of plutonium by 200-area topsoil: Document HW-7-4776, August 31, 1946.

Kay, W. L., Retention characteristics of 200 area topsoil for product: Document HW-3-3427, February 22, 1946.

are extracted and fixed onto the surfaces of soil particles as waste fluids infiltrate. The data presented by Healy are briefed beyond, with parenthetical comment by the writer.

a. Unneutralized fluid from the "231 sump tank" was batch fed downward through "topsoil" packed in a tube 2.125 inches in diameter and 2 feet long, and discharged

[REDACTED]

from a funnel or screen (aerated?) at the base. Total feed was 14.4 liters with 487 μg plutonium contained; total effluent was 13.7 liters with 0.025 μg contained plutonium. Thus, only 0.005 percent of the plutonium fed was accounted for in the effluent; the plutonium retained by the column amounted to 0.24 μg per gram of soil. (The fluid not accounted for as effluent indicates a retention of 51 percent, by volume, in the soil column; evidently the column had not drained to equilibrium at the end of the adsorption test, because the sandy "topsoil" of the Hanford area could scarcely have a specific retention nearly so great. However, it can scarcely be inferred that the excess fluid in the column had retained the plutonium. It is understood that the "231 sump tank" fluid is less concentrated than much of the waste fluid which has been cribbed.)

b. Following the adsorption test just described, the column was washed with 20 liters of distilled water at an average rate of 204 ml per hour. A total of 0.86 μg plutonium was washed out. (Only 0.2 percent of the previously retained plutonium was removed from the soil column by this washing. However, the effect of distilled water can not be taken as analogous to that of rain or snow melt infiltrating from the land surface, for percolating water so derived would contain appreciable quantities of bicarbonate, calcium, and magnesium; also it probably would have a pH value different from that of distilled water.)

c. Another soil column was "spiked" with 4 μg plutonium, then washed 130 days with distilled water at the rate of 60 ml per hour. Altogether, 0.7 percent of the plutonium was washed out. (The concentration of plutonium before washing was 0.0035 μg per gram of soil — that is, only 1.5 percent of that in the test described by paragraph 12a. The proportion removed by washing was 3.5 times, and the volume of wash water was 75 times that in the test of paragraph 12a. This "washing test" suggests that even when its concentration is very small the adsorbed plutonium is not inseparably bound to the soil particles.)

d. Healy summarizes the earlier adsorption test by Kay, which involved a "large" soil column and "solution neutralized to the same extent as it is neutralized before discharge from the 231 sump tank". Before 0.063 μg

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plutonium had been adsorbed per gram of soil, the effluent fluid was carrying plutonium through the column in concentrations of from 5 to 28 percent of that in the feed. (Presumably this test more nearly duplicated conditions under which wastes have been cribbed in the 200 areas. In this test the concentration of plutonium adsorbed was only one-fourth that of the test described in paragraph 12a, yet substantial amounts of plutonium escaped.)

13. The tests just cited are by no means conclusive as to the degree or permanence in which plutonium can be adsorbed by earth materials of the Hanford area. Healy concludes that, pending further tests to show that the adsorption phenomena are reproducible, "general conclusions should not be drawn on such details as column breakthrough". Also, Healy implies strongly that degree of adsorption depends largely on the pH of the percolating fluid; however, the writer does not concur that pH is, or may be, the principal controlling variable.

14. Beginning in March 1947 and continuing into 1948, the prime contractor has carried out exploratory drilling to ascertain the extent to which radioactive materials have been dispersed underground by past methods of cribbing, and to evaluate potential hazards from the proposed discharge of "second cycle" wastes by infiltration. In some detail, this program has explored the vicinity of cribs and "reverse wells" in the 200-W and 200-S areas. One written report which has come to the attention of the writer recently 3/, outlines the procedure and the

3/ Brown, R. E., and Ruppert, H. G., Underground waste disposal at Hanford Works, an interim report covering the 200 West area: Document HW-9671, May 3, 1948.

findings in the 200-W area. Briefly, in this area, plutonium and fission products are reported to have been found in substantial concentrations within rudely lenticular zones with apexes beneath the several cribs. Because the volumes of these lenticular zones was found much too small to have contained the volumes of fluid discharged into the several cribs, also because the zones are well above the regional water table, evidently plutonium and fission products have been extracted from the cribbed fluid and detained by the earth materials, but the fluid itself has percolated on. This detention of plutonium was found to have reached from 10 to 195 feet horizontally from the cribs, and from 10 to 35 feet below them. Detention of fission products has reached as much as 280 feet horizontally and 105 feet vertically. These showings are for conditions at the time

[REDACTED]

of test drilling. Although contemplated by the prime contractor, the zones of extraction have not been re-sampled to ascertain whether the plutonium or fission products, or both, have since diminished in concentration or increased in reach from the cribs.

15. The report on this past exploration in the 200-W area reaches certain fundamental conclusions with which, on the basis of facts there presented or otherwise known to him, the writer can not concur. These conclusions are briefed, with the writer's comment in parentheses, as follows:

a. "The plutonium and fission products in the wastes are removed within a relatively short distance of the cribs;" also, of the plutonium and fission products contained in the 18,000,000 gallons of radioactive waste dissipated by infiltration in the 200-W area up to December 1, 1947, none "is known or believed to have penetrated to the water table" 4/. "The very fragmentary factual data in the report 5/

4/ Op. cit., pp. 1, 18.

5/ Op. cit., table 1.

indicate that, for any one crib, not more than about one-third of the plutonium or two-thirds of the fission products infiltrated has been accounted for within the adjacent zone of extraction. The implications in the quoted conclusions, that complete removal has been demonstrated and that ground water has not yet been contaminated, seem to evade the issue that two-thirds or more of the plutonium remains unaccounted for.)

b. After extraction by or onto earth materials, and "barring unforeseen conditions", the radioactive material "is safely bound with the sediments in a state where it can cause little danger in the future" 6/. (Information available

6/ Op. cit., p. 18.

to the writer contains nothing conclusive as to the nature of the binding forces, nor as to conditions which might reverse those forces. In this connection, following paragraph 24 is pertinent. At least with respect to plutonium, whose chemical toxicity is extremely great and whose radioactive half life is measured in centuries, the quoted conclusion seems premature.)

[REDACTED]

c. Wastes with radioactivity greater than that of wastes cribbed thus far "can apparently be safely discharged into the ground" 7/. (If foregoing comment

7/ Op. cit., p. 20.

is valid, this particular conclusion seems unduly optimistic. The writer here reiterates his feeling that the disposal of fluid radioactive wastes at the Hanford Directed Operations by infiltration into the ground has been tolerable only as an expedient, until practicable means can be devised for making such fluids inert before they are discharged.)

16. If the past and present practise of cribbing certain fluid wastes from the 200 areas is continued indefinitely, even in volumes no greater than heretofore, the writer believes it altogether possible that radioactive plutonium and fission products will percolate to the regional water table, or will be intercepted by a relatively impermeable stratum and accumulate in a body perched above the regional water table (in the latter connection, see paragraph 16c). Indeed, present knowledge does not exclude the possibility that such has occurred already.

a. Once these radioactive materials reach the regional water table, they will inevitably move with the ground water and, after a lapse of years, presumably would seep into the Columbia River or the Yakima River. The extent to which they might be diluted by ground water while in transit is problematic. Accordingly, it would be premature to conclude that radioactivity of intolerable intensity would never result at points of effluent seepage into one or the other of the two rivers.

b. Once a perched body of waste fluid accumulates beneath the infiltration areas, within a relatively few years it might enlarge to reach the land surface close at hand, and there discharge fluid with residual activity of intolerable intensity. This possibility creates a focal point of potential hazard in the Cold Creek Valley, which is immediately south and southwest from the 200 areas, and which is inferred tentatively to be underlain generally by materials of low permeability. If this inference is correct, if perched toxic fluids should percolate to land surface along the northeast flank of the valley, and if the surficial materials of the valley were wet from winter rains or from discharge of non-toxic wastes in large volume (the Cold Creek Valley has been suggested as a convenient drain for non-toxic wastes), then toxic material

[REDACTED]

might be flushed quickly through the valley into the Yakima River and thence into the Columbia River. During the dry season, if the surficial materials were not wet, the percolating fluid might evaporate and leave toxic residue to be carried down-wind in one of the not infrequent dust storms.

c. The contingencies just outlined would be accelerated to the extent that a perched water body resulted from the present practice of discharging non-toxic fluid wastes onto the land surface in the west part of the 200-W area. A perennial pond has been created there, in the order of 225 feet above the regional water table. That a perched ground-water body already has been created in the underlying earth materials is at least suggested in the report on waste disposal previously cited, which, with respect to the 241-T area some 600 yards south of the pond, states that "the exploratory wells lost water during drilling to a depth at which the contamination from two overlying cribs appeared and from that depth downward to the bottom of the wells, the water remained in the wells". In the 241-T area the reach of plutonium and fission products detained from cribbed wastes was found to be much greater horizontally, and much less vertically than elsewhere. It is inferred tentatively that the extraction and detention took place in the uppermost part of a perched zone of saturation.

17. As a first logical step, in investigating the problems just outlined, the prime contractor now is sinking some 27 test wells to and just below the water table within an area extending about 7 miles southward from Gable Mt. and about 16 miles eastward from the high terrane which bounds the Cold Creek Valley on the west. Locations of these wells are substantially as proposed by the writer in an earlier memorandum 8/. Personnel of the Geological Survey share the responsibility

8/ Piper, I. M., Tentative outline (No. 2) of investigations pertinent to disposal of certain toxic and non-toxic wastes from the Hanford Engineer Works: classified memorandum to P. P. Smith of the General Electric Company, Richland, Wash., March 17, 1948.

of monitoring the drilling and classifying the samples. With respect to the area covered, which spans only the 200 areas and environs, this program is intended to (1) determine in general terms the form of the regional water table and its directions of movement; (2) evaluate roughly

[REDACTED]

the relative volumes and stratigraphic features of any distinct classes of the earth materials in the zone of aeration, with respect to their inferred relative capacities to extract and detain the radioactive components of cribbed wastes; and (3) establish outpost wells by which to trace the movement of any radioactive products which may reach the regional water table. Some further exploration of details probably will be found advisable. This exploratory program covers only a minor part of the Hanford reservation.

PROBLEMS OF A MAJOR EMERGENCY

18. Among conceivable major emergencies or catastrophes at the Hanford Directed Operation, the greatest probably would result if cooling water ceased to circulate through a pile, and if the devices for shutting down that pile failed to operate. Tentatively, also to stimulate further consideration, two patterns of resulting events are projected, as follows:

a. If water jackets did not drain, mounting and undissipated heat within the pile might cause a steam explosion at relatively low temperature but in a force sufficient to demolish the pile and its containing building. Aside from dust thrown into the air and carried down wind, coarser radioactive debris would be scattered widely. That which fell on the land surface would create radiation hazards to be located, isolated, and treated as practicable; ruptured irradiated slugs would create the principal hazards. A substantial amount of the debris would inevitable fall into the Columbia River — from ruptured slugs, fission products would be dissolved or entrained; radiation from other debris would induce activity in the river water. Altogether, especially during the low water season, this submerged debris might impart to the river at Hanford a radioactivity of moderate but intolerable intensity for days or weeks.

b. It seems equally likely that the steam explosion just projected would lack force to demolish the pile, and would only rupture pipe connections so that all cooling medium would be dissipated. Then, demolition of the pile presumably would follow by explosion at very high temperature, with much of the pile vaporized but with a substantial quantity of molten residue blasted into the river through the effluent sewer. A segment of the river so might become radioactive at extremely high intensity.

[REDACTED]

c. Under the most catastrophic contingency of this sort, it would seem possible only to monitor the radioactive segment of the river until it had been discharged from the Columbia River, with a natural travel time in the order of from three to five days between Hanford and the ocean. Under some circumstances, also if flood-control reservoirs had been constructed as will be proposed by the Corps of Engineers in its pending "308 review report", any activated river water might be diluted somewhat by releasing stored water upstream; some additional dilution might be effected, and travel time prolonged, by raising gates to increase pool capacity at dams downstream. In this connection, the tentatively proposed John Day dam, with provision for 2,000,000 acre-feet of emergency flood-control storage, would afford the greatest potential effect. Dilution and delay of the activated segment might be substantial during the low-water season, if upstream storage were released and if downstream pool capacities were manipulated in synchrony with stream velocities. However, the potentialities for dilution and delay would be small or non-existent during a major flood.

d. Monitoring any activated segment of the river until it had reached the ocean would of course require fairly intimate knowledge of current velocities and patterns through the full range from extreme low water to extreme high water, would require thoughtful instrumentation, and would involve a comprehensive warning system to all downstream water users and residents. Complexities would be greatest in the lowest reach of the river, where current velocities and salinity fluctuate with the ocean tides. Once the segment had passed downstream would come the possibly prodigious task of decontamination. Neither time nor space is here available to carry this conjectural analysis into detail; indeed, any further detail would seem fruitless until coupled with a systematic study of river hydraulics and other pertinent factors.

19. In the 200 areas at Hanford, conceivable major emergencies would seem to be those of explosive demolition, also rupture of pipes and processing receptacles by blast, earthquake, or collapse of structures. In those contingencies, extremely radioactive or chemically toxic fluids might be vaporized, scattered over debris, or released into the ground. The latter event which is of concern in this statement, would involve problems analogous to those of intentional waste disposal by infiltration, but perhaps tremendously aggravated in terms of hazard intensity and with the points of release possibly not known. Probably the extreme

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would be the rupture and draining of one or more of the tanks in which "first cycle" fluid wastes are stored. Here, underground dilution to a tolerable radioactive intensity would be unlikely to occur naturally and probably quite impracticable to accomplish artificially. As now visualized, possible measures of control would seem limited to confining the released fluid underground by creating a hydraulic barrier through injection of non-toxic waste water, intercepting with pumps, grouting a cut-off curtain, or refrigerating the ground invaded. Such measures obviously would involve serious mechanical and technical difficulties; their effectiveness could not be estimated in advance without intimate knowledge of geologic and ground-water conditions.

SUGGESTED HYDROLOGIC INVESTIGATIONS

Ground-water features

20. Full evaluation of, and reasonably adequate answers to the problems heretofore outlined — problems of water supply in the south part of the reservation (paragraphs 3, 4), of contamination by radioactive wastes in the production areas (paragraphs 6, 7, 10, 11, 16), and of certain major emergencies (paragraph 19) — requires fairly comprehensive knowledge of geologic and ground-water features of all the Hanford reservation, and of its immediate environs as pertinent. The requirement exists now. Accordingly, systematic investigation of these two features is recommended to be undertaken immediately, to include the following elements:

a. Areal and stratigraphic mapping of the reservation and related environs, incorporating data from natural and artificial exposures, also from available logs and cuttings of wells and test holes. (The present construction program involves many cuts which expose features not otherwise visible; unless mapped currently, this information will soon be lost.)

b. Structural mapping of the volcanics in the vicinity of Gable Mt. and Gable Butte, also locally along the west margin of the reservation. (These rocks underlie all the reservation, beneath stream deposits and other sedimentary materials. The program of exploratory drilling described in paragraph 17 is disclosing that, at least in the northwest part of the reservation, their concealed upper surface is extensively at such depth that they may greatly influence directions of ground-water movement; hence, their structure is pertinent.)

c. Local geophysical traversing by airborne magnetometer or by the resistivity method, or both, to delimit the upper surface of the volcanics where such information is pertinent. (See justification in subparagraph "b", above. Heretofore,

[REDACTED]

the writer has recommended against such geophysical methods as a general substitute for test drilling; however, they are now proposed as probably the most effective tool for the next stage in refining knowledge as to the forms of concealed rock surfaces. Currently, the prime contractor is considering an interim drilling program of about five wells in addition to those of paragraph 17, to verify one hypothetical interpretation of these forms; in the considered opinion of the writer, this interim program is so small in relation to the scale of the features being explored, that its results may obscure rather than clarify. Indeed, by test drilling alone, it seems hopeless to acquire adequate information within reasonable time and at reasonable cost.)

d. Canvass of all available wells for data on their construction and yield, coupled with pumping tests and records of artificial infiltration to evaluate transmissibilities of the several water-bearing zones, where feasible. This canvass to be kept up-to-date as additional wells are drilled.

e. Periodic measurement of water levels in a net of observation wells distributed over the reservation, to evaluate the natural and artificial fluctuations in ground-water conditions. (To round out such a net some wells would need be drilled for the purpose; in the main, these are not urgent and can be of small diameter and relatively inexpensive construction.)

f. Chemical analyses of water samples from wells selected to represent each of the distinct ground-water bodies, where those bodies are not contaminated.

21. It is believed that fundamental general information, such as sought by the investigative program just outlined, is properly a responsibility of the Atomic Energy Commission rather than of a prime contractor. Also, to gain the advantages of unbiased perspective, broad experience, diverse facilities, and a full official record of the basic data obtained, it seems advisable that any work in this field be undertaken by the Geological Survey under a transfer of funds by the Commission. Excluding geophysical traversing and construction of observation wells, the cost of this investigative program is estimated tentatively as \$35,000 for each of two years. For the two items excluded from this estimate, necessary scope and cost can best be estimated after results of the current drilling program (paragraph 17) have been interpreted more fully.

[REDACTED]

Research with respect to underground disposal
of radioactive wastes

22. As interpreted by the writer, it seems to be the judgment of the prime contractor at Hanford that (1) essentially all radioactive components of cribbed wastes have been completely and permanently extracted by earth materials penetrated, (2) this extraction takes place by the physical process of adsorption onto the surfaces of earth particles, (3) there is only a mild urgency to delimit the reach of radioactive contamination underground, by exploratory drilling and periodic sampling of the earth materials, and (4) any concern with the fundamental phenomena of this extraction is essentially academic and not urgent at this time. Whether or no this interpretation is correct, it is the considered judgment of the writer that research into the phenomena of extraction is an immediate and urgent need. Phenomena not yet fully understood may well explain why the radioactive materials in wastes heretofore cribbed have been neither fully nor rigorously accounted for underground (see paragraph 15a), and so may confirm the present possibility that a substantial and unevaluated hazard exists in those wastes not now accounted for statistically. Immediate research into these fundamental phenomena is justified further by its applicability to waste-disposal problems at other operations under the jurisdiction of the Atomic Energy Commission, to hazards in the potential industrial use of atomic energy, and to the location and design of underground installations for military purposes.

23. Research should undertake to demonstrate whether the phenomenon of extraction is primarily one of adsorption onto the surfaces of earth particles, of base-exchange reaction with some component or components of the earth materials, or otherwise. Also, with respect to the immediate problem at Hanford, it should seek to evaluate the interplay between (1) the degree and permanence of extraction and (2) the chemical and physical properties of the fluids cribbed or to be cribbed, also of the fluids existing naturally in the earth zones of aeration and of saturation.

24. Information now available to the writer neither proves nor disproves either adsorption or base-exchange to be the fundamental process -- indeed, one seems as valid as the other. However, the distinction is critical if Hanford waste-disposal experience should be applied to another area. Specifically, if the process is one of adsorption onto particle surfaces, capacity to extract radioactive components may depend principally upon texture (size, shape, and arrangement of particles) rather than mineralogic composition of the material; another material of like texture, in another area, would be expected to have about the same capacity for extraction. However, it may well be that large aggregate area of particle surface and large extractive capacity are characteristic of certain particular mineral components. Also, if adsorption is the fundamental process, capacity to hold the extracted radioactive components probably would not change greatly with time. On the other hand, if base-exchange is the fundamental process, extractive capacity depends on the concentration, in the earth material, of minerals with base-exchange properties, does not depend on texture, and may change with time. A

hypothetical explanation, or [REDACTED] involves the following [REDACTED]

[REDACTED]

hypothetical explanation, speculative in part, involves the following sequence: (1) the earth materials into which wastes have been infiltrated at Hanford are derived in considerable part from volcanic rocks, which rather commonly contain minerals with base-exchange properties; (2) before wastes had infiltrated, any base-exchange media of those earth materials had reached equilibrium with the soil waters, in which calcium and magnesium doubtless are the principal cations; (3) in the waste fluids here concerned, it is understood that the dominant cation is sodium; (4) when infiltrating, fluid of such composition probably would lose sodium and gain calcium, ion for ion, by reaction with earth constituents which have base-exchange properties and which previously had been in equilibrium with calcium-base soil water; (5) radioactivity commonly is "carried" by some ion or suspended particle, in the waste fluid speculatively by sodium ion which would enter into the base-exchange reaction; (6) ultimately the base-exchange media would reach equilibrium with the composition of the infiltrating fluid, and further exchange of ions would cease; (7) after infiltration of waste fluid at that place was discontinued, percolation of calcium-base soil water would be resumed, and the base-exchange reaction might be reversed, with sodium ion and "carried" radioactivity released to the soil water; and (8) finally, the base-exchange media would again reach equilibrium with the calcium-base soil water, with previously captured sodium ion all released. This speculative explanation is intended only to suggest the sort of action which might take place. It opens the possibility that, with time, radioactive components now "fixed" on earth materials beneath the cribs at Hanford would be released, to percolate on to the water table. This process would be so prolonged that radioactive fission products might have decayed to a tolerable level of activity, but not so the plutonium. It is believed that all possibility of base-exchange as the controlling process of radioactive fixation at Hanford must be ruled out before one would be justified in concluding that no ultimate hazard has been created by infiltrated wastes.

25. Owing to its applicability to diverse problems, also to avoid duplication of effort and possible inadequacy of results by several prime contractors, the fundamental research here considered is pictured as an obligation of the Atomic Energy Commission. An adequate research team would need combine the backgrounds of the nuclear physicist, chemist, soils technician, hydrologist, and mineralogist working jointly and largely at a single place. Certainly the peculiar experience of the Geological Survey and the facilities being assembled for its "trace elements" laboratory could meet a large part of this need. It is left for further consideration whether this experience and these facilities can most advantageously become the nucleus of a comprehensive research effort.

[REDACTED]

26. In a general attack on this research problem, attention could well be focussed initially on the extraction characteristics of homogeneous materials and then progress to inhomogeneous earth materials. With respect to extraction at Hanford, research should of course be on those earth materials which underlie the 200-area cribs and, at least in part, on samples of those materials as little disturbed as possible. To collect such samples, the writer has suggested in his memorandum of March 17, 1948 9/that a shaft be sunk through a representative section of the materials.

9/ Op. cit., memorandum to P. P. Smith, p. 6.

of the materials, with sample tubes being driven and excavated in successive segments from a foot to a few feet long. This suggestion still is valid, although it is now recommended that selection of a shaft site or sites be deferred until completion of the exploratory drilling program described in paragraph 17, by which the character and distribution of materials is being determined in general terms.

Surface-water features

27. Fully prudent schedules for long-term operation at Hanford, including but not limited to a schedule for coping with possible emergencies such as are outlined in paragraphs 18 and 16b, would require comprehensive knowledge as to the regimens of the Columbia River and certain reaches of a few tributaries to that trunk stream. However, (1) available information on stream regimen is fragmentary and uncoordinated; (2) until fuller information is acquired, only the most general aspects of potential problems can be projected; and (3) present stream regimens will be modified substantially by the McNary Dam, which is under construction, and by a number of multiple-purpose dams now projected on the main stem of the Columbia River and certain principal tributaries, by the Corps of Engineers and other governmental agencies. Thus, only the more obvious and immediate aspects of a pertinent investigative program can be suggested at this time, including the following:

a. On the Columbia River upstream from the Hanford reservation, establish a master station for continuing determination of dissolved solids, suspended sediment, and temperature of the river water. (Determinations of radioactivity of water and sediment might also be pertinent.) It is contemplated that samples would be taken at least daily, and analyses made on individual samples or on composites, according to steadiness of river flow. At this time, the most advantageous site for such a station seems to be the railroad bridge crossing the Columbia River at Beverly, about 20 miles upstream from the reservation. A subsidiary station would be needed on lower Crab Creek, which enters the river about 2 miles below the bridge

[REDACTED]

[REDACTED]

crossing and which ultimately will carry much of the tail water from the northern and central parts of the Columbia Basin irrigation project. Analytical data would be correlated with the flow past existing gaging stations on the Columbia River at Trinidad and on Crab Creek near Smyrna. If and when the projected Priest Rapids dam is constructed, the paired sampling stations both would be submerged; however, a site for an equivalent single station presumably would be available at the re-located railroad crossing. Excluding any determination of radioactivity in water or sediment, costs are estimated roughly at \$15,000 a year.

b. Devise and institute measures for continuously determining the quantity and radioactivity of sediment transported by the Columbia River as "bed load", also the radioactivity of the river water and of its suspended sediment, about at the downstream boundary of the reservation. For the purpose, probably it would be advisable to evaluate a reach of the river channel, ending downstream about at the point of inflection between normal pool level of the McNary Dam and low-water profile of the river. The objective here outlined involves a phase of river mechanics not well understood; estimates of scope and cost both are deferred for further consideration.

c. Establish gaging stations on Cold Creek and its tributary, Dry Creek, at the west foot of the Yakima Range, near the west boundary of the reservation. It is contemplated that these would be maintained for several years to evaluate runoff characteristics related to the potential emergency condition of paragraph 16b. Several recording and non-recording precipitation gages would be desirable on the two watersheds. Costs are estimated roughly at \$5,000 for construction and instrumentation of stations, and \$1,750 for operation each year.

d. Canvass points of water diversion and other works along the Columbia River from Hanford to the ocean, also along the Yakima River below Cold Creek, as necessary to list and roughly appraise the individual hazards to water supplies and other civilian facilities in the contingency that the water of either river should become excessively radioactive. Also, with respect to the potential major emergency of paragraph 18, compile and interpret the diverse available data on pattern and velocity of currents, backwater effects of ocean tides, and other pertinent features of river hydraulics. The principal sources for such information probably would be the Corps of Engineers and the Geological Survey. These seem to be the first, but probably inadequate steps toward an adequate system for alerting the downstream area if ever necessary; fixing the ultimate scope of this investigative activity seems best deferred, to follow the initial steps here specified. For those initial steps only, cost is estimated to be from \$25,000 to \$30,000.

[REDACTED]

28. The investigations of surface-water features here outlined fall within the peculiar experience of the Geological Survey and advantageously could be delegated to that organization. However, they would merge with problems of river biology and public health, in which the Geological Survey is not qualified; hence, several delegations of related investigative responsibility would need be integrated closely.

Coordination of investigations

29. This memorandum has been concerned primarily with hydrologic problems related to the Hanford Directed Operations, and especially with phases of those problems which might advantageously be delegated to the Geological Survey as agent for the Atomic Energy Commission. It is contemplated that such delegations, if made, would be with the full understanding and concurrence of the prime contractor, to avoid any competitive approach to fields in which the responsibility of the Commission to the general public might overlap the responsibility of the prime contractor for orderly operation of the works. Further, it is realized that problems and investigative fields here outlined may have counterparts at other operations of the Commission, with those other problems being attacked independently. Accordingly, the writer urges strongly that the key personnel of all such investigations under the jurisdiction of the Commission be made into an informal panel for exchanging concepts and experiences, and for unifying effort.

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