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DESCRIPTION OF ORNL LIQUID WASTE SYSTEMS, HAZARDS EVALUATION - VOL. 3

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ABSTRACT

The collection, treatment, and disposal of radioactive liquid wastes at Oak Ridge National Laboratory are described in detail. Illustrations of facilities and tables of data on waste volumes and radionuclides discharged to the environment are included. The philosophy and history of ORNL waste management are discussed, and proposals for improving the liquid waste systems are made.

Standards of construction and containment, assumptions made to evaluate the potential hazards of release of radioactive material, and methods of calculation used for development of this hazards analysis are given in ORNL-2956, Summary Report - Hazards Analyses of Radiochemical Processing and Waste Disposal at Oak Ridge National Laboratory, Sects. 4.0, 5.0, and 6.0.

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DESCRIPTION OF ORNL LIQUID WASTE SYSTEMS

1.0 INTRODUCTION

The goal of radioactive waste management at Oak Ridge National Laboratory is to dispose of the wastes as safely and as economically as possible. At present the following approach to this goal is being taken:

1. To confine the major portion of long-lived fission products from all types of waste in tanks or in ground where they become chemically attached to the soil.*

2. To dilute low-level wastes in the surface water drainage system. The dilution factors available in these media are used to decrease the concentration of such long-lived fission products as Sr^{90} and Cs^{137} and all other isotopes to the maximum permissible concentrations set by the National Committee on Radiation Protection and the International Commission on Radiological Protection.**

3. To monitor the waste streams before and after discharge in order to follow the success of this program.

Radioactive liquid wastes are segregated at their sources according to composition and radioactivity level and are collected, treated, and disposed of in three separate systems:

1. "Hot" chemical waste: 7000 gpd, 0.001-0.08 curie/gal, the most radioactive waste at ORNL.

2. Liquid uranium waste (or "hot" metal waste): very small volume, moderate radioactivity.

3. Mildly contaminated process waste water: 800,000 gpd, 0.1 to 1.0 μc/gal.

Sanitary wastes and "cold" waste water from sources unlikely to produce radioactive contamination are handled in other liquid waste systems not included in this discussion. Figures 1 and 2 are schematic flowsheets of the radioactive liquid waste systems. Figure 3 shows the layout of the "hot" chemical waste and process waste water systems.

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* (a) W. de Laguna, K. E. Cowser, and F. L. Parker (ORNL), "Disposal of High-level Radioactive Liquid Wastes in Terrestrial Pits - a Sequel," Proceeding of Second United Nations International Conference on the Peaceful Uses of Atomic Energy, UN-1767 (Sept. 1958).

(b) K. E. Cowser and F. L. Parker (ORNL), "Soil Disposal of Radioactive Liquid Wastes at ORNL: Criteria and Techniques of Site Selection and Monitoring," Health Physics, Vol 1 (1958).

** "Maximum Permissible Amounts of Radioisotopes in the Human Body and the Maximum Permissible Concentrations in Air and Water," Handbook 69, National Bureau of Standards, U. S. Department of Commerce (June 5, 1959).

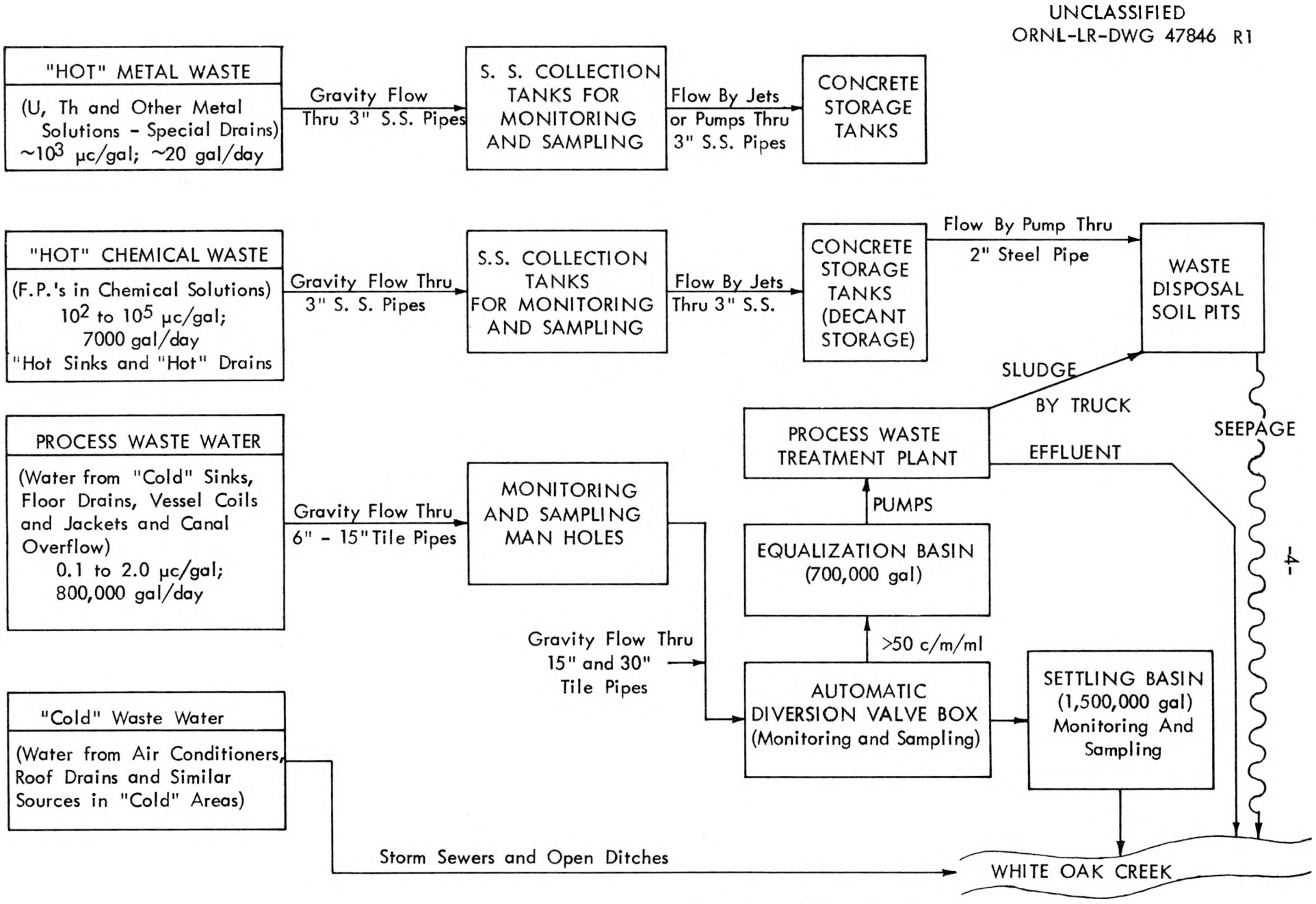

Fig. 1. Existing ORNL Liquid Waste Systems

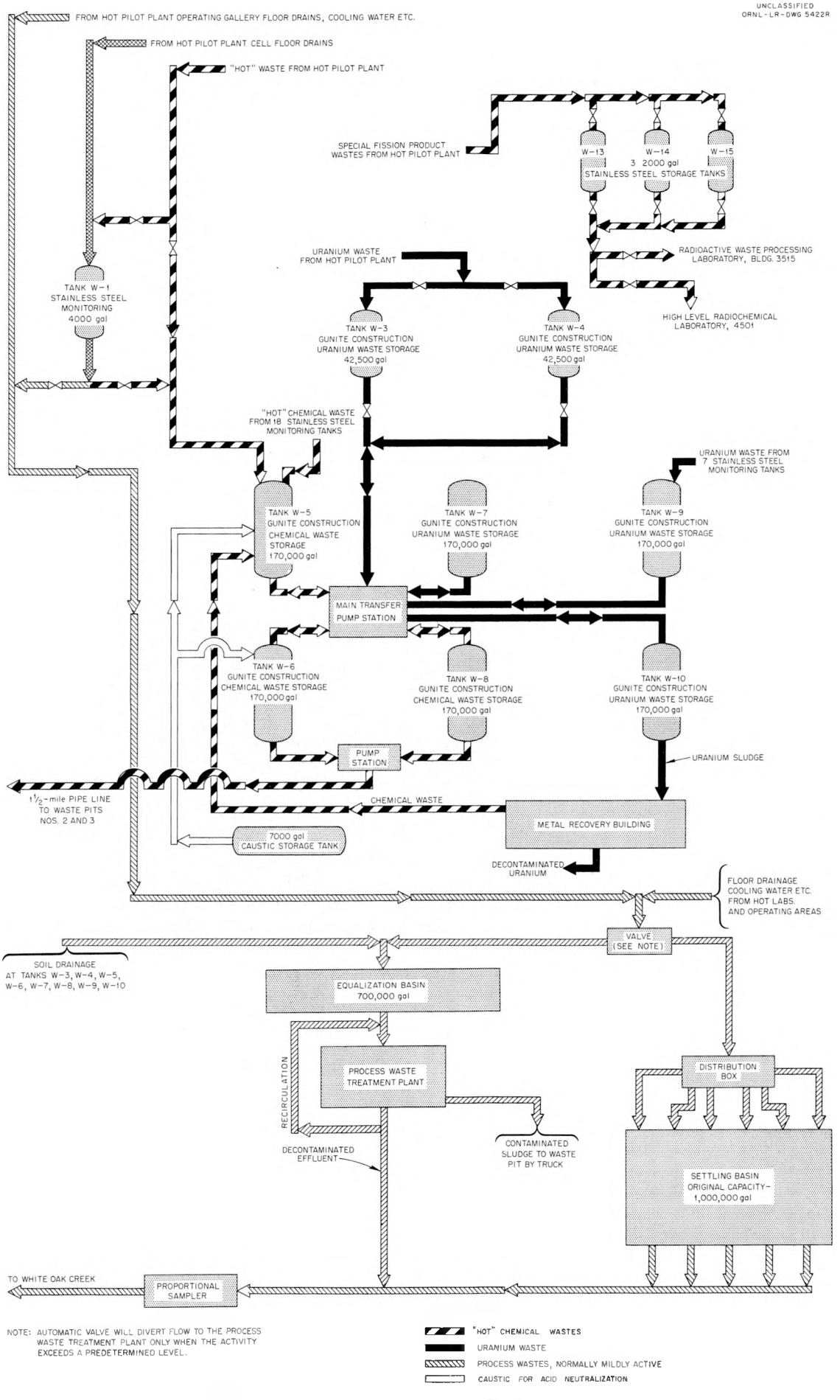

Fig. 2 ORNL Simplified Liquid Waste Disposal Flowsheet

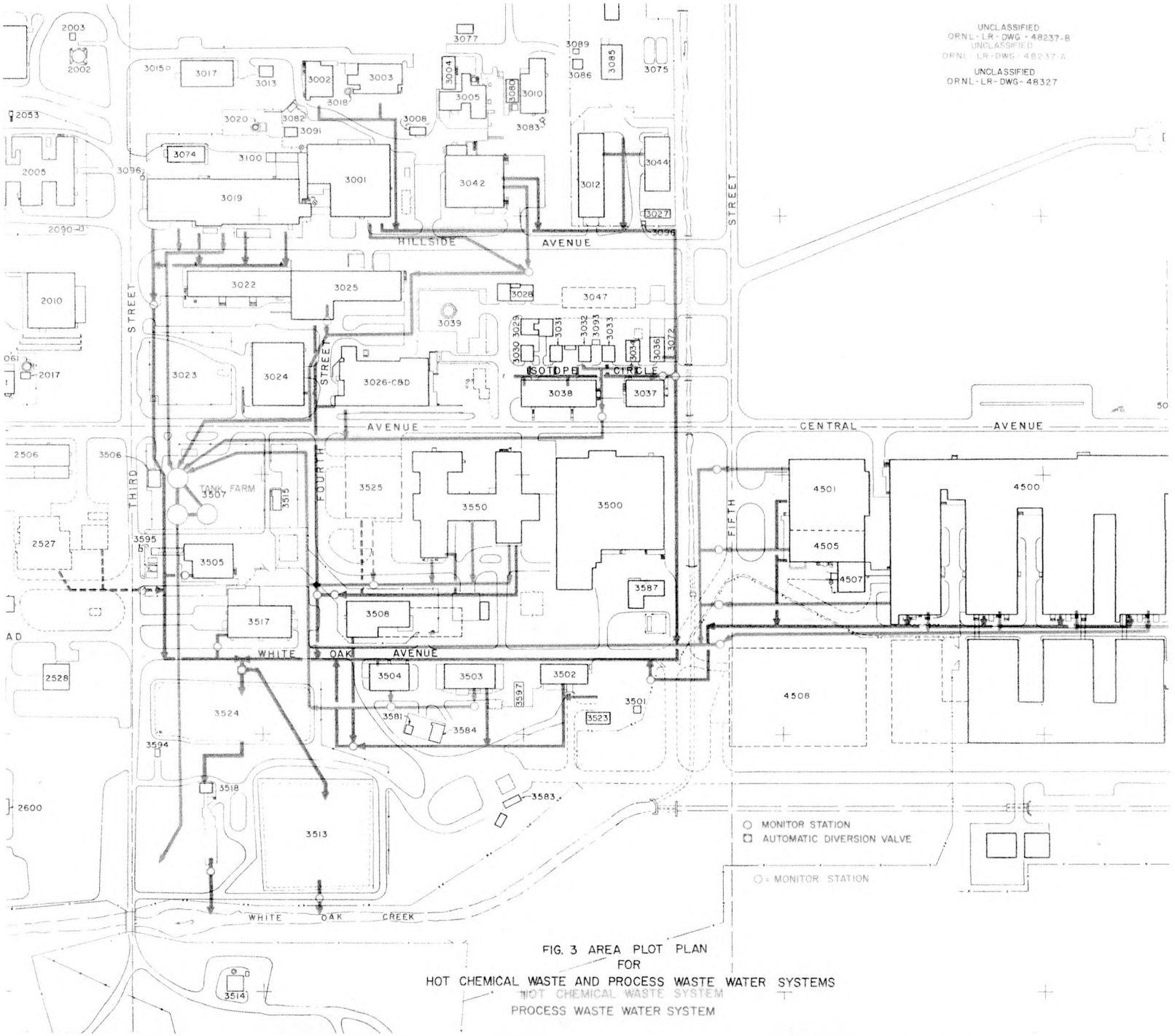

FIG. 3 AREA PLOT PLAN
FOR
HOT CHEMICAL WASTE AND PROCESS WASTE WATER SYSTEMS
HOT CHEMICAL WASTE SYSTEM
PROCESS WASTE WATER SYSTEM

Responsibility for segregating, collecting, treating, and disposing of all radioactive wastes since the beginning of the Laboratory has been delegated to one group, the Operations Division, which must also measure and record all radioactive contamination as it is discharged to the environment. A manual of detailed procedures for operating the liquid waste systems is followed by Operations Division personnel. Responsibilities for studying the effectiveness of radioactive waste disposal in the environment by stream sampling and surveys and for reporting the degree of contamination in these streams have been delegated to the Health Physics Division. The separate delegation of these responsibilities provides an independent check on methods of operation and analysis and on concentrations being released to the environment.

Control of radioactive waste discharges to the creek is now somewhat limited when the large-volume process waste water stream becomes unusually contaminated; when contamination in this stream exceeds 50 β c/min/ml, the process water supply to the Laboratory must be decreased in volume to maintain adequate impounding space for the waste until the source of contamination is eliminated.

2.0 SUMMARY

Modifications to existing ORNL liquid waste systems are being developed to improve the handling of current wastes and to permit wastes of higher radioactivity levels to be handled safely in the future. Figure 4 diagrams the proposed radioactive waste systems. Comparison of Fig. 1 with Fig. 4 shows the proposed modifications and additions to existing systems.

Two new liquid waste systems are proposed: "very high level waste" (>1000 curies/gal) composed of evaporated raffinate from first cycle solvent extraction pilot plant (Bldg. 3019) demonstrations on the highest level fuels anticipated from power reactors; and "high level waste" (5 to 1000 curies/gal) composed of evaporated first cycle raffinate from moderate heat-generating reactor fuels. Both types of waste will be stored in stainless steel tanks equipped with appropriately designed cooling coils to remove the fission product decay heat.

Some of the "high level waste" has been handled in the existing ORNL "hot" chemical waste system and accounts for the marked increase in radioactivity discharged to the waste pits in 1959. After provisions have been made to collect separately all wastes containing more than 5 curies/gal, the remaining ORNL "hot" liquid wastes, designated "intermediate level wastes," will be collected in the existing "hot" chemical waste system. It is proposed to install an evaporator to concentrate this waste, the overheads to be sent to the process waste water system and the bottoms to be stored in existing concrete tanks or in proposed stainless steel tanks if cooling is required.

A new-model waste seepage pit has been constructed to improve the disposal of "hot" chemical waste on an interim basis while the evaporator and storage tank details are being designed. Installation of a soil column in series with the new seepage pit to provide selective adsorption of strontium, ruthenium, and cesium on various bulk minerals

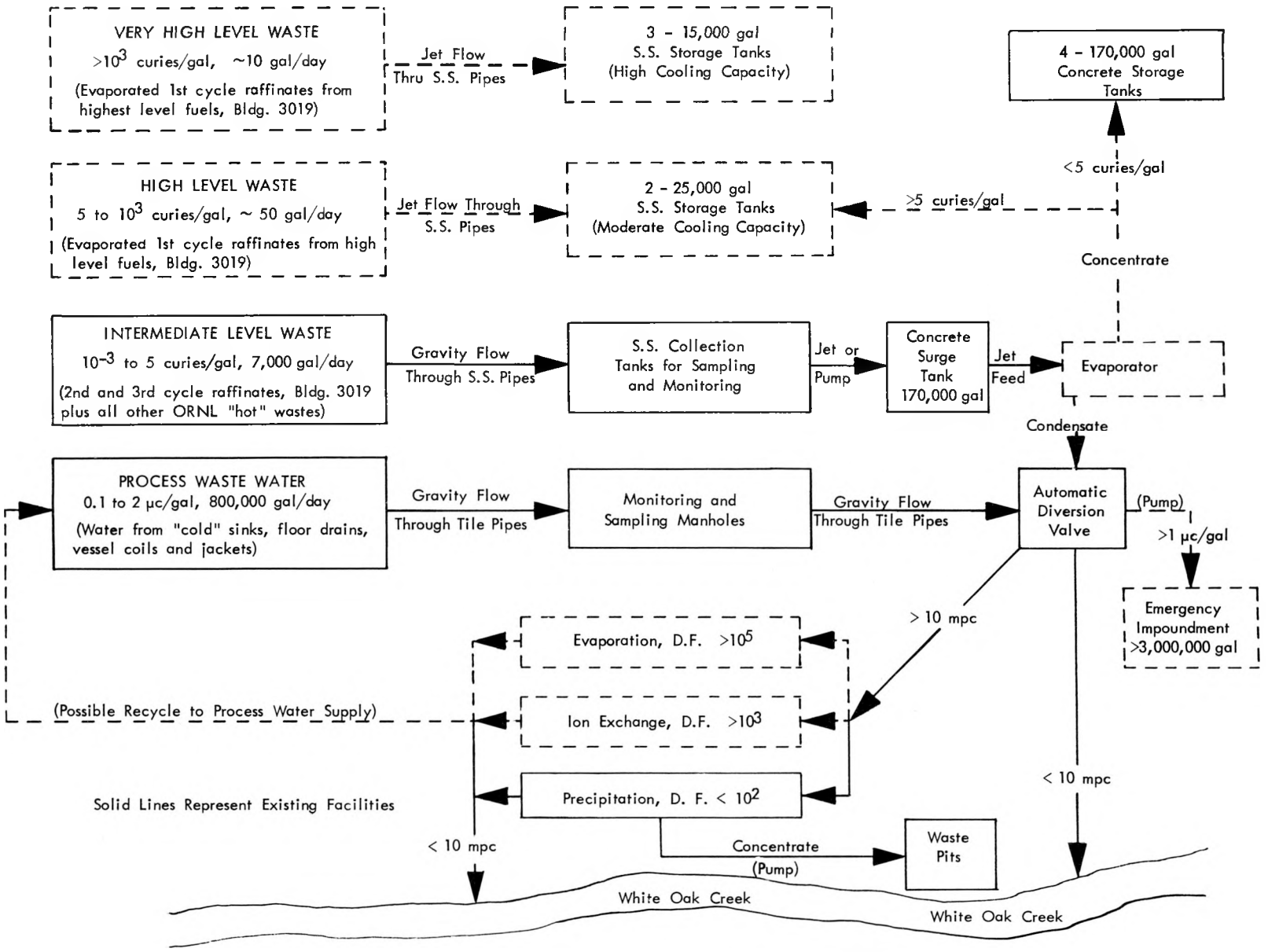

Fig. 4. Proposed ORNL radioactive liquid waste systems.

is under consideration. The existing waste pits are to be removed from service, treated with agents to fix the fission products adsorbed in their shale beds, and sealed with asphalt to minimize seepage. After the evaporator and storage tanks are in service, the use of soil adsorption methods for retention of radioactivity will be abandoned at ORNL for all but the lowest activity level wastes.

Improvement of the large-volume low-activity-level process waste water system is proceeding as follows:

1. Volume reduction to increase the feasibility of applying more refined treatment methods than the lime-soda precipitation process now used. It is roughly estimated that the process waste water flow can be decreased to a minimum of 250 gpm (360,000 gal/day) by removing the major cooling water users to recirculating systems equipped with pumps, heat exchangers, and cooling towers. Preliminary designs for recirculating process water in the major pilot plants have been prepared. Installing thermostatically controlled valves on process water supply lines to major condensers is a less expensive and less effective alternative proposal to recirculation.

2. Improved treatment to decrease radioactivity discharged to the river. The equalization basin for the existing treatment plant has been enlarged to increase holdup capacity; doubling the processing capacity of the treatment plant, adding flocculation aids to enforce waste clarification, and adding a vermiculite treatment step to improve strontium removal are under consideration. Design studies to compare costs and effectiveness of several multistage evaporation techniques with each other, ion exchange, and precipitation methods are in progress. The feasibility of recirculating the entire process waste water stream after treatment is also being investigated.

3. Improved monitoring to detect surges of radioactivity. Continuous radiation detectors have been specifically designed for the process waste water system. These will be installed with proportional samplers in existing and new monitoring manholes. The automatic diversion valve is to be equipped with a new detector sensitive to alpha and soft beta radiation.

4. Emergency impoundment of large volumes of excessively contaminated waste. Detailed designs are in preparation for building a 3,000,000-gal seepage basin and the associated pumps and pipe to handle infrequent incidents of very high radioactivity levels in process waste water.

In addition to the improvements in the liquid waste systems in the Laboratory proper, it is proposed to provide better control over the natural basin that receives ORNL liquid wastes after discharge from the Laboratory. A new channel for White Oak Creek from its junction with Melton Branch to a point below White Oak Dam is proposed to provide secondary containment for the radioactivity in the waste disposal pits, provide several hundred million gallons of emergency impoundment capacity for contaminated process waste water, decrease scouring of radioactive mud from the dam basin by heavy rains, and decrease the danger of a failure of White Oak Dam.

This channel by-passing the dam would carry the runoff from the 6-sq mi area drained by White Oak Creek and Melton Branch, decreasing to 0.5 sq mi the drainage area served by the basin behind the dam and including the ORNL waste disposal pits. The decrease of flow through the dam basin would not only decrease scouring of the 17-year accumulation of radioactive mud from the basin (thought to be the source of activity increases in the Clinch River after heavy rains) but would also make the basin available for emergency impoundment of contaminated water for several months at a time. The basin would also serve to intercept transport of the radioactive contents of the waste pits in the event of a washout or earth slide that might collapse the steeper pit sides.

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3.0 WASTE MANAGEMENT AT ORNL 1943 - 1957[3]

The present size of the Laboratory and the scope of its work have been reached by a series of expansions. The means of handling the considerable quantities of waste produced by the processes developed and tested at the Laboratory have had to be changed from time to time to keep pace with the expanding program.

The Laboratory was established in 1943 as a temporary pilot model for the Hanford, Washington, works. The Graphite Reactor, a chemical separations plant (the "Hot Pilot Plant"), and a number of large underground concrete (gunnite) tanks were constructed then. The tanks were intended to store all the most radioactive liquid chemical waste and the liquid uranium waste accumulated during the life of the Laboratory, which was expected to be one year. However, expansion of the scope of the work in 1943 and indefinite continuation of the Laboratory increased the quantities of waste, necessitating a method of disposal to augment storage tanks. It was decided to precipitate as much of the radioisotopes as possible in the storage tanks and to decant from the tanks those remaining in solution, dilute them with the Laboratory's large volume of process waste water, and disperse them into White Oak Creek. A portion of the precipitated radioisotopes remains as a sludge in the storage tanks at the present time. A dam was built across White Oak Creek 1.7 miles below the Laboratory in the autumn of 1943 to create a controlled area for the discharge of radioactive waste. A settling basin of 1,500,000 gallons capacity was completed in July 1944 to serve as the waste collection and sampling facility and as a stilling pond to permit radioactive solids to settle from the waste before discharge to the creek.

Additional decontamination of the radioactive supernatant by decay was gained by receiving and holding waste in one of the large storage tanks for as long as time as possible while decanting to the settling basin from another tank containing aged waste. This procedure allowed sufficient time for much short-lived (and hence more intense) radioactivity to decay before the waste was discharged to the creek. The isotopes removed by this procedure were 8-day iodine-131, 28-day cerium-141, 33-hour cerium-143, 41-day ruthenium-103, 12.8-day barium-140, and 40-hour lanthanum-140.

Thus, the 7,000 gallons per day of highest activity waste at ORNL was given a precipitation step, about one month's holdup for decay, triple settling (in the tanks,

the settling basin, and in the lake behind the dam), and about 500,000 to 1 average dilution in the Clinch River. It was calculated at that time that a maximum 5 curies per day of mixed fission products could be discharged safely into the lake, and for several years this criterion was used. An average of 254 curies per year, considerably below this level, has been maintained to date (see Table 1) in the controlled discharges from the Laboratory. This method of disposal by dilution and discharge through a regulated natural drainage basin was considered adequate as a temporary measure, but in 1949 the agreement upon more stringent tolerances necessitated an improvement.

From June 1949 until June 1954, the "hot" chemical waste was concentrated by evaporation in a pot-type evaporator instead of being decanted and diluted in the lake. During this period the evaporator processed a total of 11,650,000 gallons,[4] reducing this volume to 432,000 gallons of radioactive concentrate that was stored in the concrete tanks. The water boiled off from this waste contained an average of only 0.014% of the radioactive contamination entering the evaporator. The effectiveness of the evaporator is demonstrated by the fact that during the period of its operation only 14.5 curies per year came from the evaporator, although an average of 320 beta curies per year was discharged to the creek from the Laboratory. The remaining contamination came from process waste water and from accidental discharges (mainly leaking waste pipes and valves). The evaporator was taken out of service in June 1954, after the first 1,000,000-gallon experimental ground disposal pit had been in operation for two years. Since that time the pits have received all the "hot" chemical waste decanted from the storage tanks.

In 1950 the Laboratory was again greatly expanded in size and scope of operation. The waste systems were expanded to handle the increased waste volumes and levels of radioactivity. Monitoring systems for all three liquid waste types were devised to aid the collection and segregation of liquid waste. Underground stainless steel tanks to monitor separately the "hot" chemical waste and the liquid uranium waste were installed near each building or area that is a source of either type waste. The tanks permit sampling and measurement of waste volumes and rates of accumulation from each source.

The monitoring scheme installed for process waste water consists of weirs mounted in manholes in the underground sewer system that collects this waste. These weirs permit measurement of the waste volume from each source and proportional sampling of the waste for determination of the radioactive contamination.

In 1951 the first experimental ground disposal pit was built. A larger (1,000,000 gallons capacity) pit was built in 1952, and two more 1,000,000-gallon pits were built in 1955. A pump and a 1.5-mile-long pipeline from the collection tank area to the disposal pit area were installed in 1954 to replace a tank truck previously used to transport liquid waste.

Between 1952 and 1957 a metal recovery process reclaimed approximately 130 tons of uranium from liquid uranium waste collected over the years in the original waste

Table 1. Yearly Volumes and Radioactivity of Liquid Wastes Discharged to White Oak Creek at ORNL, 1950–1959[a]

Year	Total Volume, 10^6 gal	Gross Beta Activity, curies			Per Cent of Gross Beta Activity Identified with Specific Radionuclides									
		Settling Basin	Retention Pond	Total	TRE (-Ce)[b]	Ce	Ru	Zr	Cs	I	Sr	Nb	Ba	Co
1950	226.4	172	15	187										
1951	297.6	169	3	172										
1952	268.2	411	87	498										
1953	239.4	289	140	429	53.1	2.6	0.8	2.6	8.5	0.2	27.6	1.0	0.8	-
1954	164.3	237	17	254	34.6	19.1	0.5	1.0	20.3	0.5	23.3	0.4	0.3	-
1955	210.6	213	54	267	30.3	14.7	3.1	0.6	31.6	0.2	18.7	0.6	0.2	-
1956	260.7	253	20	273	24.4	12.3	2.0	0.5	42.1	0.1	15.1	1.0	0.2	2.2
1957	272.3	(combined)		189	25.8	4.4	1.0	10.2	36.5	0.0	18.0	0.7	0.0	1.8
1958	232.0			92	24.0	4.6	1.4	0.7	50.2	0.6	15.3	1.1	0.6	1.5
1959	313			181	25.0	16.9	31.7	0.9	11.7	0.1	10.7	0.5	0.1	2.4

[a]Volume of settling basin effluent measured in weir box with liquid level float recorder. For determination of radioactivity, continuous proportional samples of the effluent are composited for daily gross beta measurements and monthly radiochemical separations and analyses.

[b]Trivalent rare earths exclusive of cerium.

storage tanks. The waste from this recovery process was sent to the "hot" waste system for evaporation or disposal to pits.

The lake behind the dam on White Oak Creek was drained in 1955 for the following reasons:

1. To perform necessary maintenance work on the dam facilities.
2. To destroy and dispose of the aquatic species in the lake.
3. To avoid attracting and harboring migratory wildfowl.
4. To provide additional safeguards by increasing retention potential.
5. To facilitate and improve control of activity releases.
6. To permit modification of sections of the lake area for research use.

The stream now flows through the lake bed and through a sluice in the dam, which can be closed to impound contaminated water when the need arises. A bypass has been proposed to carry the stream flow around the dam to minimize disturbing contaminated sediments in the old lake bed, but this proposal has not been carried out to date. A continuous sampler and a radiation monitor (submerged in a container through which stream water is circulated) have been installed at the dam. The monitor can detect a "slug" of radioactivity and can sound an alarm, but it is considered a stop-gap instrument until a better one can be developed.

Studies of wildlife in the lake were made between 1950 and 1953[5] and in 1956[6,7] to determine some ecological effects of radioactive contamination. Agricultural crops are being grown in the contaminated mud of the lake bed to study uptake of radioactivity by plants.[8,9]

In 1957 a waste water treatment plant was completed and put into operation. The function of this plant is to reduce the level of radioactive contamination in the low-activity process waste water discharged to White Oak Creek. An automatic diversion valve is currently operating to feed the entire process waste water flow to the treatment plant whenever the level of radioactivity in the waste exceeds a given point. When the activity level is below the set point, the automatic valve diverts the waste around the treatment plant and to the creek through the settling basin.

A multicurie fission product pilot plant was completed in 1957 to recover strontium-90, cesium-137, and other valuable radioisotopes from high-activity liquid wastes. This pilot plant should be most valuable for treating extremely high-level waste from future processes planned for the Laboratory.

4.0 CURRENT HANDLING AND DISPOSAL METHODS AND FUTURE PLANS FOR LIQUID WASTES

4.1 "Hot" Liquid Chemical Waste

The concentration of radioactive components in ORNL "hot" chemical waste is normally between 0.001 and 0.08 curie per gallon measured in the concrete storage tanks. During an experimental program of processing short-decayed material in 1959, wastes having activity levels as high as 75 curies per gallon were produced; but the volume of these wastes was small enough that dilution by other wastes in the storage tank reduced the level to 0.08 curie per gallon. Because the research and development nature of the Laboratory brings about frequent changes in the processes that produce waste, the waste composition is not consistent. Larger volumes and higher radioactivity levels are expected from future operations. The main radioisotopes are usually cesium-137, ruthenium-106—rhodium-106, strontium-90—yttrium-90, and trivalent rare earth elements. Strontium, cesium, and trivalent rare earths constitute the major fraction of radioactivity on an average disintegration per minute basis. Sodium and nitrate account for about 70% of the nonradioactive solids in the waste.

The handling of "hot" chemical waste is illustrated in Figs. 1 and 2, which are simplified flowsheets of the Laboratory's waste systems. The main sources of the liquid chemical waste are chemical processing pilot plants. Radioisotope production facilities and research laboratories produce wastes of smaller volume and lower activity level. The special fission product wastes shown in the upper right-hand corner of Fig. 2 are recovered and consequently do not contribute directly to the waste stream.

"Hot" chemical waste is discharged from process vessels in laboratory and pilot plant cells into "hot" drains, which are stainless steel pipes leading to underground stainless steel monitoring tanks. There are now 19 of these 500 to 4000 gallons capacity tanks in service (including tank W-1, Fig. 2); their total capacity is approximately 34,000 gallons. Each tank is located near its main contributor to permit gravity flow to the tank. The function of these monitoring tanks is to collect the waste and to provide a means of sampling it and of measuring its volume. The tanks provide the Operations Division with a means of checking on waste contributors for rate of waste production and to be sure each type of waste gets into its proper system for treatment and disposal. Each tank has connections to the highly radioactive chemical waste system and to the process waste water system to give a choice of treatment depending on composition, radioactivity level and other considerations.

Figure 5 shows the burial details of the monitoring tanks. Each tank is anchored to a concrete saucer that slopes toward a sump. The sump collects ground water seepage and any liquid that leaks from the tank. Liquid in the sump is sampled periodically for

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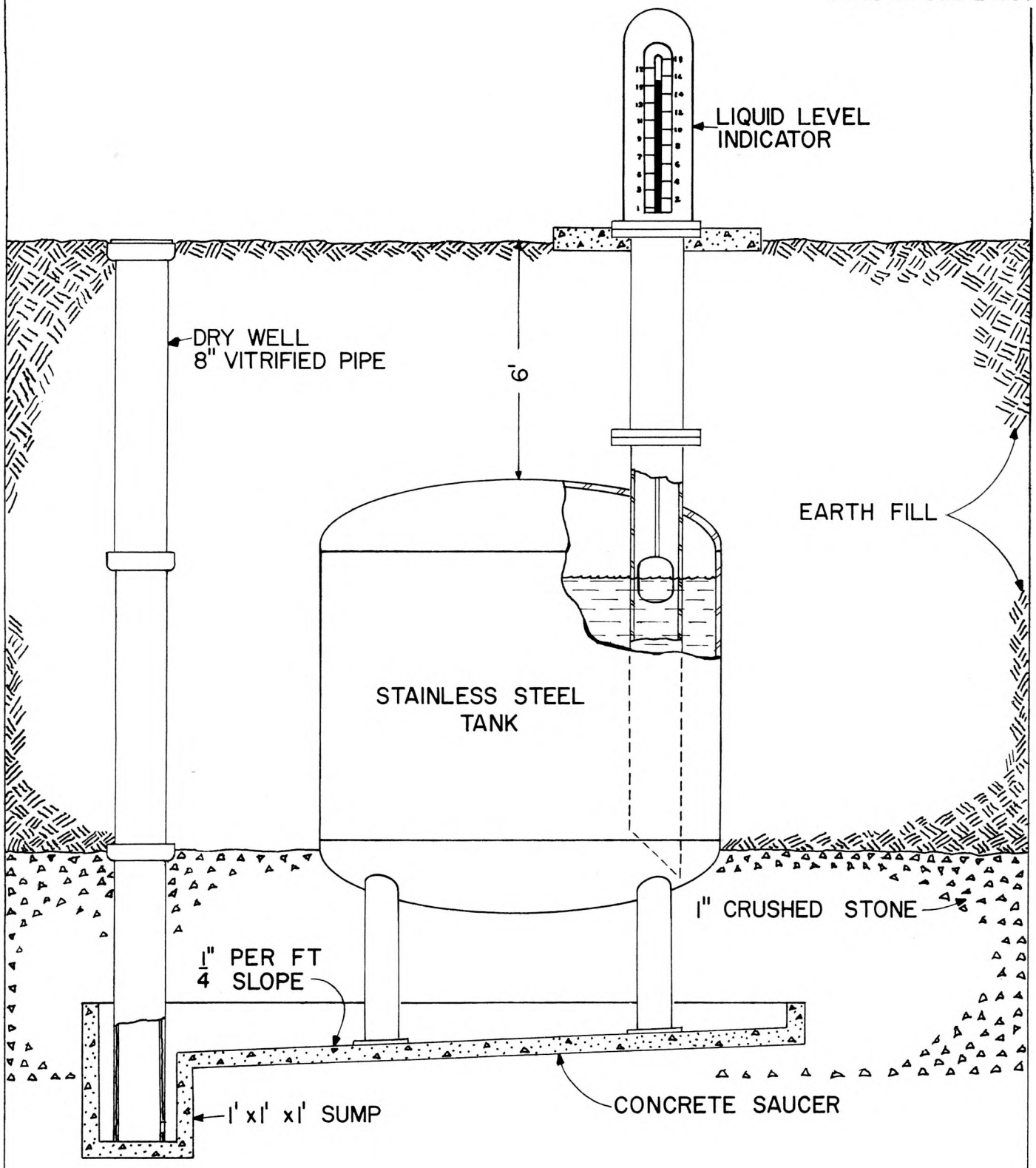

Fig. 5 Dry Well & Waste
Collection Tank Installation

radioactivity through a "dry well" to determine whether the tank has leaked. During the past 15 years three tanks were emptied and abandoned after leaks were discovered in this manner. Because most of these leaks were caused by acid corrosion of the tanks, caustic soda to neutralize incoming acid waste is now added to each tank. No leaks have been discovered since this procedure was started.

Each tank is equipped with a float-type volume gage, which shows on a board above ground the quantity of waste in the tank. Although the rate of waste accumulation in all 19 monitoring tanks is continuously recorded at a central station by a telemetering system, a waste system operator visits each tank every 4 hours to check the waste volumes lest a tank overflow because of a failure in the telemetering system.

When a monitoring tank becomes filled, the operator switches on a self-priming, packless pump to transfer the waste to one of the three 170,000-gallon concrete storage tanks in the storage farm centrally located in the main X-10 operating area. These tanks rest on concrete saucers that drain to a system of dry wells for leak detection similar to those of the monitoring tanks. The central storage tanks also have volume gages, samplers, and an underground system of transfer lines that permit transfer of the wastes from one tank to another.

The function of the central storage tanks is to provide temporary storage for "hot" chemical waste while the short-lived radioisotopes decay (see Sect. 3.0). Also, most of the fission products including almost all the strontium-90 and alpha-active isotopes are precipitated and remain in these tanks. These tanks provide adequate surge capacity to accommodate normal accumulation for Laboratory operations even during occasional shutdown and repair of pumping equipment. Waste supernatants are periodically decanted from the central storage tanks and pumped approximately 1.5 miles through a 2-inch-diameter underground steel pipe to the disposal pits. Table 2 lists the sludge accumulation and the available capacities of the central storage tanks.

Table 2. Sludge Volume and Capacity of ORNL Central Waste Storage Tanks

Tank	Sludge Volume, gal	Available Capacity, gal	Current Use
W-5	60,000	100,000	Chemical Waste
W-6	86,000	79,000	Chemical Waste
W-7	30,000	135,000	Chemical Waste
W-8	86,000	79,000	Chemical Waste
W-9	12,000	153,000	Metal Waste
W-10	10,000	155,000	Metal Waste

The waste pits are three 1,000,000-gallon open cavities bulldozed in the earth in a location chosen for remoteness from the Laboratory, the type of soil, and the fact that underground drainage is toward White Oak Creek.[1,10] The soil, Conasauga shale, has the property of removing and retaining most of the radioactive components while the waste water and certain nonradioactive chemicals seep through it toward White Oak Creek. Waste enters pit No. 3, which overflows through a valved pipe to pit No. 2, which overflows similarly to pit No. 4. Figure 6 is an aerial photograph of the waste disposal area showing the pits in the foreground, the creek, and, in the upper left-hand corner, a part of the main X-10 area. The pits are each 15 feet deep with sides sloping at an angle of 30°. Their top dimensions are 210 by 100 feet. The pits are covered with wire screen to prevent access to wild life. The waste discharged into the pits is sampled and analyzed for radioisotopes and stable chemical ions, and the movement of these materials in the soil and in the seepage into the creek is monitored by the Health Physics Division. The only radioisotopes detected in the seepage to date are ruthenium-106, cobalt-60, and antimony-125. Yearly discharges of radioactivity to the pits have been as follows:

1953	7,700 curies
1955	21,400
1957	42,000
1958	53,000
1959	280,000

The sharp increases in recent years were due mainly to higher radiation levels in processing at the Hot Pilot Plant. By the end of 1959 the total waste discharged to the pits since the start of this practice was 15,284,000 gallons containing 447,000 curies (at time of discharge). The discharge of waste supernate to the shale pits at activity levels previously used will not be continued after a chemical waste evaporator is installed. A potentially serious break-through of ruthenium-106 activity in the east bank of waste pit No. 4 occurred in the latter part of 1959. This event caused the activity released to the creek from the pits in 1959 to rise to 1320 curies. Excavation of the area showed that the bulk of the release came through a narrow channel which flowed into a swampy area east of the pit. The situation has been corrected temporarily by intercepting the leakage and pumping it back into the pit.

Interim and Long Range Plans for "Hot" Chemical Waste. As a result of the leakage from waste pit No. 4 and in view of increasing levels of radioactivity in chemical processing demonstrations at the Laboratory, studies have been made on means to improve disposal of ORNL "hot" waste, both for the immediate future and for the long term. In order to discontinue the use of pit No. 4 as soon as possible, a new pit (No. 5) is under construction in an area east of the existing pits that was carefully selected over a year ago (Fig. 5). The new pit is a seepage trench 300 feet long by 20 feet wide (40,000 gallons capacity) excavated in shale. Its design incorporates several refinements: (a) a crushed limestone layer for cesium adsorption, (b) a loose-jointed tile pipe distribution system to spread inflowing waste over the whole pit, (c) a wedge-shaped cross section to provide

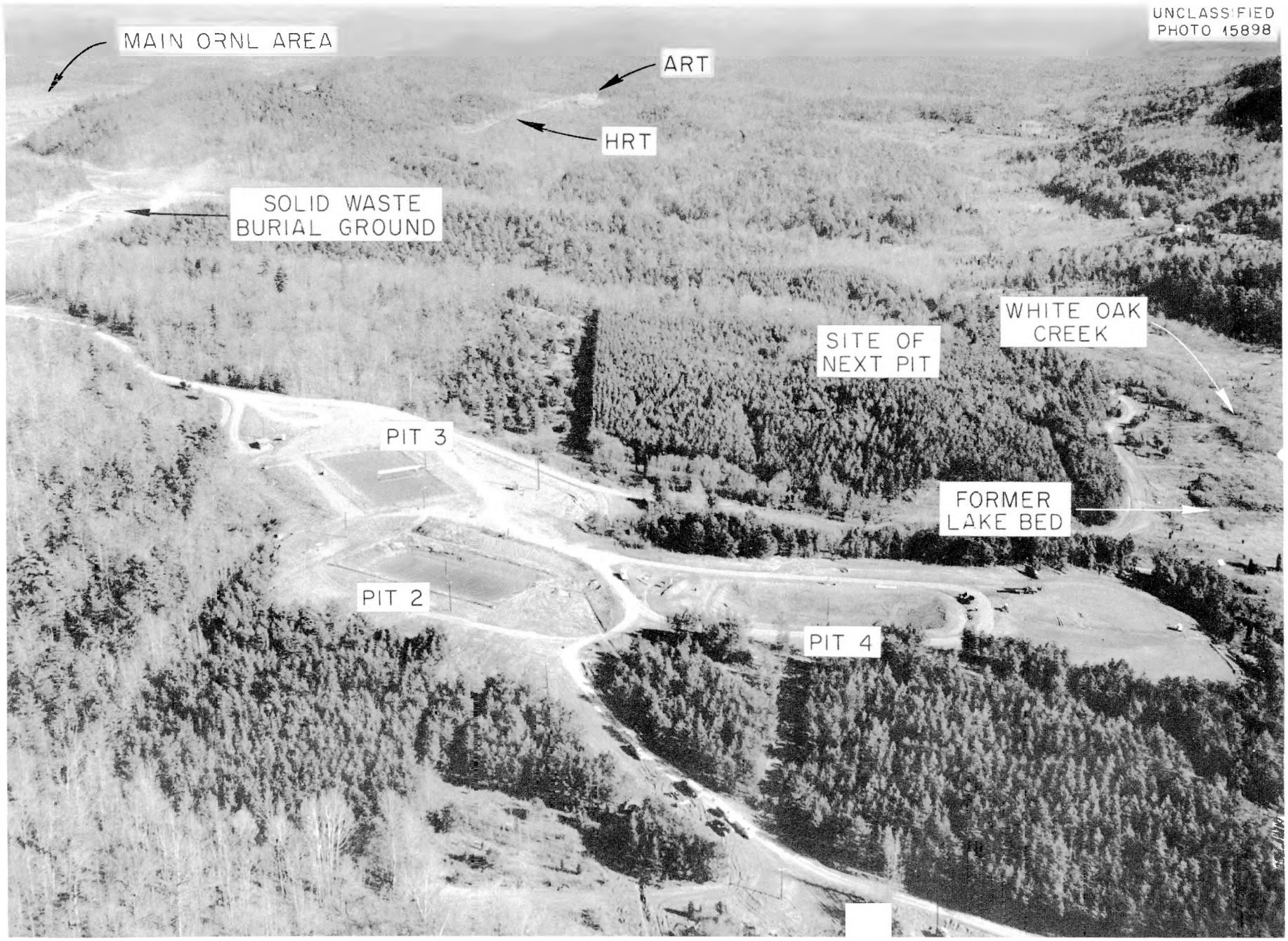

Fig. 6 ORNL WASTE DISPOSAL AREA

more side area than bottom area for seepage of water out through a very large area of shale, and (d) a water-resistant (asphalt) cover to keep out rain. It is planned to discontinue using the existing pits after the new trench has been proved acceptable. The pits will be treated with copper ore to fix ruthenium and then sealed by spraying with asphalt. A new 3-inch-diameter pipe line from pumps in the tank farm to the new trench is planned to replace the existing 2-inch line.

Experiments are being conducted on treatment of "hot" chemical waste with various minerals and/or chemical systems to remove the radioisotopes. It appears that ruthenium, the only radioisotope difficult to remove, can be removed by chemical treatment and pH-temperature control in a soil column containing various minerals. Efforts are being made to develop a soil column that does not require the chemical treatment to remove ruthenium. Since various copper compounds interact much more rapidly with ruthenium in waste than most soils or minerals, experiments are proceeding on Conasauga shale saturated with $CuSO_4$ solution. If this copper-bearing shale successfully removes ruthenium, it appears that the amount of ruthenium penetrating the soil for any distance from a soil column could be lowered from the present 5% to less than 0.5%. Tests of copper sulfide ores at high pH presently show 30% ruthenium removal. It should be stressed that the ruthenium is in resistant form, having penetrated through a number of feet of soil (approximately 95% is fixed in the soil, leaving only 5% still in solution). If the present work with copper-bearing soils and ores continues to be successful, a soil column containing appropriate material to fix ruthenium as well as other fission products will be constructed on the "hot" waste pipe line upstream of the new seepage trench. The structure envisioned would be a covered concrete box divided into compartments containing the bulk minerals specific for the removal of each radioisotope. The effluent from this box would flow through the new seepage trench for dispersal into the shale.

For the longer term planning on disposal of high-level liquid waste, studies are being made on the feasibility of collecting separately the most radioactive components (those greater than 5 curies per gallon) and storing them in tanks equipped with cooling coils. The remainder of ORNL "hot" waste would then be termed "intermediate-level waste" (0.001 to 5 curies per gallon), which could be reduced to about one-tenth its present volume by an evaporator yielding a decontamination factor between feed and overheads of 10^5. The overheads would be combined with the process waste water stream and the bottoms stored in the existing concrete tanks, which have approximately 600,000 gallons capacity available. (See Table 2.)

A preliminary estimate based on the above concept and including two 25,000-gallon high-level tanks, one 400-gallon-per-hour submerged-coil evaporator, and a 750,000-gallon-per-day ion exchange plant for process waste water treatment indicated that the cost of these modifications would be $1,543,000.

In addition to the proposals described above, detailed designs have been prepared for handling the very high-level wastes from the proposed Power Reactor Fuel Processing (PRFP) pilot plant program. Table 3 lists the volumes and heat generation capacities expected in these wastes. The wastes under "Lower Heat Generating Fuels" in the upper half of the table can be stored in the proposed 25,000-gallon tanks for "high-level wastes" previously mentioned. The wastes under "Higher Heat Generating Fuels" in the lower half of the table are to be termed "very high-level wastes," which must be stored in special tanks equipped with very-large-capacity cooling systems. The three 15,000-gallon tanks proposed for these wastes are described in a hazards evaluation report on very high activity waste storage.

The "hot" waste systems currently proposed to meet the higher levels of processing demonstrations at ORNL thus are (see Fig. 4):

1. Very high-level waste (>1,000 curies per gallon)

   Source: Building 3019 first cycle raffinate from highest-level fuels
   Storage: Three 15,000-gallon tanks with high cooling capacity

2. High-level waste (5 to 1,000 curies per gallon)

   Source: Building 3019 to first cycle raffinates from lower level fuels
   Storage: Two 25,000-gallon tanks with moderate cooling capacity

3. Intermediate-level waste (0.001 to 5 curies per gallon)

   Source: Building 3019 second and third cycle raffinates and all other ORNL "hot" wastes

4.2 Liquid Uranium Waste ("Hot" Metal Waste)

The quantity of liquid uranium waste is much less than it was earlier in the history of the Laboratory, as it is now produced at a maximum rate of only 100 gallons per week. In the sense that it is actually a solution of re-usable uranium contaminated with fission products, this is not a true waste. It is collected and stored temporarily prior to treatment for recovery of the uranium. Between 1952 and 1957, approximately 130 tons of uranium was recovered. The separated fission products are discharged to the "hot" chemical waste system. Figures 1 and 2 illustrate the handling of liquid uranium waste.

The liquid uranium waste from the various contributors is collected separately from other liquid waste by means of a system of seven monitoring tanks (total capacity 7500 gallons), similar in all respects to those described above for "hot" chemical waste. Each buried tank serves a source of liquid uranium waste, which flows by gravity through

Table 3. Predicted Cumulative Waste Volumes and Activity in High- and Very High-Activity Waste Storage Systems

Year	Volume, gal	Heat Generation, Btu/hr	Activity curies/gal
		Lower Heat Generating Fuels	
1961	1,710	22,000	800
1962	12,960	99,000	470
1963	24,760	79,550	200
1964	66,560	605,000	570
1965	75,160	293,635	240
		Higher Heat Generating Fuels	
1963	9,200	1.4×10^6	9,400
1964	9,600	0.655×10^6	4,200
1965	12,400	1.8×10^6	9,000

special stainless steel drains from the source facilities to the tanks. The waste volumes in the tanks are recorded at the central station by the previously described telemetering system, and a waste system operator checks the tank gages every 4 hours to prevent overflows. The waste from full tanks is pumped to the central tank farm, where three 170,000-gallon and two 42,500-gallon underground concrete tanks store it until enough has accumulated to warrant running the uranium recovery facility.

Because the currently small quantities of liquid uranium waste are not expected to increase, two of the 170,000-gallon storage tanks (W-7 and W-9) can be devoted to storage of future "intermediate-level waste" concentrate. Tank W-7 is now temporarily used for "hot" chemical waste hold-up. (See Table 2.)

4.3 Process Waste Water

The sources of process waste water are equipment cooling systems, floor drains, decontamination pad drains, storage canals, laboratory sinks, and discharges from low activity operations. It is the least radioactive of all laboratory liquid wastes except sewage and storm water, yet it is the most difficult to manage because of its combination of radioactivity and large volume. The 800,000 gallons per day of this waste make storage impractical and necessitate disposal on a current basis. The waste is collected, sampled, and discharged to the creek continuously. Figures 1 and 2 illustrate the relation of the process waste water system to the other liquid waste systems.

The process waste system sometimes serves as an emergency "warm" system. Much of the radioactive contamination put through this system is a result of equipment failure, human error, or accidents that cause a misdirection of contamination from the "hot" chemical waste system. Whenever unusually high levels of radioactivity occur in process waste water, an effort is made to divert the radioactive portion to the "hot" chemical waste system as soon as possible. A network of 6- to 30-inch diameter vitrified clay pipes collects and conveys the process waste water by gravity flow to a central monitoring point near the inlet to the 1,500,000-gallon settling basin, where the volume of flow is measured and sampled continuously. The samples are collected every 4 hours and analyzed for gross beta activity. The process waste water collection system is divided into several sections, each of which is served by a strategically located monitoring station. Each station is a concrete manhole in which are mounted a V-notch weir, a water level recorder for determining volume of flow, and a finger-type pump for collecting samples continuously. When the radioactivity level at the central monitoring station rises to about 150 c/m/ml* or greater, the source responsible for the increase can be located by referring to the monitoring samples, and corrective action can be taken to minimize discharges of radioisotopes through this low-level system.

The yearly volumes and radioactivity of the process waste water during the years 1950 through 1959 are summarized in Table 1. The total volume of flow has ranged from about 165 to 313 million gallons per year. The level of gross beta activity normally ranges from less than 50 to several hundred c/m/ml with occasional transient levels above

*c/m/ml = counts per minute per milliliter. All results are referred to second-shelf counting using an end-window Geiger counter.

1000 c/m/ml, depending upon operating conditions in the Laboratory. The fourth column in Table 1, headed "Retention Pond," refers to a small volume of drainage from the monitoring pads underneath and from the soil around the underground waste storage tanks in the central tank farm. This pond previously served as a monitoring point for the detection and measurement of any leakage in the "hot" chemical and liquid uranium waste piping and storage systems. The retention pond stream has been intercepted and is now pumped to the equalization basin of the process waste treatment plant. The total gross beta activity in discharges to White Oak Creek from the process waste water system and the retention pond has ranged from 172 to 498 curies per year. The waste discharged from the collection system is normally clear with very little suspended matter; but it varies widely in acidity or alkalinity, the pH ranging from about 2.0 to 11.5.

The flow of the effluent from the settling basin is measured at a weir box near the point of discharge to the creek, and composite samples are collected by a Trebler proportional sampler. Radiochemical analyses of these samples for seven years (1953-1959) are summarized in Table 1. The chemical, radioactive, and physical properties of the waste discharged from the settling basin may be influenced by sedimentation in the basin or by heavy growths of algae, both of which are capable of concentrating radioactivity.

Process Waste Water Treatment Plant.[11,12,13] Increases in the chemical processing operations and in their radioactivity levels at ORNL since 1951 have increased the volume and activity level of process waste water discharged to the creek (Table 1). On several occasions surveys showed that the level of radioactivity in the Clinch River for short periods exceeded the recommended average concentration limit for unidentified radionuclides.[2] These incidents emphasized the need for a treatment plant to reduce the level of radioactivity in the process waste water. The reduced levels of radioactive discharge for 1957–1959, despite several radiation incidents, demonstrate that the treatment plant operation plus monitoring efforts within the Laboratory have been of great benefit.

The radioactive contamination discharged to the creek has always passed through the process waste water system as a very dilute solution chemically similar to "hard" water. The over-all results of extensive laboratory and pilot plant studies indicated that a process waste water treatment plant should be designed to use a horizontal-flow lime-soda water softening process with provisions for alternative use of phosphate coagulation to remove strontium and the addition of clay to increase the removal of cesium.

The plant, completed in August 1957, is located near the central monitoring and diversion station at the outlet of the process waste water collection system. It has a design capacity of 500,000 gallons per day, and provision has been made for future expansion to double this capacity. In addition to the routine treatment of waste, the plant is designed to give special treatment to waste containing abnormally high concentrations of radioisotopes caused by accidental or emergency releases.

Figure 7 is a diagram of the facilities for treatment and disposal of process waste water. When the inlet valving is operated manually, the plant receives all process

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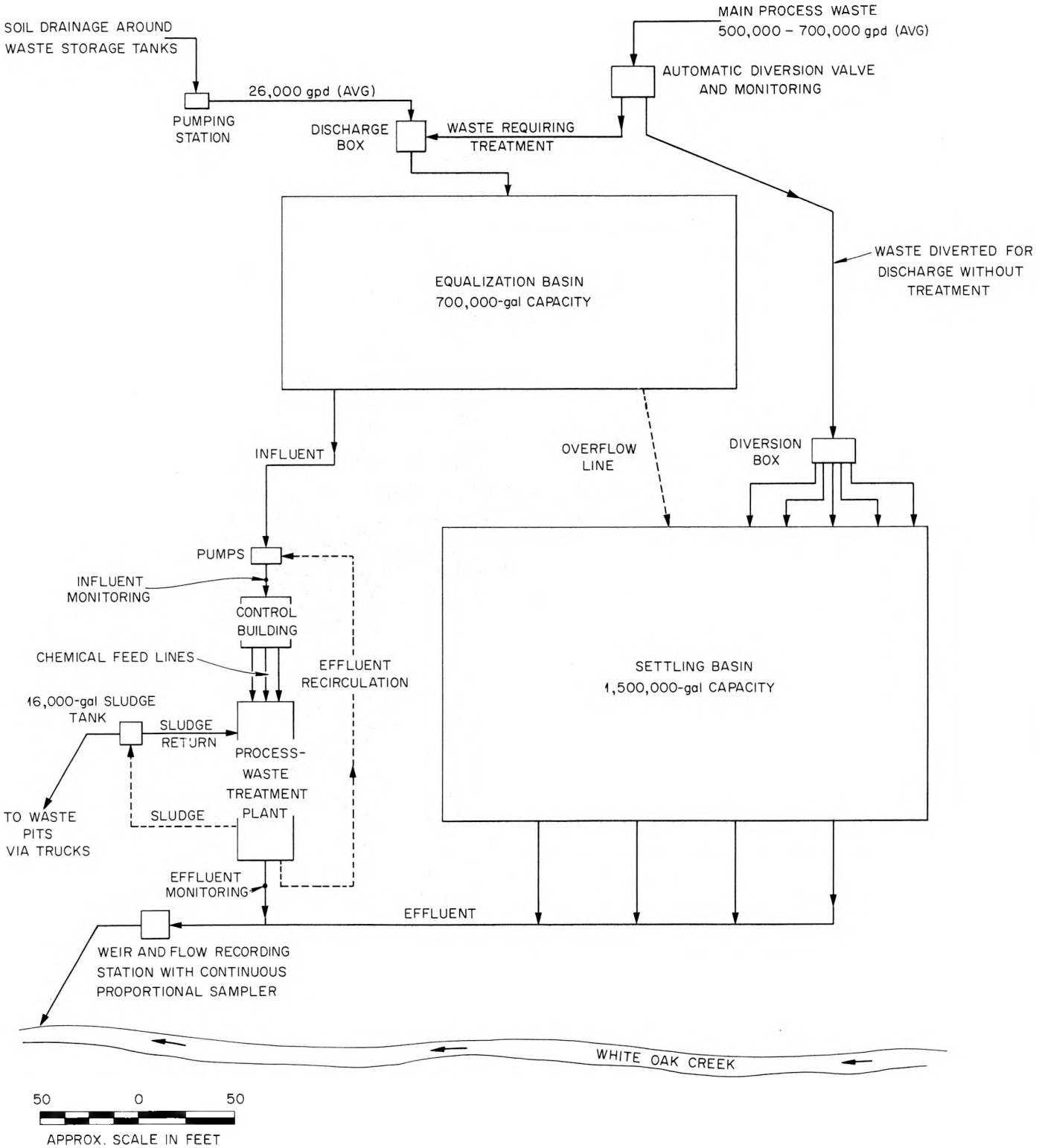


Fig. 7 Flow Diagram of Process Waste System

water flowing between 8:00 a.m. and 8:00 p.m., the period when most of the contaminated discharges occur. This method results in (1) the treatment of large volumes which might not need decontamination and (2) the possible bypassing of active wastes at night. Therefore, an automatic diversion valve was provided which, in response to submerged Geiger-Mueller tubes, permits low level wastes which contain a greater concentration of radioactivity than a predetermined amount.[14] The 700,000-gallon capacity equalization basin serves to minimize fluctuations in the composition of the plant influent and to supply waste to the treatment plant as needed.

Figure 8 is a cut-away view of the process waste water treatment plant. Uniform flow rate through the plant is maintained by two 350-gallons-per-minute centrifugal pumps drawing from the equalization basin. Two gravimetric feeders apply slurries of lime and soda ash to the flash mixer, which has a detention time of 1.5 minutes. (A third feeder is available for clay, trisodium phosphate, etc., as needed.) The three coagulation basins in series, providing 30 minutes of slow mixing, are followed by 2 hours' settling in a 12 x 70 x 8-foot deep basin. The effluent is discharged to the creek. It can be recycled through the plant for additional treatment, although this has not yet been attempted.

The sludge that precipitates in the settling chamber contains the radioisotopes removed from the waste. A sludge scraper operating continuously moves it along the concrete bottoms of the settling chamber into hoppers at the deep end of the chamber. Valves permit the sludge to drain from the hoppers to a 16,000-gallon concrete tank for short-time storage before disposal. Two plunger-type pumps lift the sludge to a partly shielded tank truck, which transports it to the disposal pits for "hot" chemical waste. A part of the sludge can be recycled through the treatment plant when this is desirable.

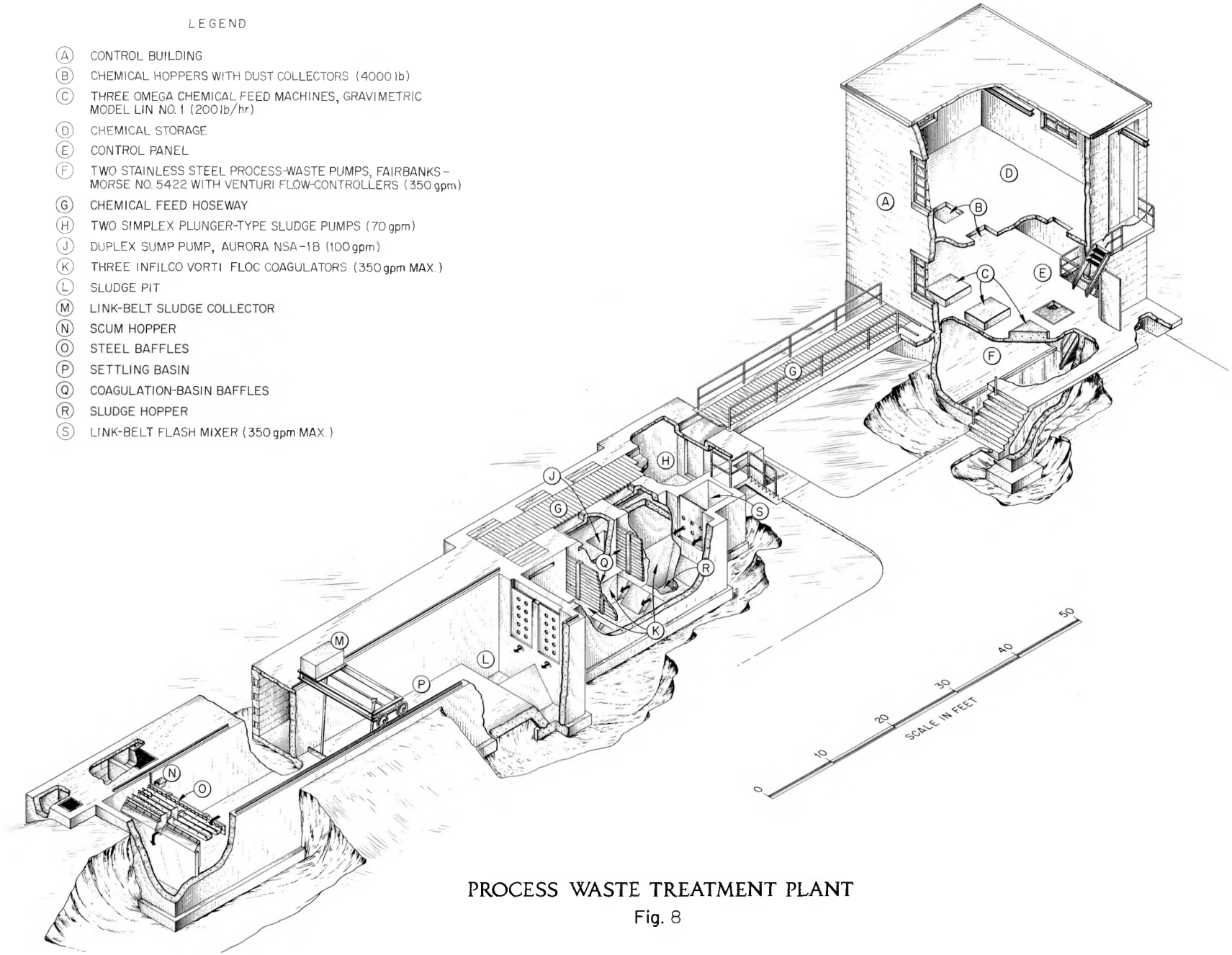
The mechanical equipment is designed to allow maintenance without draining the chambers, thus utilizing the waste water as a shield to protect personnel from exposure to radiation from the radioactive sediments in the chambers.

Interim and Long-Range Plans for Process Waste Water. In the latter part of 1959 a leak in a steam coil submerged in a highly radioactive evaporator solution in Building 3019 resulted in a release of activity into the process waste water system which was more serious than any single incident previously experienced. It is estimated that 500 curies of mixed fission products was released into the system. A much greater release was prevented by special emergency procedures. The incident demonstrated the need for more holdup capacity in the supply pond (equalization basin) for the waste treatment plant, more treatment capacity, more effective treatment, and better monitoring in the process waste water system.

To correct the deficiencies in the system the following measures are currently being taken:

LEGEND

- (A) CONTROL BUILDING
- (B) CHEMICAL HOPPERS WITH DUST COLLECTORS (4000 lb)
- (C) THREE OMEGA CHEMICAL FEED MACHINES, GRAVIMETRIC MODEL LIN NO. 1 (200 lb/hr)
- (D) CHEMICAL STORAGE
- (E) CONTROL PANEL
- (F) TWO STAINLESS STEEL PROCESS-WASTE PUMPS, FAIRBANKS-MORSE NO. 5422 WITH VENTURI FLOW-CONTROLLERS (350 gpm)
- (G) CHEMICAL FEED HOSEWAY
- (H) TWO SIMPLEX PLUNGER-TYPE SLUDGE PUMPS (70 gpm)
- (J) DUPLEX SUMP PUMP, AURORA NSA-1B (100 gpm)
- (K) THREE INFILCO VORTI FLOC COAGULATORS (350 gpm MAX.)
- (L) SLUDGE PIT
- (M) LINK-BELT SLUDGE COLLECTOR
- (N) SCUM HOPPER
- (O) STEEL BAFFLES
- (P) SETTLING BASIN
- (Q) COAGULATION-BASIN BAFFLES
- (R) SLUDGE HOPPER
- (S) LINK-BELT FLASH MIXER (350 gpm MAX.)



PROCESS WASTE TREATMENT PLANT

Fig. 8

1. Enlarging the equalization basin for the waste treatment plant from 700,000 to 1,000,000 gallons capacity.

2. Installing pumps and a 6-inch-diameter piping system to interconnect the settling basin and the equalization basin and to extend to the waste disposal area in the valley containing White Oak Dam.

3. Constructing a 3,000,000-gallons-capacity emergency impoundment basin in the shale formation near waste pits Nos. 2, 3, and 4. This impoundment basin will be served by the 6-inch pipe line and pumps to be installed near the settling basin. If the level of radioactivity in process waste water should rise to a predetermined value, this waste could be pumped to the emergency impoundment basin, which will hold about 3 days' normal flow of process waste water. It is expected that the impounded waste water will slowly seep through the shale to White Oak Creek, leaving the contamination on the shale.

4. Improving the monitoring system in process waste water manholes near the major producers of this waste. All the monitoring stations will have weirs for flow measurement, continuous proportional samplers, and continuous radiation monitors. This monitoring system should provide early detection of high radioactivity in process waste water and should help locate the source of the radioactivity. This monitoring system was initiated in 1950 but was never completed. The ORNL Instrument and Controls Division is developing an improved continuous beta-gamma radiation detection device for these monitoring stations as well as a continuous monitor for soft beta and alpha detection at the automatic diversion valve.

For the long-term planning on treatment and disposal methods for process waste water, studies of the following possibilities are being made to increase both the capacity and degree of cleanup of this stream (see Fig. 1):

1. Doubling the size of the present lime-soda plant and using flocculation aids to enforce clarification. This should decrease strontium-90 to 10 times the MPC under conditions of normal operation, but would fall short of this during periods of contamination or when any complexing agents such as Turco or versene are present in the waste. Experiments are planned with flocculation aids in the lime-soda plant to test this effectiveness.

2. Addition of a vermiculite treatment step to the effluent from the above. This should decrease strontium-90 to the range of 1 to 10 times the MPC, but the vermiculite represents an additional solid for disposal.

3. Installation of an ion-exchange process and use of the lime-soda plant for clarification and feed adjustment. This should decrease the strontium-90 to 0.1 to 1 times the MPC but additional laboratory work is required for evaluation of performance with actual waste.

4. Evaporation should decrease the strontium-90 content to 0.01 to 0.1 times the MPC and would probably be least subject to varying waste conditions and concentrations. It would also be the most expensive treatment of any being considered.

5. Recirculation of all process water with complete demineralization or evaporation would decrease storage problems and yield best decontamination. On the other hand, it would represent the highest capital cost.

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