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INVESTIGATION REPORT OF THE RELEASE OF STRONTIUM-90 FROM THE
BUILDING 3517 CELL VENTILATION IMPROVEMENTS CONSTRUCTION SITE

ON NOVEMBER 29, 1985

OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

DATE PUBLISHED: January 21, 1986

Prepared by the
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Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract No. DE-AC05-84OR21400

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II. LIST OF ACRONYMS AND ABBREVIATIONS

AC	Analytical Chemistry (Division)
ADM	Action Description Memorandum
Bq/l	Bequerels per liter
CE	Construction Engineer
CFC	Certified for Construction
CFR	Code of Federal Regulations
CFS	Cubic feet per second
Ci	Curie
C ² AF	Cost Plus Award Fee
cpm/ml	Counts per minute per milliliter
CRM	Clinch River Mile
DB	Diversion Box
DEM	Department of Environmental Management
DOE-ORO	Department of Energy - Oak Ridge Operations
E&OS	Environmental and Occupational Safety (Division)
EB	Equalization Basin
ERC	Emergency Response Center
ES&H	Environment, Safety, and Health (Staff)
FDDL	Fission Product Development Laboratory
GPP	General Plant Project
LLW	Low Level Waste
LSS	Laboratory Shift Supervisor (ORNL)
MH	Man Hole
MHD	Melton Hill Dam
MPC	Maximum Permissible Concentration
mrad/hr	Millirad per hour
mrem	millirem
NRC	Nuclear Regulatory Commission
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
p Ci/l	pico curies per liter
P&E	Plant and Equipment (Division)
PSS	Plant Shift Superintendent (ORGDP)
PVC	Polyvinylchloride
PWTP	Process Waste Treatment Plant
QAA/P	Quality Assurance Assessment/Plan
rad/hr	rad per hour
Rd	Retardation Factor
STP	Sewage Treatment Plant
TDE	Tennessee Department of Health and Environment
TEMA	Tennessee Emergency Management Agency
TRU	Transuranium (Processing Facility)
TVA	Tennessee Valley Authority
WOC	White Oak Creek
WOCC	Waste Operation Control Center
WOD	White Oak Dam
WOL	White Oak Lake
WTP	Water Treatment Plant

III. SCOPE OF INVESTIGATION

This Type B Investigative Report provides an evaluation of all relevant events and activities that led to, were an integral part of, and subsequently resulted from ORNL's November-December 1985 strontium-90 release incident. The impacts were evaluated in terms of radiological doses to ORNL and Rust employees associated with the incident, ORGDP employees who consumed potable water potentially impacted by the incident, and Kingston, Tennessee, residents who also consumed potable water potentially impacted by the incident; and in terms of reductions in ORNL's low-level liquid radioactive waste storage capabilities. The management systems evaluated include: (1) those intended to reduce the potential of occurrence of such events and (2) those intended to provide adequate response to such events should they occur. Inherent in the management system evaluations were reviews of applicable planning activities and intra- and inter-organization communications. The composition of the investigation board and its appointment are contained in Appendix 1.

IV. SUMMARY

As an integral part of ORNL's program to upgrade the gaseous radioactive waste handling systems for Building 3517, construction work on the Cell Ventilation Improvements, Building 3517 Project, was initiated by Rust Engineering on October 24, 1985. A major portion of the project necessitated an excavation just east of the building to uncover two large ventilation ducts. The excavation was in an area of highly contaminated (up to 2 rad/hr) fine gravel backfill. Shoring was installed to protect workers from wall collapse and health physics coverage was provided on a continuous basis while workers were onsite.

During the next four weeks, the construction effort was interrupted several times, for varying lengths of time, to resolve a funding question, to allow for planning to remove a bypass duct, to allow for a ventilation system filter change, for a holiday, and due to rainy weather. The excavation walls in the areas not immediate to the work gradually collapsed to a degree that a 12-inch storm drain line was exposed.

On November 27, 1985, following prolonged and sometimes heavy rainfall, elevated levels of beta radioactivity were detected in the diversion box leading to the 3524 Equalization Basin, a facility normally used to collect aqueous radioactive waste prior to treatment in the Process Waste Treatment Plant. Dye tests indicated the increased radioactivity was infiltrating the Process Waste System and that the source was the 3517 excavation. No other actions were taken.

On November 29, 1985, following and during additional heavy rainfall, the excavation walls collapsed further and resulted in the breaking of the exposed storm drain line. The full flow of the drain entered the excavation and subsequently moved into the shallow groundwater immediately underneath and adjacent to the site. The contaminated water subsequently found its way into nearby deteriorated sanitary sewer lines, storm drain lines, and the Process Waste Treatment System. After passing through each of these separate systems at different rates, the contaminated water entered White Oak Creek (WOC) where it moved downstream through White Oak Lake (WOL) into the Clinch River.

Immediately upon discovering the storm drain line break, ORNL operating personnel initiated actions to divert the storm water around the site. Samples were collected from several drain lines. Unfortunately, the analyses of these samples as well as the direct beta readings provided by instream monitors were misinterpreted to be due to cesium-137 only, a radionuclide of less environmental concern than strontium-90. This initial failure to recognize the presence of strontium-90 led on-the-scene personnel to mistakenly believe that there was no impending concern and thus no need to notify ORNL management or DOE, or to take additional mitigative actions.

On December 2, 1985, samples were collected from the White Oak Lake discharge and analyzed for strontium-90. The analytical results revealed a strontium-90 concentration ((160 Bequerels/liter)(Bq/l)) approximately 20 times that normally released. ORNL management, Energy Systems staff and DOE were notified. The following day, DOE notified the Tennessee Department of Health and Environment (TDHE), who subsequently notified the Tennessee Emergency Management Agency (TEMA).

Since the ORGDP potable water intake is located on the Clinch River only a few miles downstream of the White Oak Lake discharge, the ORGDP Shift Superintendent was also notified (on December 2) of the elevated strontium-90. In accordance with standard operating practices, he subsequently had the potable water intake operation shut down until further evaluation of the situation could be made.

On December 3, after sampling of the ORGDP potable water distribution system had revealed strontium-90 concentrations slightly higher than the Safe Drinking Water Act's limits for routine human consumption, ORGDP employees were advised not to drink the water.

On December 4, ORGDP water intake operations were resumed for all uses other than human consumption. Also on December 4, at the advice of TEMA, the city of Kingston discontinued potable water intake for one day, as a precautionary measure.

During the several days following the determination of the strontium-90 release, extensive actions were taken to mitigate the offsite consequences. "Clean" runoff waters were rerouted around contaminated areas, contaminated groundwater was collected, concentrated and stored, and White Oak Lake discharges were coordinated (with TVA through TEMA) with high rates of discharges from Melton Hill Dam to maximize dilution in the Clinch River.

By December 6, the rate of strontium-90 release from White Oak Lake had begun to decline and on December 13, following a flushing of the distribution system, ORGDP resumed normal potable water operations. On January 3, 1986, TEMA agreed with DOE that no further reporting of strontium-90 releases from White Oak Lake was necessary and the incident was considered ended. The total quantity of strontium-90 released during the event was approximately 7 mg (1 curie), as compared to a normal monthly release from White Oak Lake of from 1.0 to 2.5 mg.

The health impacts of the release were negligible. The radiological doses (500-600 mrem spread over 60 employees) incurred by Rust and ORNL employees who worked around the excavation site and the various drainage systems to mitigate the release were determined to be well within DOE recommended limits. The maximum radiological dose received by any individual (ORGDP employee or member of the public) who may have ingested Clinch River water contaminated with strontium-90 emanating from this incident was determined to be less than 0.2 mrem. The applicable Safe Drinking Water Act standard is 4 mrem for an annual average dose.

Another impact of the incident was the depletion of approximately 29,000 gallons of ORNL's crucial low-level liquid waste storage capacity, through the collection of contaminated groundwater removed from the area; the removal being effected to reduce the quantity of strontium-90 released to the Clinch River.

The probable cause of the incident was less than adequate protection of the radioactively contaminated excavation site near Building 3517, and in particular, the exposed storm drain line. The contributing factors to the release were the high concentration of strontium-90 in the excavation soil and the deteriorated condition of nearby drain lines.

Other findings resulting from the investigation indicate a need for:

- improved pre-project planning at ORNL for prevention of environmental releases during construction activities, especially in areas significantly contaminated with radioactivity;
- improved training at ORNL of construction and other site personnel, including the Lab Shift Supervisor, in the recognition and mitigation of potential unplanned releases, especially for work in radioactively contaminated areas, and improved monitoring/inspection of construction sites by the appropriate environmental specialists to help recognize potential release problems;
- improved planning at ORNL for responding to unplanned releases once they have occurred;
- a thorough review of environmental release detection capabilities at ORNL and ORGDP; and
- improved communication and coordination between ORNL, DOE, and the appropriate state agencies such as TEMA and TDHE.

V. FACTS

The major events that led to, were part of, and resulted from the ORNL strontium incident of late November-December 1985 are summarized in Table 1 and covered in greater detail in the following section.

As part of the fission product research and development work at ORNL, Bldg. 3517 [Fission Product Development Laboratory (FPDL)], went on-line in 1958. The purpose of the facility was to separate kilocurie amounts of cesium, strontium, cerium, and promethium from Redox- and Purex-type waste streams. With the advent of the Systems for Nuclear Auxiliary Power (SNAP) Program and increased demand for cesium-137 sources, the requirements for cesium-137, cerium-144, and strontium-90 were increased to megacuries per year. The chemical processing cells at Bldg. 3517 were shut down in 1975 and maintained in protective storage. A plan for decommissioning that portion of the FPDL has been prepared. Since 1975, decontamination of the FPDL has been conducted on an as needed basis to provide a safe working environment for operating and maintenance personnel or to allow the installation of new equipment. Current activities in Bldg. 3517 involve preparation of large megacurie sources of cesium-137 and strontium-90 and the processing and handling of iridium-192 prior to shipment to customers. The facility is operated by the Operations Division, one of the Laboratory's Support and Services Divisions (Appendix 2).

The cell ventilation system for Bldg. 3517 leads to underground ducts and a filter pit outside the building. Over a period of years, the integrity of the exhaust duct and underground filter pit had deteriorated to the point that inleakage of groundwater was a problem and the filter pit would not pass the required DOP filter efficiency test. Two General Plant Projects (GPP) were approved for construction in order to correct these deficiencies. They were identified as the Cell Ventilation Improvements, Bldg. 3517 (FY 1984 GPP) and the Prefilter and Drain System, Bldg. 3517 (FY 1985 GPP). The criteria for the project designs were prepared by ORNL Operations Division in conjunction with Engineering Division. The Title II design was performed by Lockwood Greene, the DOE Architect Engineer. Title III inspection was performed by Martin Marietta Energy Systems. The Action Description Memorandum (ADM) for the project stated that high levels of soft beta radiation from strontium-90 might exist in isolated hot spots within the existing below ground filter pit. The ADM also cautioned that the storm drain near the construction site "be protected throughout the construction period to prevent accidental entry of contaminated spillage or construction debris into the storm drainage system." A Safety Assessment (ORNL/ENG/SA-1074 dated August 27, 1984) stated that "there will be a possibility for personnel exposure to contamination during excavation and tie-in to the existing system." A Quality Assurance Assessment Plan was originally prepared and issued on August 20, 1984, and revised and reissued on August 26, 1985. Under potential problems or failure modes "containment breach" as a "personnel hazard" was addressed, specifically relating to the concrete duct and enclosure. On August 23, 1985, the Certified for

Table 1

CHRONOLOGY OF MAJOR EVENTS ASSOCIATED WITH STRONTIUM-90 RELEASE INCIDENT

DATE	TIME	EVENT
2/28/85		ADM issued for Cell Ventilation Improvements on Building 3517 Project. Need for construction site protection mentioned.
9/17/85		Preconstruction Meeting Held. No mention of need to protect construction site.
10/24/85		Construction Started. Excavation initiated just east of Building 3517.
10/24/85-11/26/85		Excavation revealed unexpected loose fill and high levels of radioactivity (2 rad/h). Shoring was installed to protect construction workers. Health Physics coverage increased to full time. Excavation walls slowly eroded in areas where workers were not present, exposing storm drain line. Construction activity interrupted several times for varying lengths of time.
11/27/85	0100	Waste Operations noted increase in activity in Diversion Box leading into the 3524 Equalization Basin.
	0714	Additional sampling and dye tests for source of activity initiated by Waste Operations. 3517 excavation site determined to be the source.
11/29/85	a.m.	Wall of excavation collapsed, breaking a 12-inch storm drain pipe. Storm water entered excavation. Storm water and process flow diversion started.
	p.m.	Radioactivity mistakenly believed to be cesium-137 only. Level of activity resulted in rapid breakthrough of cesium from PWTP ion exchange columns.
12/2/85		Increased strontium-90 at White Oak Dam (WOD) detected.
	1700	Official notifications made to DOE-ORO, Energy Systems ES&H, and Public Relations.
	1745	LSS notified.
	1800	ORGDP PSS notified by ORNL LSS of excess concentrations of strontium-90 discharged from WOL and ORGDP sampling initiated.
	1815	ORGDP sanitary water plant intake operation shut down.

Table 1 (Cont.)

CHRONOLOGY OF MAJOR EVENTS ASSOCIATED WITH STRONTIUM-90 RELEASE INCIDENT

DATE	TIME	EVENT
12/3/85	a.m.	DOE-ORO notified Tennessee Department of Health and Environment (TDHE).
		TDHE notified Tennessee Emergency Management Agency (TEMA).
	0900	ORGDP notified DOE-ORO and Energy Systems ES&H, followed by announcement to ORGDP employees of release of strontium-90 and shutdown of water plant.
	1000	Sump installed adjacent to ORNL sanitary sewer manhole to collect contaminated water. DOE-ORO notified TEMA of increased strontium-90 levels in water at Kingston.
	1100	Gates to White Oak Dam closed.
	1345	ORGDP sample results indicated potable water contained strontium-90 concentrations slightly above Safe Drinking Water Standards.
	1530	Contaminated water flowing through storm drain to White Oak Creek stopped.
	1545	ORGDP employees advised not to drink potable water.
12/4/85		Kingston water treatment plant closed one day.
	1700	ORGDP potable water intake restarted for uses other than drinking water.
	1800	WOD reopened with releases coordinated with water flows by TVA and TEMA.
12/5/85		Situation determined to be under control.
12/8/85		Contamination infiltration isolated in sanitary sewer line.
12/13/85		ORGDP sanitary water system placed back in full service, after system flushed.
1/3/86		TEMA agreed no further reporting necessary.

Construction package of detailed drawings and specifications for the Rust construction effort were transmitted to Energy Systems Construction Engineering for forwarding to Rust. On September 9, 1985, a Construction Excavation/Penetration Permit was signed off on by Energy Systems personnel and forwarded to Rust. On September 10, 1985, Energy Systems issued a project scope letter to DOE ORO Construction Division requesting "that the CPAF contractor be authorized to perform all field work." This scope letter was superseded by another on November 1, 1985. On September 17, 1985, a preconstruction meeting was held which included mention of health physics and industrial hygiene monitoring as well as cautions regarding utility interferences and contamination. Attendees at the meeting included representatives from Luckwood-Greene, the Title I and II architect engineer; Rust Engineering, the construction contractor; and the following Energy Systems organizations: Industrial Hygiene, Safety, Radiation and Safety Surveys, Plant and Equipment, Operations, and Engineering.

Rust Engineering started construction on October 24, 1985. The project called for intercepting the two 30-in. diameter cell ventilation ducts located underground, outside the east end of Bldg. 3517 (Figure 1). Excavation was started to reach these two ducts. Shortly after initiating construction activities, Rust encountered two conditions: (1) the area being excavated contained a high volume of fine gravel backfill and (2) the contamination level of the spoil and backfill was sufficiently high to create radiation fields of 200 mrad/h to 2 rad/h. Health Physics coverage was requested and assigned on a continuing basis while work was in progress. The high volume of gravel caused the excavation walls to be unstable. An effort was made to protect the areas in the excavation that were occupied by workers, by erecting temporary walls. When Rust finally reached the south 30-in.-diameter duct, there had been sufficient wall collapse at the southeast corner of the excavation to expose a portion of a 12 inch diameter storm drain line. The storm drain line was constructed of four foot sections of vitrified clay pipe with bell and spigot joints. It was noted that the exposed joints were not sound and there was water leaking into the excavation. This condition has been noted with many vitrified clay pipes that Rust has uncovered at ORNL. A pump was installed to remove water that was accumulating in the excavation from a number of sources, including leaks from the the 12-inch storm drain.

The Bldg. 3517 operator, an Operations Division engineer, and a Health Physics group leader stated that they expressed concern about the exposed storm drain and the deterioration of support for the pipe. The Construction Engineer and the Rust foreman stated that they were not notified of this situation. There were no written communications regarding the deficiencies associated with the storm drain. There was no communication of this condition to higher levels of ORNL management. Construction activity was interrupted for varying lengths of time, by a funding authorization question, piping for removal of a 12-in. bypass duct, a filter change, a holiday, and rainy weather. The storm drain pipe continued to remain exposed and leak.

FIGURE 1 PIPING SYSTEMS AT BUILDING 3517 SITE

On November 27, 1985, there was rain most of the day, which was heavy at times. Around 0100, Waste Operations personnel noticed an increase in activity in the Diversion Box (DB) leading into the 3524 Equalization Basin (EB). Activity in the DB is monitored by an on-line beta-gamma monitor with readout in the Waste Operations Control Center (WOCC). Beta-gamma monitors are also in place at the 7500 Bridge, White Oak Creek (WOC) Weir, White Oak Dam (WOD) Weir (this sensor was not operating), and the Sewage Treatment Plant (STP). The EB collects the liquid process waste for the Laboratory prior to its being processed through ion exchange resin columns in the Process Waste Treatment Plant (PWTP). Liquid samples were taken at the DB, pump station, and manholes, and flows were checked. The sample at the DB showed 545 counts per minute/milliliter (cpm/ml) beta, and the flows were normal. On-line radiation monitoring indicators for the DB, located in the WOCC, are set to indicate High Alert (Yellow Bar Chart Display) at 2500 counts per minute and High Alarm (Red Bar Chart Display) at 4000 counts per minute. Normal levels are displayed as a green bar chart. The DB activity decreased until 0714 when an increase was again detected. Additional samples were taken, and various potential contributors (e.g., Oak Ridge Research Reactor) were contacted. The samples were normal, and activity at the DB was 300 cpm/ml. There was no construction activity during the day; the Bldg. 3517 ventilation system was down during replacement of the cell bypass filters. Throughout the day, Waste Operations personnel continued to look for the source of the activity in the DB. They put dye into the excavation east of Bldg. 3517, found it in the DB, and concluded that the activity was coming from the excavation. This information was not provided to anyone outside the Waste Operations group and no action was taken as a result of the information. It continued to rain into the night.

On November 28, 1985, (Thanksgiving Day) fluctuations in activity at the DB were seen. A sample was pulled for a cesium scan. The scan showed cesium at 1,081 Bq/l. A later sample taken from the Bldg. 3517 excavation showed gross beta of less than 1 cpm/ml. The weather continued to be rainy.

Early in the morning of November 29 on-line monitoring indicated that activity in the DB was again high. Samples were taken at all manholes, drywells, the Bldg. 3517 excavation, and Pump Station 1. The sample results were normal. Sometime during the early morning, a portion of the wall of the excavation collapsed, breaking the 12-in.-diam storm drain pipe. The full flow of the pipe entered the excavation site. Activity in the DB became extremely high. A sample taken at the DB at 0345 showed 4,130 cpm/ml; 30 min later it reached 16,630 cpm/ml. The Waste Operations foreman was notified and he instructed that the Laboratory Shift Supervisor (LSS) be notified and an analytical chemist be called in to identify the beta emitter. No notification went to the Operations Division senior management, to Laboratory management, the Nuclear and Chemical Waste Program management, or to the Environmental and Occupational Safety (E&OS) Division. The Waste Operations supervisor and analytical chemist arrived at the Laboratory. A sample was taken from the effluent of one of the PWTP ion exchange columns and the DB. The analytical examination by gamma scan indicated cesium with trace amounts of radioactive europium and Cobalt 60.

At 0645, the LSS called in a Rust foreman to move a backhoe that was in danger of falling into the excavation due to the collapse of the excavation wall. At this time, the Waste Operations supervisor inspected the excavation and saw that the drain pipe was broken. Actions were started to divert all storm water away from the pit. Pumps were installed to pump water to the process waste system. The activity in the DB decreased to 4,600 cpm/ml. At 1530, the WOCC computer indicated high activity at the DB. The operators reviewed drawings to check for appropriate locations for additional samples and sampled two process waste line manholes (MH): MH 210 north of the 3517 excavation site and MH 211 south of the site (see Figure 1). At 1730, the sample results showed MH 210 to be less than 1 cpm/ml beta, while MH 211 was 177,000 cpm/ml beta. The Waste Operations foreman notified the Waste Operations supervisor and the Bldg. 3517 foreman who came to the Laboratory. They inspected the Bldg. 3517 site and discussed the situation. The Bldg. 3517 foreman found the cell ventilation filter pit in "high alarm" and all three low-level waste (LLW) tanks full. These tanks receive water from the sump pump in the filter pit located in the outside excavation. The breaker to the pump was found to have tripped and was reset. The pump started pumping contaminated water to the tanks again. The Bldg. 3517 operator informed his supervision of the situation and was told to bring in a chemical operator to empty the LLW storage tanks. A pump was placed in MH 210 and pumped to MH 229 to divert flow away from the process line that ran north and south under the west edge of the excavation. It was also planned to pump the remaining liquid from MH 211 to the LLW system, but the leakage volume was so large that it was determined to be undesirable to pump it to the LLW system. The remaining flow continued to go to the EB by way of the DB. Samples at the DB that afternoon read as high as 29,916 cpm/ml beta. No notifications were made beyond first line supervision within Operations Division and the LSS.

On Friday evening, the increased level of activity resulted in rapid breakthrough of cesium from the PWTP ion exchange columns. The columns were normally run until a level of 20 Bq/l cesium-137 was seen in the effluent. The PWTP employs three strong acid resin columns for the removal of radioactive materials from the process waste liquid. The three columns are operated one at a time in series with a weak acid column that conditions the water being processed. Then the loaded column is replaced in the waste stream by another column and the loaded column regenerated by nitric acid wash. The material from the regeneration process is sent to the LLW system. The Waste Operations supervisor contacted the Group Leader of the Environmental Analysis Group, E&OS Division, and they discussed raising the effluent limit for the columns to 5,000 Bq/l cesium-137. This was agreed to because operating at the normal limit would have used up all four of the ion exchange columns before they could have been regenerated. This would have resulted in the overflow of highly contaminated water to White Oak Creek (WOC). It was determined by Department of Environmental Management (DEM) personnel that the 5,000 Bq/l cesium-137 effluent at the PWTP would have resulted in approximately 10% of the maximum permissible concentration (MPC) at WOC for cesium. Grab samples of the effluent from the PWTP were taken to the Analytical Chemistry (AC) Division laboratory at

the Transuranium Processing Facility (TRU), Bldg. 7920, for cesium analysis. A chemical operator arrived at Bldg. 3517 and pumped 4,995 gal of liquid from the tanks to the LLW system. Samples taken at the Sewage Treatment Plant (STP) indicated less than 1 cpm/ml beta. Heavy rainfall caused a larger than normal flow (through sewer line infiltration) to the STP. This caused contaminated sewage to be diverted to the west lagoon to be held for processing later, when flows returned to normal.

At approximately 2230, the LSS informed a member of the DEM of the activities that had occurred during the day. This staff member notified the DEM Department Head who in turn notified the E&OS Division Director. The DEM Department Head spoke with the LSS to confirm the details of the occurrence. He was informed that the excavation had been flooded, water had entered the filter pit sump and was pumped to the Bldg. 3517 tanks, and gross-beta counts indicated no environmental problem. The LSS also contacted the Operations Division Director to inform him of the status of operations at the High Flux Isotope Reactor and to notify him that an excavation outside Bldg. 3517 had caved in due to excess rainfall. The Operations Division Director was told that the DEM had been contacted, samples taken, and there was no environmental problem. An entry in the LSS log indicated that the problem was cesium contamination, was now confined to the process waste system, and that STP and stream samples were "good."

On November 30, 1985, the radioactivity at the DB began to decrease and the high sump alarm for the filter pit cleared. The DEM Department Head again spoke with the LSS to confirm the information discussed with the Evening Shift LSS the night before. Waste Operations personnel pulled samples at the DB every hour; at WOC, 7500 Bridge, and WOL every 2 h; and a sample at WOD for a (cesium) scan once daily. The WOD sample was less than 10 Bq/l beta cesium-137 (total activity discharged at the WOD typically was in the 9 to 12 Bq/l cesium-137 range). Samples taken by Waste Operations were being analyzed at the TRU Facility where high background levels and available counting equipment prevented thresholds of detection below 1 cpm/ml (approximately 240 Bq/l strontium-90). The DB samples continued to show decreasing values throughout the day. In conversation with the LSS, the DEM Department Head was informed that he would be notified if there was any basis for environmental concern.

On December 1, 1985, the sampling plan implemented by Waste Operations continued. DB activity continued to decrease. The LSS log indicated a reading of 7 cpm/ml at the STP. Activity in WOC decreased to less than 1 cpm/ml beta and then increased to 3 cpm/ml. This was assumed to be coming from cesium-137 from the ion exchange column breakthrough at Bldg. 3544, the PWT. During the day, there was zero flow from Meiton Hill Dam (MHD) into the Clinch River, except for the periods 1700 to 2000 and 2000 to 2100 when there was 9,200 and 8,100 cfs, respectively. During the evening when the ORNL Executive Director returned to Oak Ridge, he returned a call to the LSS and was told of an operational problem at the High Flux Isotope Reactor. When the Executive Director asked if "anything else was going on", the LSS stated that the storm drain in the excavation had broken, the water had been diverted, and things were under control.

On December 2, 1985, there was zero flow from MHD until 0500. Flows until 1100 averaged approximately 9,000 cfs. Early morning samples taken by Waste Operations indicated gross beta readings of 3 cpm/ml at the STP, 22 cpm/ml in sewage MH 141, and 1 cpm/ml in WOD at the 7500 Bridge. During the morning, a composite and a grab sample were taken from WOD and analyzed for strontium-90 to confirm previous assumptions that the beta activity being observed was from cesium only. ORNL's Analytical Chemistry (AC) Division has the only capability at ORNL to analyze samples for drinking water standard levels of strontium-90.

From 1100 to 1500, there was zero flow from MHD. At the PWTP, the acid wash for the ion exchange columns was increased in an attempt to increase column efficiency. The regeneration sequence was changed in an attempt to clean up the effluent being discharged. The grab sample taken from WOD was analyzed by 1630 that afternoon and indicated 160 Bq/l strontium-90 and a sample from the 7500 Bridge indicated 270 Bq/l strontium-90. At 1630 the E&OS Division staff and Division Director discussed the levels of strontium-90 at WOD. Initial interpretation of the sample results did not take into consideration the presence of radon-222 daughter products. Subsequent recounts of the samples, after decay of these daughter products, indicated somewhat lower levels of strontium-90 but still above the level of concern. The ORNL Public Relations Department Head was queried by DOE-ORO of an occurrence at the Laboratory and asked to check into the circumstances. He contacted the DEM Department Head for information. DEM notified Operations Division of the levels of strontium-90 in the creek grab samples and started taking grab samples for environmental analysis. The Executive Director was informed of the situation regarding strontium-90 levels at WOD. It was decided to take grab samples at 1700 and 0200. The E&OS Division Director arranged with a senior radiochemist from AC Division to analyze samples for strontium-90. The Emergency Samples Coordinator of the AC Division was not contacted. At 1700, official notifications by E&OS Division were made to DOE-ORO, to Energy Systems ES&H, and to Public Relations. State officials of the Tennessee Department of Health and Environment (TDHE) were not notified until Tuesday morning by DOE-ORO. The Tennessee Emergency Management Agency (TEMA) was not notified by DOE but was notified by TDHE personnel, which allowed for subsequent interface between DOE-ORO and TEMA. The LSS was not notified until 1745, and at that time by a member of the Energy Systems ES&H staff. A decision was made by E&OS personnel to keep WOD gates open. At 1700, flows at MHD increased to 17,200 cfs for 1 h and then flowed at 12,800 cfs, 9,200 cfs, and 8,000 cfs for an hour each. Flow was discontinued at 2100 until 0500 the next day.

The ORGDP Plant Shift Superintendent (PSS) was notified by the ORNL LSS at approximately 1800 on December 2, 1985, that abnormally high concentrations of strontium-90 were being discharged from WOL into the Clinch River. Because the ORGDP sanitary water plant (K-1515) takes intake water from the Clinch River downstream of the WOL discharge (Figure 2), steps were taken immediately to shut the water plant down in accordance with established operating practices. The shutdown was completed by 1815.

FIGURE 2
OFF-SITE SAMPLING STATIONS

The ORGDP PSS notified the Department Head of Environmental Management; the Department Head of Industrial Hygiene and Health Physics; the Manager of Health, Safety, and Environmental Affairs Division; the Shift Superintendent Coordinator; and the Manager of Plant Support and Protection Division and Acting ORGDP Plant Manager, by about 1900. In accordance with established operating practices, water samples were taken at the following locations: the intake pumping station on the Clinch River (K-1513), the raw water storage tank (K-1514), and the in-process water before the sand filters (K-1515). By 2145, these samples had been collected and lab personnel called in to perform analyses. DOE was notified the following morning.

On the morning of December 3, there was a meeting at ORNL with Operations Division, E&OS Division, Energy Systems ES&H, and Public Relations personnel to review the occurrence history. A press release was prepared. Allowance for daughter product decay, sample processing, and sample counting limited the number of samples that could be processed by the low-level laboratory to eight every 6 h. Sample results were generally available 8-12 h after being submitted to the laboratory. Existing procedures for strontium-90 analysis in water are documented in the Martin Marietta Energy Systems Environmental and Effluent Analysis manual, but they are slightly different than EPA recommended procedures. Routine (every 6 h) environmental samples for strontium-90 were established at four on-site locations and four down-river locations. On-site locations were the 7500 Bridge, the STP influent and effluent, and WOD. The down-river locations were Gallaher (ORGDP water intake), Clinch River Mile 10, Centers Ferry, and the Kingston Water Treatment Plant (WTP) intake (Figure 2). This sampling program occupied the total capacity of the AC Division Low-Level Radiochemistry Group and left no capability in that organization for processing of samples to identify the source and the pathway of release. A sample taken at the outfall of storm drain WOC No. 6 indicated 4,310 Bq/l strontium-90. This outfall was located just upstream of the discharge of the PWTP into WOC. From 0500 to 1100, flows from MHD averaged 9,400 cfs.

On December 3 at 1000, a meeting with the Energy Systems Senior Vice President, ORNL Operations Division, E&OS Division, Energy Systems ES&H, and Public Relations personnel resulted in a decision to auger a sump adjacent to the sewage system to collect contaminated water from MH 141, to divert storm drains and to close the gates at WOD. When the seepage into MH 141 was stopped, the activity in the manhole was sharply reduced. Water continued to be diverted from the excavation area and the gates to WOD were closed at 1100. Rust personnel repaired the broken storm drain pipe in the excavation at Bldg. 3517. From 1200 to 1700, there was zero flow from MHD. Several meetings took place to review the occurrence and actions taken. The press release was updated. A decision was taken to divert the storm drain flow away from WOC No. 6, and the contaminated water in the pipe was pumped to the EB. At 1825, TEMA was notified by DOE-ORO that the strontium-90 concentration at Kingston was 0.4 Bq/l. DOE recommended that the Kingston water plant be shut down. At 1930 TEMA advised that they did not recommend that the Kingston water plant be shut down at that time but

that available reservoir capacity be utilized first.. TEMA requested processed water samples from Kingston and inlet and processed water samples from the Rockwood plant. This request was relayed to ORNL. The Kingston WTP operated normally (essentially a 0800 to 1700 operation) on December 3. Increased water flow from Melton Hill Dam was received during the remainder of the day.

On the morning of December 3, a team was assembled at ORGDP to determine the actions to be taken. The team was composed of the Manager of Plant Support and Protection Division and Acting ORGDP Plant Manager; the Manager of Health, Safety, and Environmental Affairs Division; the Department Head of Industrial Hygiene and Health Physics; an Industrial Hygienist; the Shift Superintendent Coordinator; the Sanitary Water Plant Supervisor; and a member of Central Environmental and Health Staff. The results of the previous night's sampling of the potable water intake were available for the team's use; these results indicated strontium-90 concentration at the Water Treatment Plant to be from about 32 to 87 pico curies/liter (pCi/l) (1.2 to 3.2 Bq/l); the background concentration for the intake being from about 0.5 to 1.5 pCi (0.02 to 0.06 Bq/l). The drinking water standard is an annual dose of 4 mrem/yr, which corresponds to about 8 pCi/l (0.3 Bq/l) in the drinking water.

The initial plan developed consisted of keeping the sanitary water plant intake closed; operating with the storage capacity of the sanitary water system; obtaining additional samples in the system distribution system; and notifying the plant population, other water users, and pertinent Energy Systems and DOE management.

Samples from the water system were taken from Bldgs. K-1001, K-1529, K-1501, K1007, and from the water plant at 0900 on December 3, 1985. Due to the analytical time required, these analyses were not available until later in the day. From the existing analytical data and the estimated operating time of the sanitary water plant, the strontium-90 levels were estimated for the storage water and this information formed the basis of notifying the potential water users and management. At 0900 notifications were made to DOE-ORO and to Energy Systems ES&H. At 0930 an announcement of the occurrence was drafted and reviewed by ORGDP, Energy Systems, and DOE-ORO representatives. At 0945 DOE-ORO Environment, Safety, and Health Division representatives notified the TDHE of the shutdown of the ORGDP water treatment plant. At 0950 the first announcement of the occurrence was made to the ORGDP employees. This announcement informed the employees of the strontium-90 release at ORNL and shutdown of the water treatment plant. The announcement stated that samples had been taken throughout the plant to confirm that the drinking water did not pose a risk. At 1345 the analytical results from the 0900 samples were received. The results were reported to Energy Systems and DOE-ORO and a second announcement to employees was issued. At 1545 employees were advised not to drink the water in the plant system. TEMA was requested by DOE-ORO to supply four water tankers for use at ORGDP. Urine samples from thirteen ORGDP employees were sent to ORNL for analysis.

Early in the day, the Oak Ridge City Water Utility was notified of the event, by ORGDP, and was requested to notify its industrial users of ORGDP water. Discussions were held with the ORNL Director of E&OS Division. The reporting of analytical results was established. It was agreed that ORNL would operate the discharge from WOL and keep ORGDP informed. ORGDP would keep ORNL informed on the operation of the ORGDP sanitary water system.

Late in the afternoon of December 3, the ORGDP plan was to include discontinuing drinking of the sanitary water, continuing the use of the water for other purposes, providing drinking water from off-site sources, developing the plan for restart of the sanitary water system, and establishing the sampling plan. The plan was based on operating the sanitary water plant for all purposes except as drinking water until the strontium-90 levels were maintained at less than 0.3 Bq/l. In addition, the levels would be maintained as low as practical to aid in returning the system to full service, and the system would be flushed prior to returning the system to full service.

On Wednesday, December 4, a sample taken the night before was found to contain 1200 Bq/l strontium-90 at the ORNL STP influent. Water continued to be released from MHD all day. The Kingston water treatment plant did not operate all day. A press release update was made. Preparations were also made in anticipation of rain later in the day. Two representatives of the TDHE visited ORNL for a briefing on the situation. The DOE-ORO Emergency Response Center (ERC) was activated. It was proposed to DOE-ORO to open the gates at WOD to 9 cfs in conjunction with water flows from MHD. During the afternoon, approval was received from the TEMA and they arranged for 3,500 cfs of flow from MHD through midnight December 5, 1985. At 1700, the ORGDP potable water intake operation was restarted. At 1800, the gates at WOD were opened to release 9 cfs, and a press release was made. The LSS received a call from the ORGDP PSS regarding the opening of WOD and had no information about it. Preliminary results of the urine samples from the 13 ORGDP employees indicated levels of strontium-90 no higher than those found in samples of the general public. The Kingston water plant, at the advice of TEMA, did not operate on December 4, as a precautionary measure.

During December 5, Operations Division personnel continued to divert some drain flows to keep contaminated water segregated from noncontaminated waste water. Larger pumps were placed at the Bldg. 3517 excavation site in anticipation of forecasted rain. Analytical sample results indicated that the concentrations of strontium-90 were decreasing at WOD, at the 7500 Bridge, and at the STP influent and effluent but beginning to increase in the Clinch River downstream of WOD. TVA agreed to flow 3,500 cfs from MHD until 0800 Monday, December 9. ORGDP was notified of the planned river flows. The Kingston water treatment plant operated normally on December 5 and continued to do so from that point on. A proposal was made to DOE by ORNL to increase the flows from WOD as the concentration of strontium-90 decreased. This was agreed to by DOE, TEMA, and ORGDP. Based on the concentration of strontium-90 at WOD, the gates at the dam were opened to release 13 cfs. TEMA and the ORGDP PSS were notified prior to each increase in flow at WOD. A University of Tennessee consultant was brought in to verify the weir calibration at WOD.

On Friday, December 6, 1985, Operations personnel continued to divert water flows and take samples. Environmental samples were taken at the eight established locations. WOD concentrations of strontium-90 were holding steady at 130 Bq/l, 7500 Bridge levels were decreasing, and the STP influent and Gallaher levels were increasing. Water was being released from WOD in conjunction with flows from MHD at a rate that would keep the concentration of strontium-90 at ORGDP below the State drinking water standard. DOE-ORO was briefed on the current status. ORNL was requested by DOE-ORO to do a Type C investigation of the occurrence, and preparation of an Unusual Occurrence Report (UOR) was started. At this point it was determined that the situation was under control. An official committee was appointed to perform an investigation of the occurrence.

On December 8, contamination was found in MH 143A of the sanitary sewer system. The flow from the west lagoon to the sewage plant inlet was stopped and sewage has been held in this lagoon since that time. At 2030 on December 9, relocation of approximately 2,000 tons of coal was started in an attempt to locate MH 143. The manhole was located at 0230 on December 10 and contaminated water was found in and around MH 143. On December 13, it was decided to isolate the section of sewer line between MHs 140 and 143A. A temporary 4-in. PVC line was installed between MH 140 and MH 221 which rerouted the sewage flow and allowed bypassing the section to be isolated. Inflatable bladder type plugs were installed in the outlet of MH 140 and inlet of MH 143A. A portable gasoline-driven 450-gpm pump was utilized to pump the sewage to MH 221; flow was established on the 4-12 shift on December 13. These actions resulted in a decrease in concentration of strontium-90 entering the STP from 280 Bq/l to 70 Bq/l. On December 16, a second portable gasoline-driven pump was located at MH 140 with flexible hose discharging to MH 143A to serve as a backup for the other system. These pumps were manned continually, using overtime personnel to prevent freeze-ups, etc. On December 16, P&E personnel started installation of an underground 10-in. PVC gravity-flow bypass from MH 140 to MH 143A. At 2015 on December 24, this line was placed in service and use of the portable pumps was discontinued.

The strontium-90 concentrations at the ORGDP water plant inlet were below 0.3 Bq/l from about midnight on December 12 and were on a downward trend. Actions were taken to flush the sanitary water system early on the morning of December 11. A PA announcement and electronic mail message at 0957 on December 9 were used to solicit employee cooperation in flushing the system. The electronic mail message was used to inform pertinent Energy Systems and ORO personnel. Samples were taken at various points in the distribution system.

On December 12, 1985, the ORNL Executive Director and Associate Director for Nuclear and Engineering Technologies met with representatives of Energy Systems Engineering Division, the ORNL Operations Division, and the ORNL E&OS Division to discuss the Bldg. 3517 Cell Ventilation Improvements Project. The approach to the project and the schedule for

project completion was discussed. The impacts of shutting down operations in Bldg. 3517 as a necessary step in the rapid completion of the project was also discussed. It was decided that work on the project would continue with special emphasis on environmental and safety concerns.

On December 12, 1985, TEMA agreed to a reduction in sampling frequency and sampling sites. Sample intervals were extended to 12 h at Kingston and Centers Ferry and samples were discontinued at CRM 10. The strontium-90 levels were monitored at the ORGOP sanitary water inlet at about 6 h intervals through December 12, at 8- to 10-h intervals through December 19, and at about 12 h intervals through December 29.

The ORGOP sanitary water system was placed back in full service on December 13 by the use of a PA announcement and an electronic mail message. Prior to the announcement, the action was discussed with ORO and within Energy Systems.

Communications have continued between ORNL and ORGOP personnel on the operational mode of the WOL discharge and the analytical results for the various points being sampled. The communication of analytical results were handled by phone to the ORGOP PSS followed by electronic mail messages to interested parties at ORGOP. TEMA was informed that ORNL and DOE were appreciative of their help in supplying the water tankers, and the tankers were returned on December 16, 1985.

On December 17, 1985, DOE-ORO requested that ORNL conduct a Type B investigation due to the significance of the event.

On December 18 and 19, 1985, representatives from TDHE visited ORNL and were briefed on the situation by Laboratory management.

On January 3, 1986, TEMA agreed that further reporting on the occurrence was not required and the incident was closed.

VI. ANALYSIS

A. PATHWAYS TO ENVIRONMENT

During the two-week period prior to the incident, spikes of activity occasionally were observed in the DB. In order to determine the origin of the activity, a dye test (Rhodamine B or "red dye") was conducted. Dye was placed in the excavation. When the dye was observed in the DB, it was concluded that the excavation was the primary source of the activity spikes.

The proximity of the Bldg. 3517 excavation, the process waste line running beneath the excavation (north/south line), and the sanitary and storm sewer lines south of the excavation (both east/west lines), are shown in Figure 1. This proximity, coupled with the sampling data accumulated during the period November 28, 1985, through December 6, 1985, suggest the following different pathways for strontium-90 movement.

1. From the Bldg. 3517 excavation, contaminated water moved into the process waste line running between MH 210 and 211. From MH 211 the water moved to MH 117 (this manhole is paved over with asphalt and was not sampled). From MH 117 it moved to the collection box just north of the DB, from there to the DB, and from the DB to the EB.
2. From the Bldg. 3517 excavation, contaminated water moved through the ground, generally southward. This groundwater system intersected the sanitary sewer lines which have been recently lined with Insituform. Because the sanitary lines are in sand and gravel beds, the groundwater moves more quickly through these trenches, outside the lines, than through the clay soil surrounding the trenches. The water moved past MHs 152, 140, 141, and 142. Between MHs 141 and 143A, the water infiltrated a deteriorated section of the sanitary sewer line.
3. Contaminated water also moved from the excavation through the groundwater to intersect with deteriorated storm sewer lines. To the west of the EB, the sanitary and storm sewer lines are in close proximity. At Bldg. 3594, the sanitary line turns west, and the storm line turns southeast. Contaminated water was found in the storm sewer junction box immediately west of Bldg. 3594 and in the junction box to the southeast of Bldg. 3594. In both cases, the contaminated water appeared to be coming from a small leak in the direction of the EB, which could indicate a leak in the EB. This situation is being investigated.

Calculations of the number of millicuries of strontium-90 entering and leaving the STP, passing the 7500 Bridge, and passing over WOD were made. Several points can be established from analysis of this data:

1. From the period November 25 through December 25, approximately 1 curie (7 mg) of strontium-90 was discharged from WOL.

2. For the 24-day period from December 2 through 25, 1985, approximately 800 mCi (about 6 mg) of strontium-90 passed over W00, compared to 637 mCi passing the 7500 Bridge. The difference is 163 mCi. Sources of strontium-90 downstream from the 7500 bridge include all Melton Valley facilities, the solid waste storage areas, and the pits and trenches areas. In December 1984, 68 mCi came from these sources, and in December 1983 the figure was 219 mCi.
3. Prior to December 3, 1985 (when pumping of contaminated water going through the storm sewer system to the EB was started), over 90% of the strontium-90 passing the 7500 Bridge was coming from sources other than the STP. From December 5, 1985, on, this figure dropped sharply and averaged 37% from December 5 through 25, 1985.
4. Comparing STP and 7500 Bridge figures with "historical" data for this time of year leads to the following observations: (a) strontium-90 release from the STP was higher than normal by a factor of about 20 early in December but had returned to near-normal levels by the end of the month and (b) releases from other sources upstream from the 7500 Bridge were "normal" after about December 8, 1985.

B. IMPACTS

Exposure to ORNL and Rust Employees

While it was recognized from the beginning of the Cell Ventilation Improvements project that there was a potential for increased occupational exposure for the construction workers due to the amount of contamination in the soil and ventilation ducts, the specific actions taken in response to the event should be and have been considered separately from those exposures seen from performing the normal project work. This event-related activity included additional time spent by Rust workers in the excavation area on corrective actions associated with pipes and excavation walls. Increased occupational radiation exposures were estimated to be on the order of 400-500 mrem distributed among 20 workers. In addition, approximately 20 ORNL employees involved in various actions, such as entering and sampling manholes, received an estimated total dose of 100 mrem (total for all 20 employees).

Exposure to ORGDP Employees and Kingston Residents

The potential radiological doses to people ingesting water contaminated with strontium-90 emanating from this event were calculated using the following assumptions:

1. The dose conversion factors set forth in the Federal Interim Primary Drinking Water Standards adopted by the State of Tennessee assumes that daily consumption of 2.2 l (365 d/y) of water contaminated with 8 pCi/l of strontium-90 yields a dose commitment to the endosteal cells of 4 mrem.

2. The nearest point downstream where the public would utilize Clinch River water for drinking water purposes was the Kingston Water Treatment Plant.
3. At Kingston, it was assumed that the water was consumed at the rate of 2.2 l/d during the period December 3 through December 29. The concentration data were taken from the raw water supply since the data on processed water were limited. For those samples for which data were available on both raw and processed water, the results were statistically the same.
4. At ORGDP, it was assumed that water consumption started on December 2 and was consumed 5 days per work week and at the rate of 1 l/d through December 29 except as follows: on December 3 consumption was only 1/2 l since water consumption was halted approximately mid-day. No water was consumed from the ORGDP supply from mid-day on December 3 through December 12. The concentrations were from inlet Gallaher samples except for December 2 and 3 when processed water data showing a concentration of 32.5 pCi/l was used.
5. Water from ORGDP is also sold to the city of Oak Ridge for use by the industrial park. The potential radiological dose to an individual industrial park user was assumed to be the same as for an ORGDP employee.

While it is possible that some strontium-90-contaminated water was withdrawn and used by ORGDP personnel prior to December 2, no sampling of the ORGDP system was conducted earlier so that definitive knowledge of this potential occurrence is not available. Since the weekly composite sample collected at WOD on December 2 showed relatively minor increases above normal strontium-90 levels, it must be concluded that the previous week's discharges were neither extremely high in concentrations nor of long duration and that ORGDP's withdrawal of strontium-90 was not significantly different than assumed.

Using the above assumptions and the Interim Drinking Water Standard conversion factors, the dose commitment to an individual living at Kingston would be 0.08 mrem to the endosteal cells while the ORGDP worker would have a commitment of 0.06 mrem. Even though the concentrations in ORGDP water samples were higher than those observed at Kingston, the dose commitment for the ORGDP worker was slightly less than that for the individual at Kingston because the ORGDP worker drank a total of 13.6 l from the river supply during the same period of time that the Kingston individual would have consumed 59.4 l.

Using the more conservative current EPA dose conversion factors, the dose to ORGDP and Kingston residents could have been no more than 0.12 mrem and 0.15 mrem, respectively. The Safe Drinking Water Act Standards is 4 mrem/y, annual average dose.

Depletion of ORNL LLW Storage Capacity

Due to the recent decision to place the hydrofracture operation on standby as a means of disposal of ORNL liquid LLW, a new strategy of solidification and storage/disposal has been adopted for the near term. This strategy is

based on volume reduction to extend the date at which existing liquid storage space is depleted. Because of the large volumes of highly contaminated process waste created during this event, the PWTP evaporator was unable to keep up with the flows through the ion exchange columns, and large quantities of regenerate solution were neutralized and sent directly to liquid LLW storage.

Neutralization (with NaOH) produces nitrate salts, which causes the LLW evaporator to operate inefficiently. As a consequence, during the month of December 1985, 114,000 gal of liquid LLW was produced (76,000 gal coming from the PWTP), which was volume reduced by a factor of only 4. This factor-of-4 volume reduction in the liquid LLW evaporator is compared to a historical reduction value of about 9 and a theoretical value (for liquid LLW other than the PWTP stream) of 30. As a result of this event, about 29,000 gal of storage space have been depleted in about one month. This is about three times the planned rate of depletion for this period in the ORNL volume reduction scheme.

C. PREVENTION PLANNING AND IMPLEMENTATION

Planning Documentation

The ADM was issued in February 1985. This document mentioned the need to protect the storm drain running through the construction site. The Quality Assessment and Plan for this project was first written during the Study and Estimate phase of the project and then later reissued (August 1985) after design was complete to reflect changes and additions which occurred during design. It did not address the nature of the material to be excavated - either its instability or its degree of radiological contamination - or the concern for protection of storm drain lines in the excavation. These kinds of construction concerns are normally not included in the QAA/P.

Capital Project planning includes a number of additional study and planning documents which highlight factors which impact cost, safety, environmental protection, and quality of the product. These documents include:

1. The "Preliminary Proposal" which evaluates the cost of the chosen method of accomplishment. Factors such as contaminated soil, pipes running through the site, etc. are considered in this document.
2. The "Safety Assessment" which defines and evaluates potential hazards, dealing both with human and environmental safety. Measures for avoiding or mitigating hazards are included.
3. The "Excavation Permit" which addresses known or suspected utilities, drain lines, special hazards, and/or precautions to be taken in a "penetration area."
4. The "Construction Safety Work Permit," "Scope Letter," and "Job Instructions" which include special instructions to the construction crew relating to problems and hazards identified in earlier documentation.

Each of these documents is prepared by Engineering Division personnel with review by the appropriate operating, health, safety, and environmental and quality assurance personnel. Each document should address particular concerns and preventative measures for mitigating these concerns, even during construction. For the Cell Ventilation Improvements Project, the documentation was less than adequate in dealing with the concern for protecting the site from inclement weather, including protection of the storm drain line.

The preconstruction meeting is the proper forum for highlighting any special concerns and precautions required by the construction contractor. The attendees at the meeting for this project included personnel from Lockwood Greene, the Title I and II architect engineer; Rust Engineering, the construction contractor; and the following ORNL organizations: Industrial Hygiene, Safety, Radiation and Safety Surveys, Plant and Equipment, Operations, and Engineering. The minutes of the meeting indicate mention of health physics and industrial hygiene monitoring needs as well as cautions regarding utility interferences and contamination. There was no evidence of mention of the need to protect the storm drain line to preclude water entering the excavation.

Preventive Actions

The initial key decisions of this occurrence dealt with the construction activities leading up to the actual storm drain pipe breaking. The amount of shoring in place in the excavation was affected by the judgment of the Rust personnel and the Energy Systems Construction Engineer of what was normal construction practice. The unexpected high levels of radiation and contamination in the excavation site also affected the time personnel could be exposed while working in the excavation, as well as the judgments regarding entering the excavation site to correct shoring problems for the storm drain. The shoring was not adequate to prevent the sides of the excavation from falling away and exposing the storm drain pipe.

Interviews with Operations and E&OS Division staff members indicated that the potential for damage to the storm drain pipe in the excavation site was recognized by several people and they stated that this concern was conveyed to the Energy Systems Construction Engineer, to Plant & Equipment Field Engineers, to Rust Construction personnel, and probably others. These communications were all verbal and there is no written documentation to substantiate the conversations and the CE and Rust personnel do not remember this communication. It is apparent that the potential problem was recognized and the verbal discussions were ineffective in causing the required corrective actions to be taken. The concern was not escalated to higher levels of ORNL management.

The construction was stopped on several occasions by both DOE and Energy Systems. This indicates that inadequate consideration had been given to minimizing the time that the excavation was open and thus the potential for adverse impacts of rainy and/or freezing weather.

D. RESPONSE PLANNING AND IMPLEMENTATION

Response Planning Documentation

No written plan exists at ORNL for responding to high levels of radiation in any of the waste water transfer systems. The practice in the past has been to identify the source of the radiation through use of dye tests, grab sampling and use of sample analysis, smoke tests, and other diagnostic tools. After the source has been identified, water coming from that source is diverted to the EB for treatment by the most expedient route. Uncontaminated water is diverted around the source of contamination by establishing a system of dikes, blocking appropriate manholes, and pumping the water collected to other manholes, bypassing the affected area.

Response Actions

Decisions during the early phases of the event were significantly hampered by the wrong assumption that cesium-137 was the only radionuclide of concern.

Operations in Bldg. 3517 have historically involved megacuries of strontium-90. This fact is known to all personnel associated with the Bldg. 3517 GPPs and was discussed in the ADM. During the early stages of this event (early during the week of November 25, 1985) when beta-gamma readings began to appear at the DB, some analysis for strontium-90 should have been performed. Cesium scan information was collected because that is relatively easy to do at the TRU facility analytical laboratory. No strontium-90 analyses were performed until Monday, December 2, 1985. There are few locations at ORNL where cesium contamination can occur in the absence of strontium-90, and this fact should have been recognized early in the event.

Early in the morning on Friday, November 29, 1985, high beta-gamma readings at the DB caused the LSS to be notified. This notification was correct and appropriate. The request to the LSS to contact an analytical chemist to determine the beta-emitting isotope was also correct and appropriate.

When the problem of the storm drain flow into the excavation site was recognized, actions were taken by the Waste Operations Foreman and Waste Operations personnel to divert the storm drain flow and to divert the process waste line flow from the area of the excavation. These actions minimized the amount of activity being flushed from the excavation site and the amount of contaminated water entering the Process Waste Treatment Plant.

On November 29 and 30, as the level of activity in the Equalization Basin of the Process Waste System increased along with the volume of liquid waste, it became apparent that the PWTP would have difficulty in keeping up with the flow. Continuing to operate the PWTP using the normal breakthrough criterion of 20 Bq/l would have resulted in all the columns being taken out of service before the first one would have completed regeneration. This action would have resulted in highly contaminated water being passed directly to WOC. The

Waste Operations Supervisor conferred with the Head, Environmental Analysis (DEM) and arrived at a decision to increase the cesium-137 effluent level to 5000 Bq/l to keep up with the level of activity being processed. This action was based on the misunderstanding that the occurrence was cesium-related and this level of release would not create an environmental concern offsite. This action proved to be fortunate for the circumstances as the levels of strontium-90 that passed through the PWTⁿ were a minor portion of the total amount released to WOC by the storm drain system and later the Sewage Treatment Plant.

On December 3, 1985, discussion took place between the ORNL Executive Director and senior managers involved regarding the use of the Situation Management Room located in the basement of Bldg. 1500S. It was determined that the event would probably be an extended one of several days and the nature of the occurrence lent itself to coordination by the Director, E&OS Division. As such, it was decided not to use the room, but to use the E&OS Division Office as a focal point for coordination. Except for some communications difficulties with DOE (e.g., difficulty in phone contacts) there were no readily apparent problems related to the handling of the occurrence that resulted from this approach. The DOE-ORO Emergency Response Center was activated during part of the occurrence and also functioned well for that time period. Again, some communication difficulties were evidenced when the Center was not occupied.

During the morning of December 3, 1985, there were several meetings to discuss the status of the occurrence. The meetings involved Energy Systems senior management, Energy Systems ES&H, Operations Division, E&OS Division, and Public Relations personnel. Three remedial actions resulted from these discussions: 1) Due to the elevated activity in sewage MH 141 it was decided to drill an auger hole outside the MH to intercept the contaminated water infiltrating into the manhole. 2) Actions would continue to divert storm drain and process waste flows away from the excavation site to minimize the further release of contamination. 3) The gates at WOD would be closed. The dam was closed at 1100 on Tuesday. At the time the dam was closed, the strontium-90 concentration at the ORGDP water intake was 0.27 Bq/l although those sample results were not available at the time. Initial sample results at approximately 1630 hours that day indicated a strontium-90 concentration at the ORGDP water intake of 0.43 Bq/l. These results had not taken in to account the fact that short lived radon daughter products had not been allowed to decay sufficiently, giving a higher than actual indication of strontium-90.

Various storm drains and other effluents into WOC were sampled on December 3, 1985. Sample results from the storm drain that discharged into the creek at WOC #6 had a concentration of 4310 Bq/l strontium-90. Upstream samples of the storm drain line indicated no activity. The storm drain flow was blocked off and the flow diverted to the Process Waste Ponds. The contaminated liquid was pumped to the 3524 EB. These actions resulted in a noticeable decrease in the level of strontium-90 activity in WOC. It thus appears that this route was the primary mechanism by which activity was released to the environment.

In conjunction with DOE-ORO a request was made to TVA to release extra water from the MHD on the evening of December 3, 1985. As a result of this request, TVA went from a zero flow condition which had existed from 1200 to 1700, to a flow of 16,000 cfs at 1700. From 1800-2000 the flow was 8000 cfs; from 2000-2100 the flow was 8400 cfs; and from 2100-2400 the flow was 9200 cfs. The flows averaged approximately 7000 cfs for the next 10 hours early December 4 and then remained at 3500 cfs through the following weekend. The gates at WOD were not reopened (and then at reduced flow of 9 cfs) until 1800 hours on December 4, 1985. This action had the effect of moving the volume of contaminated water in the Clinch River downriver, certainly past the intakes for ORGDP and probably past the intakes for the city of Kingston. Sample data indicated that the levels of strontium-90 at these two intakes were below the state drinking water standard of 0.30 Bq/l at the time of these increased water releases. The sample results available at the time indicated the concentrations of strontium-90 downriver to be increasing, which favored a decision to release water to dilute or move the contamination further down the river. This decision also resulted in the release of a large volume of water from MHD which was subsequently not available to dilute the necessary releases of contaminated water from WOD.

Again, in conjunction with DOE-ORO a request was made to TEMA to reopen the gates at WOD. The request was made at 1530 hours on December 4, 1985. The level of WOL at the time was an elevation of 748 feet. Normal level is approximately 745 feet and maximum level is 750 feet. At the rate of fill at WOL at that time, it was felt that there was approximately one day's time before the lake would overflow the gates at WOD. Permission was requested to release water at a rate of 9 cfs (normal flow is 11-12 cfs). It was felt that this was a conservative rate of release that would ease the amount of contaminated water accumulating behind the dam and would not result in significant elevations of downriver concentrations of strontium-90. Approval was received from TEMA at 1800 and the gates to the dam were opened to release 9 cfs. Subsequent approvals were received for each request to increase the flow rates from WOD as the concentration of strontium-90 at the dam decreased. Ultimately, ORNL received permission to adjust the release rates as the concentration of strontium-90 at the dam decreased, with the stipulation that ORNL would report the adjustments to TEMA. During the period of releases from the afternoon of December 4 through December 6, concentrations of strontium-90 at the ORGDP water intake (Gallaher) and at Clinch River Mile 10 reached a high of approximately 0.50 Bq/l.

During the early phases of the release incident, some actions and results by ORNL AC and Operations groups led to erroneous conclusions about the nature and severity of the incident. Based on radiochemical analyses made during the week of November 25, it was thought that small quantities of cesium-137 were being released from ORNL into WOC due to problems at the Bldg. 3517 excavation site. Gross beta radiochemical analyses and in-line continuous monitoring of the WOC water showed slightly elevated beta radioactivity levels starting about November 29. A special radiochemical analysis made during the early morning of November 29 showed that cesium-137 was present at high levels in the process water system near the Bldg. 3517 excavation site. No specific

analysis for strontium-90 was requested or made during the early phases of the incident. Strontium-90 analyses of WOC water were started on December 2, followed by analysis of Clinch River water by ORGDP early on December 3. Both of these analyses showed that a significant quantity of strontium-90 had been released into the Clinch River. The initial ORNL conclusion that cesium-137 was the only radionuclide that was being released was a critical error that prevented the immediate implementation of corrective actions to minimize the magnitude of the release.

The conclusion that cesium-137 was the only radionuclide being released was based on radiochemical analyses performed at the TRU Analytical Laboratory during the week of November 25 and on a special analysis made by an experienced radiochemist called in on November 29. Several times during the week of November 25, the DB south of the Bldg. 3517 excavation had high levels of beta radioactivity based on responses from on-line, continuous monitoring instrumentation in the DB. These high beta activity levels were confirmed by in-laboratory analyses at the TRU laboratory. The TRU laboratory also found that no alpha radioactivity was in the DB and that cesium-137 was present at elevated levels. On the early morning of November 29, the DB activity level went very high, and an Operations supervisor requested an analysis to determine the identification of the radionuclides causing the elevated beta activity. The TRU laboratory does not have radionuclide identification capabilities, and an experienced radiochemist was called in to perform the requested analysis.

Gamma-ray spectral analyses were performed on samples from the DB. The 0.66 MeV gamma-ray peak of Ba-137m, a decay product of cesium-137 was the only significant feature of the gamma-ray spectrum. There was no evidence for the presence of strontium-90 in the sample, but the measurement method that was used is relatively insensitive to strontium-90. (Strontium-90 does not emit discrete gamma-rays in its decay. At high levels of strontium-90, however, bremsstrahlung produced from the beta decay can be seen in gamma ray spectra). Strontium-90 at levels at least equal to and perhaps 10-100 times greater than the cesium-137 level could have been present in the sample without detection. (The sample was discarded soon after analysis so there was no opportunity to analyze for strontium-90 by chemical separation and beta counting methods). The analysis results were reported to an operator at the WOC and to the LSS.

The conclusion that cesium-137 was the only radionuclide present in the DB was premature and may have been in error. Less than adequate communications between Operations and AC personnel contributed to the premature conclusion. Operations personnel were unaware of the insensitivity of the analysis procedure for strontium-90, and the analytical chemist had only limited information about the nature of the operational problem so as to make a judgment on the possible presence of strontium-90. Neither Operations Division nor AC Division management were aware of the incident at the time, so that a more in-depth evaluation of the situation was not made.

Closing of White Oak Dam (WOD)

On Monday, December 2, 1985, the E&OS Director and DEM Department Head discussed looking at the levels of strontium-90 at WOD. A grab sample was taken from WOD and analyzed for strontium-90 as a means of confirming that the gross beta activity being seen was cesium-137. The analysis verified the presence of significant amounts of strontium-90 and changed the character of the occurrence from an operational abnormality to an occurrence with potential environmental impact. An analysis of the weekly composite sample at WOD also showed an increase in the level of strontium-90. These actions were critical in changing the focus of the remedial actions from being centered on a cesium-137 incident. Discovery of the strontium-90 involvement led to the offsite notifications to DOE, the State, and Energy Systems ES&H and resulted in the closing of the ORGDP water treatment plant intake. Discussions among the E&OS Director, DEM Department Head, and Environmental Analysis Head did not fully consider closing of WOD. WOD historically has not been used as a means of regulating environmental releases from ORNL. The solubility of strontium-90 indicated that storing an appreciable amount of contaminated water behind the dam would not result in any appreciable precipitation of the strontium-90 or any significant dilution. With the heavy rainfall, the water behind the dam would have to be released in any event. It was felt that releasing the water was better than storing it and having to release a larger amount later. Without the benefit of predetermined criteria for closing the dam, a full understanding of the hydrology of the Clinch River and the potential for minimum downstream dilution of the strontium-90 was not available and thus not factored into this decision. On the following day, after better understanding of Clinch River low flow concerns, the dam was closed until arrangement could be made with TVA to increase Clinch River flows.

ORGDP Potable Water Operations

A documented standing operating instruction for shutdown of the ORGDP water treatment plant does not exist; however, it is standing practice to shut down the sanitary water plant and take water samples anytime a suspected problem exists in the Clinch River. Even though this is not a documented standing operating instruction, this is an established practice and is understood by operating personnel.

Established operating practices were effective in shutting the ORGDP sanitary water treatment plant intake, notifying key personnel, and establishing a team to handle the situation. The decision values for advising employees not to drink the water was not preplanned.

ORGDP's recognition of the event was dependent on notification by ORNL personnel. Once this notification was received, appropriate actions and communications were taken. The storage capacity of the ORGDP sanitary water system is about 4 million gal which is sufficient for one- to two-days operation. This provides time to evaluate the conditions at the water intake without interruption of plant operations. The operations; health, safety, and environmental management; and DOE personnel were notified in accordance with

previous agreements. The action to advise employees not to drink the water was taken as a precautionary measure to allow for subsequent evaluation and to assure that radiation exposure was maintained as low as reasonably achievable (ALARA).

The sanitary water treatment system was used to provide water for commodes, showers, and process cooling. The water was available to employees, and the decision of not drinking the water depended on the employees' actions. Water tankers were provided in six locations throughout the plant for drinking and cafeteria uses.

Monitoring and Analysis

Flow monitors and radiation monitors are installed in 12 process waste system manholes upstream from the EB. There are also flow and radiation monitors at the 7500 Bridge, at the weirs on Melton Branch and WOC, and at WOD. These monitors operate in real time and signal when an "abnormal condition" exists. The existence of an "abnormal condition" triggers systematic "grab sampling" to quantify the condition and locate the cause. There are no specific predetermined instructions for the "grab sampling." A "grab sampling plan" is developed by Waste Management Operations supervision at the time the "abnormal condition" is identified, based on the nature and location of the condition.

Current procedures for routine monitoring of ORNL effluents consist of sampling and analysis of liquid wastes before discharge and analysis of samples from WOC water at the 7500 bridge and at WOL. In addition, four on-line, continuous beta monitors are located on WOC (2), Melton Branch, and at WOD. Grab samples for liquid wastes and WOC water are analyzed for gross alpha, gross beta, and cesium-137 content. Specific strontium-90 analyses are not conducted on a routine basis; any strontium-90 that would be present would be included in the gross beta measurements. The Operations Division is responsible for collecting samples for analysis, for interpreting results on these samples, and for monitoring the continuous gross beta readings from the on-line instruments. The AC Division is responsible for analysis of grab samples. These analyses are performed at the TRU laboratory on an around-the-clock basis. Gross beta radioactivity was measured at the TRU laboratory with a GM counter which has a counting efficiency of 6.9% for strontium-90 with yttrium-90 in equilibrium. The background of the counter is 17 beta counts per minute. Two milliliter aliquots of creek water were evaporated to dryness and counted for 10 min. Samples are routinely handled in a radioactive contamination zone. Based on counting statistics, the detection limit for the GM counting system for strontium-90 is approximately 500 Bq/l (2 cpm/ml) (95% confidence). Other monitoring activities are performed by the EOS Division. These activities involve composite sampling of WOC, Melton Branch, and Clinch River water to establish population exposure levels; radiochemical analyses are performed by the Low-Level Radiochemical Analysis Group in AC Division.

Based on a preliminary assessment, the on-line continuous gross beta monitoring instruments on WOC do not have adequate sensitivity and selectivity to detect levels of strontium-90 in WOC that could result in exceeding Safe Drinking Water Standards when released into the Clinch River. The instruments detect gross beta radioactivity, and because cesium-137 also emits beta particles and occasionally is present in WOC, there is no clear indication when strontium-90 is present in the creek. Also, the on-line instruments have problems because of build-up of deposits on the sensitive counting probe. This build-up causes difficulties in the interpretation of the monitoring data and requires that the probe be cleaned frequently to obtain reliable information. The on-line monitoring instruments are useful in that they provide an instantaneous measurement of beta radioactivity in the creek. Unfortunately, in this incident, the slightly elevated readings from the instruments were interpreted as cesium-137 contamination in the creek and the presence of strontium-90 was not realized.

All of the on-line monitoring equipment was functioning properly at the time of the "incident" except the radiation monitors at WOD. These monitors have never worked properly since being installed in 1984. The inoperability of the WOD radiation monitors did not affect this event because the upstream monitors did signal abnormally high radiation levels. The "high alert" and "high alarm" settings on the monitors at the 7500 Bridge, the WOC weir, and the STP were too high to cause these sensors to go into "alert" or "alarm" status. The DB radiation alarm was in alert status on numerous occasions beginning in mid-November and in alarm status constantly from November 29, 1985, through the event.

Response Notification

An extremely important aspect of communications was the need for prompt and accurate notification of significant events to the proper people. There were several occasions where notification was less than adequate. In the early stages of the event, on November 27 and November 28 (Thanksgiving Day) there were indications of increases in gross beta activity in the DB. This in itself was not unusual and a cesium-137 scan verified 1081 Bq/l of cesium-137 on November 28. When the storm drain pipe broke in the excavation on the morning of November 29, the gross beta counts in the DB jumped from 4130 to 16,630 cpm/ml. This clearly signaled a departure from normal and the Waste Operations Foreman, Operations Division, was called. The Foreman instructed that the LSS be notified and an analytical chemist be called in to identify the type of activity present. The notification to the LSS was proper and in accordance with guidance provided in a January 28, 1985, Official Bulletin, "Notification of Unusual Conditions, Incidents, and/or Utility Failures." Up to this point, the notification also complied with the guidance contained in a memo from the Executive Director to all Division Directors (dated November 1, 1985, subject: "ES&H Occurrence Notification and Reporting to ORNL Management.") Under this guidance, the person experiencing the event would notify his/her supervisor; the supervisor would notify the LSS; and the LSS would notify the Executive/Laboratory Director and the Division Directors for E&OS, Health, and Laboratory Protection divisions. The criteria for implementing this notification process for environmental releases of

radioactivity was "any nonroutine release to the air, water, or ground which could cause a member of the general public to receive a dose commitment which exceeds 0.01 mrem." The offsite impacts of the elevation in gross Beta levels at the DB would have been extremely difficult to arrive at with any degree of promptness or accuracy. Notification did not go beyond the LSS at this point. This Friday after Thanksgiving Day was also a holiday for most of the Laboratory employees and many were out of town at the time.

At 0715 on November 29 the AC Division personnel performed a gamma scan of the DB and PWT effluent samples and confirmed the presence of cesium-137. Neither the need for the analysis nor the results of his analysis were reported to AC Division supervision.

On the afternoon of November 29 at 1730 another opportunity for notification arose. A sample of the process waste MH 211 southwest of the Bldg. 3517 excavation showed 177,000 cpm/ml while the upstream MH was at background. This discovery prompted notification of the Waste Operations Supervisor, the Bldg. 3517 Operator, and the LSS. No notification beyond this level was made. When the Bldg. 3517 Operator arrived and examined the situation, he notified his supervision in Operations Division. No notification beyond this point was made (the Operations Division Director was out of town at the time).

On the evening of November 29 at 2200 the Waste Operations Supervisor and the Head, Environmental Analysis discussed and agreed on increasing the PWT ion exchange column cesium-137 effluent to 5000 Bq/l. This information was not relayed to their supervision at the time.

The previous four events occurred in the context that the perception of the occurrence was one of an operational upset involving cesium-137 only and that the offsite impacts were not particularly serious. Had higher levels of supervision and/or management been made aware of the circumstances of the occurrence then perhaps the strontium-90 analysis and recognition of the potential seriousness of the environmental consequences would have been initiated earlier. The specific guidance in the internal notification memo was very difficult to apply in these circumstances. In the later stages of the occurrence when remedial actions were being taken by various Laboratory organizations (e.g., opening or closing WOD and changing the effluent characteristics of the PWT), the LSS was not notified. This was an inadequate flow of communications in the reverse direction.

Even after DOE had been notified of the incident on December 2, the subsequent notification of State personnel (TDHE) was delayed until mid-morning December 3. TEMA was not notified by DOE as had been previously arranged, but TEMA was notified by TDHE. Both TEMA and TDHE expressed concern for not being notified earlier.

The decision of ORGDP personnel to delay reporting of the potable water intake operation shutdown until the following morning was in accordance with existing operating practices.

Proper notification of significant occurrences must also involve the Laboratory's Public Relations Office. That Office received its first notification of some type of on-going occurrence from their counterparts at DOE-ORO. To be effective in coordinating with the various information media, the Public Relations Office must be kept aware of incidents when they occur. Public Relations was involved throughout the remainder of the occurrence and issued several press releases and updates.

Later in the occurrence, the need arose to coordinate actions with TEMA and TVA regarding releases of water from MHD; these were important to proper decisions regarding opening or closing WOD. This information was not available until December 3, 1985.

E. CESIUM-137 VERSUS STRONTIUM-90 IN THE ENVIRONMENT

Earlier in the "Analysis Section" there was a discussion about a communications problem which led to the erroneous assumption that the gross beta readings seen in the DB and MH 211 were due to the presence of cesium-137 and not strontium-90. This erroneous assumption led to a delay in action to minimize the release to the environment and activate notification chains. A very legitimate question concerning this matter is why it was thought to be acceptable to release cesium-137 at the levels but not strontium-90. This question is answered below.

Cesium-137 has a much shorter biological half life (residence time in the body) than strontium-90 and a much lower environmental mobility. These factors are documented in several places:

1. 10 CFR 20 (Standards for Protection Against Radiation), Appendix B, Table II, Column 2 shows the following values for soluble cesium-137 and strontium-90, respectively:

Concentration Limits Isotope	uCi/ml	pCi/L	Bq/l
cesium-137 (soluble)	2 x E-5	2 x E+4	740
strontium-90	3 x E-7	3 x E+2	11.1

NRC licensees may not release licensed materials to unrestricted areas in concentrations greater than those shown above (water pathway) without special authorization. As shown, the concentration limit for cesium-137 is 67 times that for strontium-90.

2. The dose conversion factor for cesium-137 is 0.05 rem/uCi. For strontium-90, it is 1.2 rem/uCi. Soluble strontium-90 delivers its dose to the bone, while cesium-137 delivers its dose to the whole body. Dose limits to the bone are 1500 mrem/y, compared to 500 mrem/year whole body. This comparison leads to a factor of 72 greater allowable exposure to cesium-137 concentrations than to strontium-90. Using the drinking water standard of 4 mrem/y exposure to any organ, the allowable exposure to cesium-137 is 24 times higher than to strontium-90.

3. Environmental mobility is decidedly lower for cesium-137 than for strontium-90. The retardation factor (Rd) (which relates the velocity of transport for a nuclide to the velocity of groundwater flow) for strontium-90 is 36, while for cesium-137 it is 350 (Spalding et al., ORNL/NFW-82/18 and NUREG-0782, Vol. 2). It is also noted (Ceiling and Spalding, ORNL/TM-7318) that Rd values for cesium-137 in ORNL soils are about two orders of magnitude higher than those given by NRC for average geologic media. A nuclide with an Rd of 1 moves at the same rate as groundwater, while a nuclide with an Rd of 10 moves at 1/10th the rate of groundwater. While the velocity relationship may not hold for surface waters because of the reduced contact with soil/sediment surfaces, a high Rd will cause localization of a nuclide in sediment deposition areas while a low Rd will allow more rapid flushing out of a stream system. Lomenick and Tamura (Soil Sci. Soc. Amer. Proc., 29:383-387) further note that cesium-137 sorbed on WOL sediments was very tightly bound and could be removed only by strong acid leaching.

F. EVENTS AND CAUSAL FACTORS CHART

The following page shows a summary chart indicating the main events of the occurrence and contributing causal factors.

BLDG. 3517
RELEASE OF STRONTIUM-90 FROM THE ORNL CELL VENTILATION IMPROVEMENT PROJECT
NOVEMBER 29, 1985

LTA - LESS THAN ADEQUATE

BLDG. 3517

AM-90 FROM THE ORNL CELL VENTILATION IMPROVEMENTS CONSTRUCTION SITE
NOVEMBER 29, 1985

VII. CONCLUSIONS

A. FINDINGS

Pathways to Environment

From November 29, 1985, through December 3, 1985, strontium-90 contamination moved from the soil in the 3517 excavation to the WOL and then to the Clinch River through the storm sewer system and through the sanitary system. Higher than normal strontium-90 concentrations in the PWT effluent may also have contributed.

Impacts

An additional 500-600 mrem of occupational radiation exposure was spread over 40 ORNL and Rust employees as a result of corrective actions associated with this occurrence. No personnel exposure exceeded DOE recommended exposure limits.

The total estimated radiological dose to an ORGDP employee or an industrial park employee who may have consumed potable water contaminated with strontium-90 ranged between 0.06 mrem and 0.12 mrem. The dose was well within the recommended allowable levels for the general public.

The total estimated radiological dose to a Kingston resident who may have consumed potable water contaminated by this incident ranged from 0.08 to 0.16 mrem.

The radiological dose received by any ORGDP employee or any member of the public due to this incident was less than five percent of the Safe Drinking Water Act's limits for a year's average dose (4 mrem/y).

The event resulted in depletion of 29,000 gal of low level waste storage capacity, about three times the planned rate for the time period involved.

Prevention Planning and Implementation

Planning for prevention of this incident was less than adequate. Even though the ADM written for the project associated with incident did include concern for storm drain line breaks, the concern was never included in other project planning documents and thus never communicated to construction personnel.

Shoring to prevent the collapse of the walls of the excavation to protect the storm drain was less than adequate.

Soil conditions in the excavation site were less compact than expected due to the abnormally high volume of fine gravel, and the radioactivity levels found in the excavation site were significantly higher than expected or documented. This created some concern on the part of the contractor and probably impacted the decision regarding shoring to protect drain lines.

Protection of the excavation site from inclement weather, especially the storm drain line, was less than adequate. Even though the vulnerability of this line was recognized by ORNL personnel, efforts to minimize the risk of breaching were ineffective.

Response Planning and Implementation

Response planning by ORNL and DOE for this event was less than adequate. Predetermined criteria for properly evaluating the significance of the event were less than appropriate. Predetermined locations for monitoring areas of the site's storm drain system were not available. Formalized agreements between DOE, ORNL, TEMA, and TVA regarding public notifications, control of Melton Hill flows, and control of WOL discharges were not available and criteria for closing WOD were not available.

Early recognition and notification of the incident was inadequate. Even though the LSS was notified promptly of notable increases in radioactivity in effluents, no subsequent notifications were effected.

The criteria for initiating reports of abnormal releases of radioactivity to the environment were inappropriate. The determination of an offsite dose (criteria for reporting being 0.01 mrem) with information that was available was virtually impossible.

The Lab Shift Supervisor was not always properly informed of actions taken by Operations and Environmental personnel, which hindered his ability to act as the response coordinator.

TEMA was not notified of the event in a timely manner.

Coordination and prioritization of analyses of strontium-90 samples were less than adequate. Investigative work was hampered due to the laboratory being overloaded with ambient stream samples.

The nature of the problem was not satisfactorily communicated to the AC personnel who provided early information on effluent radioactivity. This contributed significantly to the failure to recognize strontium-90 contamination in the beginning of the incident (November 29).

Procedural problems occurred in the analysis of strontium-90. These problems were associated with the presence of radium-226 daughter products in isolated strontium-90 products. It was necessary to allow a 3-h delay in counting to permit decay.

The procedure used for environmental strontium-90 analysis is documented in the Martin Marietta Environmental and Effluent Analysis Manual. The procedure differs slightly from the EPA recommended procedure. The differences are technically insignificant but could be important in the future interpretation of the data by regulatory agencies.

There is no standard battery of analytical procedures that can be applied to early samples taken during a suspected environmental release that will characterize the types of radionuclides that might be involved.

All samples taken were not kept for reanalysis (if needed later) until the end of the event.

The delay by ORGDP (from late December 2 to the following morning) in notifying DOE of the potable water intake shutdown was in accordance with existing operating practices but the issue should be revisited as a result of this incident.

The in-stream radioactivity monitors generally functioned adequately but the information provided did not result in early recognition and mitigation of the problem.

Decisions and subsequent actions relating to rerouting of "clean" waters around contaminated areas and to pumping and treating of contaminated ground water were appropriate and timely. Such actions significantly reduced the impact of the incident.

Use of the E&OS Division Director's office instead of the ORNL Situation Management Room did not adversely affect the response, but may have inhibited some communication with DOE.

During the times that the DOE ERC was not utilized, communications from ORNL and ORGDP were hindered.

B. PROBABLE CAUSES

The probable cause of the occurrence was less than adequate protection of the excavation site. Other contributing factors were the high level of mobile strontium-90 in the soil, the heavy rainfall, and the poor condition of the area storm, sanitary sewer, and Process Waste Transfer lines that allowed infiltration; and less than adequate preproject planning to properly consider these problems. The storm drain line break also resulted from failure to implement corrective actions after observation of the situation, recognition of potential adverse impacts, and verbal expressions of concern.

The probable cause of the delay in notification of and subsequent proper response to the incident was the incorrect assumption that early radiation levels found in various streams was cesium-137, rather than strontium-90.

C. JUDGMENT OF NEEDS

Prevention Planning and Implementation

The current ORNL system for project planning should be thoroughly reviewed and upgraded as necessary to ensure proper incorporation of concerns for unplanned environmental releases during construction activities.

Specific training should be given to all personnel having a potential to be involved in construction projects in the recognition and prevention of unplanned releases. The training should emphasize prevention, even if involvement of higher management is required to make changes.

Provisions should be made for routine inspection of construction sites in areas of contamination with potential for adverse impacts, and for documentation of conditions.

Response Planning and Implementation

The current system for planning for and dealing with unplanned releases to the environment once they occur should be thoroughly reviewed, upgraded as necessary and documented. Specific emphasis should be placed on developing procedures which: (1) establish appropriate criteria for timely recognition of an abnormal release, and (2) establish a predetermined course of action for mitigating releases as well as for reporting to the appropriate ORNL, Energy Systems, DOE, and State personnel. Specific concerns associated with this incident that should be reflected in the procedures include:

- Utilization of readily obtainable and easily understood parameters for detecting an unplanned release.
- A means for ensuring timely notification of all appropriate personnel.
- A predetermined arrangement with DOE, TEMA, TVA, and any other appropriate agencies to ensure proper control of streamflows, public notification, etc.
- Predetermined information on the hydrology of WOC, WOL, and the Clinch River, including impacts of rainfall.
- A means for selecting the appropriate response team.
- A plan for effecting quick sampling of appropriate drains and streams that will allow for timely isolation of a release source.
- A plan for intercepting and/or mitigating releases, based on the early sample data, near the sources as well as at locations farther downstream.
- A plan for ensuring around-the-clock analytical capabilities to measure low levels of strontium in drinking water (0.3 Bq/l).

The current capabilities for monitoring ORNL effluents and the ORGDP potable water intake related to both early detection of abnormal conditions and precise historical information gathering should be reviewed and upgraded as necessary. Areas that need special attention include:

- ° The turnaround time for determining strontium-90 concentrations in water samples.
- ° The appropriateness of the current strontium-90 analytical procedures relative to EPA-approved procedures.
- ° The existing analytical capabilities and standardized analyses (and standardized units) for timely determination of all the most common radionuclides found in ORNL streams.
- ° The retention of samples collected during an incident for possible future reevaluation.
- ° The coordination of analytical samples within the laboratories during an incident.

The current ORGDP practice of reporting shutdown of its potable water intake operation should be reviewed in view of this incident and upgraded if necessary.

The ORNL Situation Management Room should be utilized when at all practical to enhance communication.

The DOE Emergency Operations Center should be utilized when at all practical to enhance communication.

DOE procedures for notification of state of Tennessee agencies (TEMA, TDHE, etc.) should be reviewed and upgraded where necessary. Training in implementation of the procedures should be provided to the appropriate personnel.

SIGNATURE PAGE

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IX. APPENDIXES

APPENDIX 1

BOARD AUTHORITY

This Type B investigation was carried out under the authority of the attached December 17, 1985, letter from Joe La Grone, Manager of DOE-Oak Ridge Operations, to Dr. Herman Postma, Director of ORNL. Since the incident investigated involved individuals and activities related to ORNL, ORGDP, and DOE, the investigating Board was comprised of representatives from each of these entities as well as from the Energy Systems Central Environment, Safety, Health (ESH) and Engineering Staffs. The Board included:

- M. E. Mitchell (Chairman) - Energy Systems ESH
- G. L. Love - Energy Systems ESH
- J. L. White - Y-12 Plant
- W. R. Golliher - ORGDP
- D. C. Parzyck - ORNL
- F. J. Homan - ORNL
- M. W. Knazovich - ORNL
- E. H. Krieg - Energy Systems, Engineering Division
- T. M. Jelinek - DOE
- D. K. Wilfert - DOE

A subcommittee, under the direction of F. J. Homan, was established to provide special insight into the chronology of events, the analysis of facts, and the conclusions associated with ORNL actions only. In addition to F. J. Homan, this committee consisted of:

- N. W. Durfee - Energy Systems, Engineering Division
- E. E. Hill - ORNL Operations, QA Coordinator
- P. B. Hoke - ORNL, Quality Assurance Department
- M. W. Knazovich - ORNL E&OS Division
- L. W. Long - Energy Systems ES&H
- T. F. Scanlan - ORNL, Waste Management Operations
- J. R. Stokely - ORNL, Analytical Chemistry

The scope of this investigation included all relevant events that led to, were an integral part of, and resulted from the late November, early December release of strontium-90 from ORNL to the Clinch River. The time period involved generally began with early project planning in February 1985 and ended when daily communications relating discharge data to TEMA were ceased on January 3, 1986. The specific event (release) was determined to have initiated on November 29, 1985, and to have essentially been under control by December 6, 1985.

COPY

Department of Energy

12/17/85 RC

Anderson	WFO	_____
Byrd	Lenhard	_____
Richmond	WFO	_____
Rosenblat	Com Syst	7525
Walters	_____	11/21/85 KVV
Zachary	_____	_____
Trempa	_____	_____
Roberts	_____	_____

[Signature]

Oak Ridge Operations
P. O. Box E
Oak Ridge, Tennessee 37831

DIST. by R. S. WILSHIRE

Date	_____
Barker	Oliphant ☒
Eads	Parzyck ☒
Garrett	Swanks ☒
Krieg	Travaglini _____
Kuykendall	Whitesides _____
Melroy	Other _____
Assoc Dir	_____
Com Syst	_____

December 17, 1985

[Signature] Handle Reply
Responsible

Note Commitment!

Dr. Herman Postma, Director
Oak Ridge National Laboratory
Martin Marietta Energy Systems, Inc.
Post Office Box X
Oak Ridge, Tennessee 37831

Dear Dr. Postma:

STRONTIUM-90 DETECTION AT WHITE OAK DAM

A Type C investigation of the subject incident was previously requested by members of my staff. However, due to the significance of the incident, a more detailed investigation is required. Therefore, it is requested that a Type B investigation be performed.

The investigation and preparation of the resulting report should conform to DOE Order 5484.1A requirements. The scope of the investigation is to include all of the factors which contributed significantly to the cause and extent of the incident. Tom Jelinek of the Environment, Safety and Health Division is available for any assistance that you may require.

Please submit a copy of the report to me by January 21, 1986. ✓

Sincerely,

[Signature]
Joe La Grone
Manager

SE-333:Mullins

cc:
J. A. Lenhard, ER-10
K. Jarmolow, Y-12

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APPENDIX 2

ORNL Organization Chart