1/24/06

IS IT JUST A PROCEDURE? - AMAG issue

NRC

A bloody PORC

| | PORC | January 24<br>1 pm<br>Walnut | 06-<br>004 |
|---|---|---|---|
| Chemistry | Unplanned Environmental Tritium Releases<br>Root Cause Report #428868<br>UFSAR req't 300ci/unit<br>but BW does 1200-3000 ci/unit? | Dudek<br>Ambler<br>Walrath<br>Wrigley<br>Smith<br>Gayheart<br>Daly<br>Leasure | |

SINCE THIS WILL GO PUBLIC (if counts?)
NRC scrub on where we are mentioned?
- do we have the answer?
- not blind-sided?

**PORC chairperson should consider asking these questions prior to or during PORC reviews:**

MANAGEMENT? - Steam dryers - AMAG

**Prior to PORC:**

- Would a joint PORC with another site facing the same issue provide more insight?
- Are the PORC members adequately independent from the issue?

technical rigor credit?

by asking more questions (ORG effectiveness mgmt oversight)

**At the beginning of an Issue presented to PORC**

- Should the PORC ask for a presentation prior to discussing the issue to clarify what is being approved and to have the presenter identify potential nuclear safety issues?
- Does the PORC have the expertise to fully evaluate the issue or could it benefit from additional members joining the quorum?

ODCM - did not know the limits or concerns

**Prior to adjournment of an issue presented to PORC**

- Has the PORC specifically questioned the nuclear safety aspects of the issue?
- Are there any dissenting viewpoints related to the issue, either within or outside the PORC, and has the dissent been openly discussed and the resolution documented?
- Has the PORC adequately encouraged a questioning attitude and not allowed "group think" to occur?

why didn't we sample for $H_3$? - mgmt oversight (lack of)

ORGANIZATIONAL ISSUE? Not just a procedural compliance.



- CAP review

2nd root cause

release package

II/2

# ROOT CAUSE REPORT

**TITLE: INADEQUATE RESPONSE TO UNPLANNED ENVIRONMENTAL TRITIUM RELEASES FROM BRAIDWOOD STATION DUE TO THE LACK OF INTEGRATED PROCEDURAL GUIDANCE.**

| | |
|---|---|
| **Unit(s):** | Braidwood Units 1 and 2 |
| **Event Date:** | 11/30/2005 |
| **Event Time:** | 11:50 |
| **Action Tracking Item Number:** | 428868 |
| **Report Date:** | 01/13/06 |
| **Sponsoring Manager:** | Janice Kuczynski JMK 1/19/06 |

| **Investigators:** | **Position** |
|---|---|
| Jason Eggart | Braidwood Chemistry Lead Investigator |
| Tom Leffler | Root Cause (RC) Qualified Investigator |
| Randy Kalb | Dresden Chemistry Investigator |
| Kim Aleshire | Braidwood EP (ODCM) Investigator |
| Glen Vickers | LaSalle RP Investigator |
| Scott Kirkland | Quad Cities Investigator |
| Jim Crawford | BWD CMO RC Qualified Investigator |
| Mike Miller | Braidwood Operations |
| Jeff Burkett | Braidwood Operations |
| Dan Stroh | Braidwood Engineering |

**Executive Summary:**

Braidwood Station identified elevated levels of tritium in the groundwater both on and off the plant property. The presence of these elevated levels violates Illinois EPA regulations (Attachment 3). The elevated levels of tritium appear to have originated from historical spills. As of January 6, 2006, acoustic testing of the blow down piping showed no measurable evidence of a leak. The tritium remediation plan will be tracked to completion under IR# 435383. The scope of this investigation was to determine the root cause of the Station's historical response(s). These responses were inadequate in that they did not effectively evaluate, mitigate or remediate these spills, which had the potential to affect the public. A review of a previous Root Cause regarding Circulating Water (CW) Blowdown (B/D) vacuum breaker failures was performed to determine if the corrective actions were effective.

In 1998, Vacuum Breaker #3 (VB-3) had a significant leak (approximately 3 million gallons), producing standing surface water on Braidwood property. The 1998 response did not address radiological concerns.

In 2000, Vacuum Breaker #2 (VB-2) had a significant leak (approximately 3 million gallons), producing standing surface water on Braidwood property. The 2000 response addressed removing surface water and re-evaluated the 1998 spill. The 2000 RCR Team wrote Problem Identification Form (PIF) A2000-04281 to have the 1998 spill reviewed for radioactivity under 10CFR50.75(g). However, NSP-RP-6101 did not specify isotopes of concern, nor did it specify the need to check groundwater. As a result, no documentation exists that a tritium analysis was performed for the 1998 spill zone characterization. The 2000 analysis was performed by an independent Certified Health Physicist and approved by site management.

Braidwood Station conservatively maintains CW B/D discharges (in the blowdown line) to approximately 1,000,000 pCi/L during releases, which is a small percentage of the Offsite Dose Calculation Manual (ODCM) limit of 10,000,000 pCi/L. The Illinois Administrative Code states that tritium shall not exceed 20,000 pCi/L in Class I Potable Resource Groundwater. The IEPA and Title 35 of the Illinois Administrative Code states "Groundwater means underground water, which occurs within the saturated zone and geologic materials where the fluid pressure in the pore space is equal to or greater than atmospheric pressure". Braidwood Station contracted a professional hydrologist who determined saturated ground water (Class I Potable Resource Groundwater) occurs 5-10 feet below the surface at the station.

Station actions (delineated in Attachment 8, Effect and Causal Factor Chart E&CF Chart) and interviews of site personnel (Attachment 2) documented that in the past, personnel did not respond to circulating water blowdown leaks as an off-site radioactive release. Rather, they focused on preventing potential National Pollution Discharge Elimination System (NPDES) violations. As long as the effluent (water) did not leave Exelon property, personnel did not always perceive a reason for concern, as NPDES requirements were considered met and site personnel were unaware of the Illinois statute regarding groundwater tritium limits. The lack of a consistent historical response by site personnel is a failed barrier.

The ***Root Cause*** was determined to be a lack of integrated procedural guidance to ensure proper identification, timely mitigation and evaluation of the spill events, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations.

The Corrective Action to Prevent Recurrence (CAPR) is to institutionalize the protocol for addressing low-level radioactive spills, including tritium and other isotopes. Many of the other corrective actions address training and verifying station personnel are knowledgeable of the regulations and the need to immediately mitigate low-level radioactive spills/leaks, leak repair prioritization, and inserting precautions in procedures that identify or inspect for leaks.

The Nuclear Safety Risk Assessment showed no impact on station operation or response to postulated accident conditions. The event was reportable under Reportability Manual, SAF 1.9, News Release or Notification of Other Government Agencies per 10CFR50.73 (Att 4).

The extent of condition involves low-level tritium spills at all Exelon Nuclear facilities, with added emphasis on Pressurized Water Reactors due to tritium production rates. Also, the Reportability Manual, LS-AA-1020, and the Off-Site Dose Calculation Manual (ODCM) do not reflect all the Illinois' statutes for groundwater tritium ***(Failed Barriers)***. Since 1996, 22 CW B/D line leaks were recorded in the Corrective Action Database. Responses varied depending on the knowledge and skill level of the personnel involved and the lack of an integrated low-level radioactivity environmental spill response procedure (Attachment 11).

A review was performed on the 2000 Root Cause Report (RCR) 38237, Circulating Water (CW) Blowdown (B/D) Line Vacuum Breaker failure and the Corrective Actions to Prevent Recurrence (CAPRs). The review concluded that CAPRs have been effective in preventing equipment failures discovered by the RCR (See "Other Issues" section). A higher level of concern for radioactivity including tritium, was noted in the response to the 2000 spill. Tritium was sampled for and detected in the surface water. The surface water was cleaned-up and pumped to the CW B/D line. However, the RCR 38237 team did not pursue underground water tritium in 2000. The root cause charter addressed only vacuum breaker issues. At this time there was a team covering the cleanup activities of the water. There was no root cause performed for radiological spill concerns or any other past spills. This was a missed opportunity.

**Condition Statement:**

Braidwood Station did not adequately respond to unplanned environmental tritium releases. The consequence of not adequately responding to these events is that elevated tritium in the groundwater has migrated off-site. The significance of the event is that groundwater tritium concentration levels are in excess of Illinois Administrative Code (IAC) limits for Class I Potable Resource Groundwater.

Are these the only 3 events of the 22 C/W line leaks that resulted in rot radiological spills?

**Event Description:**

Review of the history of all the Circulating Water Blowdown vacuum breakers showed there were three equipment failures that caused major leaks. In 1996, VB-1 had a leak of approximately 250,000 gallons due to a primer valve failure. The only documented response to this event was the repair of the valve. During the review of this event, the team could not find any documentation of sample analysis for radioactive materials. There was no documentation that there was any spill remediation performed. Elevated levels of tritium as of January 2006 have been identified in the groundwater on the Braidwood property close to (northeast of) VB-1. In two locations, the elevated levels were above or near EPA drinking water standards. The elevated levels associated with this location do not extend beyond Braidwood property.

In 1998, VB-3 failed and released approximately three million gallons to the ground. Once again, the only response to this event was to repair the valve as soon as possible. During the review of this event, the team could not find any documentation of sample analysis for radioactive materials. The NPDES Coordinator was notified and determined that there were no environmental concerns because the water had not reached a waterway. There was no documentation that there was any spill remediation performed.

In 2000, VB-2 failed and released approximately three million gallons to the ground. A local resident reported the spill to the station. RP was notified a day later about this issue. The RP Manager spoke with the RP Technical Superintendent and discussed the need to collect samples of available water. The sample results indicated >20,000 pCi/L tritium was present. Once again, the only response to this event was the repair of the valve as soon as possible. The water was pumped back into the B/D line and wells were installed in the area of the 2000 leak to characterize the local hydrology. Based on calculations and conclusions by a professional hydrologist, underground water in the area of VB-2 would take approximately 15 years to flow off-site. Therefore, subsequent actions only included spill clean up and 10CFR50.75(g) documentation completion. No further groundwater tritium analysis was performed.

Following the review of the three vacuum breaker failures and the corresponding station response to those events, the Root Cause Team then focused on the processes and procedures that were in place at the time of the events. The procedures reviewed are contained in Attachment 6.

At Braidwood there was no site or Corporate procedure for guidance on low-level radioactive spills. The Hazmat procedure (BwAP 750-4) did not address radiological spills. NSP-RP-6101 for 10CFR50.75(g) for decommissioning does not reference tritium. The Reportability Manual (LS-AA-1020 & 1110) does not reflect ODCM REMP/RETS reporting requirements for unplanned release paths.

Also, these procedures did not reflect 35 IAC 620 Groundwater Tritium Release Path and the required 20,000 pCi/L limitation.

Engineering Walk down PM Procedure (ER-BR-400-101) and OPS Walk down PM Procedure (0BwOS CBW-A1) do not contain any precautions or steps for addressing tritium in the groundwater. Operational procedures BwOP CW-12, BwOP WX-526TI and BwOP WX-501TI have no guidance to isolate the B/D system if a known leak has occurred during a routine radwaste release to the Kankakee River.

The work control process (WC-AA-106) has no guidance for prioritizing a circulating water blowdown system leak. The current process designates these work orders as a "C" priority. The environmental procedures concentrate on NPDES compliance associated with oil or hazardous materials and by design, provide no guidance on radiological spills.

During the review, draft 1990 procedure CSG-001, (General Action Plan For Response To Unmonitored Releases And Very Low Level Radioactivity Spills) was found. This procedure contained instructions for mitigating intrusion of low-level radioactive spills into the groundwater. This procedure was never implemented.

Interviews played an integral part in the determination of this root cause due the lack of information that was available to the team for the three Circulating Water Blowdown events. The interviews indicated that there was no integrated uniform process for responding to unmonitored releases of low-level radioactivity spills. Statements made indicated that NPDES/environmental concerns were better understood than radiological concerns. It was understood that the effluent was already approved for radiological release to the environment. Therefore it was assumed to be in compliance with all regulations when it was released to the ground.

Based on the Stations differing response to Circulating Water Blowdown Vacuum breaker events, a lack of integrated procedural guidance to control unmonitored releases of low-level radioactivity spills, and statements made during the interview process, it is the evident that a formal procedure is required for these types of events.

Due to the extended period of time and the number of events, the timeline became very complex. Page 1 of the E & CF chart depicts the timeline for all vacuum breaker issues. Page 2 and 3 are for barrier analysis of the events on VB-2 and VB-3. For clarity, the timeline is the E&CF Chart in Attachment 8. Displayed in this section are:

- Event timeline with events that led up to this Root Cause Investigation,

- The 1996 Vacuum Breaker #1 (VB-1) leak
- The 1998 Vacuum Breaker #3 (VB-3) leak, and
- The 2000 Vacuum Breaker #2 (VB-2) leak.

Outlined below are the most noteworthy events with regard to Illinois EPA TITLE 35, Part F, Chapter I, PART 620, Class I Potable Groundwater, e) 3) tritium shall not exceed 20,000 pCi/L and potential impact on the public by exceeding the National EPA limit published in 40CFR141. The National EPA limits radiation exposure for the public from drinking water to 4 mrem per year, which would occur if a person were to drink two liters of water per day with an average of 20,000 pCi/L of tritium.

**Event Timeline**

October, 1990

- CSG-001, "Draft General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills" developed but not implemented ***(Causal Factor 1, Root Cause).***

1991

- Illinois statute 35IAC620 enacted, which places radioactivity limits on potable resource groundwater. This new regulation was not integrated into Exelon Procedures ***(Causal Factor 4).***

November 26, 1996

- Found 1" pipe from VB-1 to the primer valve failed. Estimated 250,000 gallons released to the ground. See attachment 8.

December, 1998

- Leak from VB-3. (See attachment 15 for more details.)

November, 2000

- Leak from VB-2. (See attachment 15 for more details)

December 2000

- VB-2 RCR for equipment failures was completed.

March 17, 2005

- On March 17th, the Illinois Environmental Protection Agency (IEPA) contacted Exelon to inform us that they were investigating tritium concentrations in wells near Braidwood Station in preparation for the Godley public hearing.
- The IEPA was working to understand why one of the Braidwood Radiological Effluent Monitoring Program (REMP) wells along the Kankakee River is indicating about 400 pCi/L concentration of tritium. This condition has existed since initial REMP sampling. The tritium is within acceptable limits and believed to be from the Kankakee River water.
- The IEPA was investigating why shallow groundwater well #2 in Godley was reported to have tritium. (Exelon, an independent contractor, and the IEPA analyses could not confirm any tritium above background levels in any of the Godley, IL wells.)

March 23, 2005

- In preparation for the upcoming public hearings for the city of Godley, the IEPA requested Braidwood Station to sample for tritium at the following locations:
    1. The cooling lake discharge canal
    2. The northwest corner of the cooling lake
    3. The two monitoring wells used for the previous environmental remediation sampling on the west side of the Turbine Building.

- The IEPA was informed that Exelon installed wells to determine a groundwater gradient near the blowdown line spill that occurred in November 2000. These wells were installed for hydrology analysis.

- The IEPA requested that Exelon provide a sample of the offsite drainage ditch and samples from the four shallow monitoring wells that were installed in the area of the November, 2000 blowdown line leak.

- The IEPA asked Braidwood Station to sample the shallow Godley well reported to be contaminated with tritium because the Agency would like to have a recent tritium analysis on it.

March 24, 2005

- An Independent contractor sampled the following per IEPA request:
    1. The cooling lake in the discharge canal
    2. The cooling lake in the northwest corner
    3. The cooling lake on the east-west dike approximately halfway in the middle
    4. The offsite drainage ditch
    5. The four shallow monitoring wells that were installed in the area of the November 2000 blowdown line leak
    6. The two monitoring wells used for the previous environmental remediation sampling (two wells closest to the Turbine Building)

April 1, 2005

- Results from the March 24 tritium samples taken at Braidwood Station indicated presence of tritium above background in the following locations:
    1. MW-4, Near the November 2000 VB-2 leak (See VB-2 timeline below)
    2. MW-6, West side of Turbine Building (very close to background)
    3. BD-101, Offsite drainage ditch

  While any levels of radionuclides above background theoretically present an increased health risk, the levels identified in these samples were well below federal standards and do not pose a significant health risk. Note: Per IEPA discussion, background tritium concentrations are 250 pCi/L.

- While the tritium levels found were low, Braidwood commenced a detailed sampling and investigative plan, in order to find and lower the tritium to as low as reasonably achievable.

April 15, 2005

- Exelon sent Godley well results and the second sample on the drainage ditch to the IEPA. Samples were collected on April 7, 2005:

| Location | Number | Result |
|---|---|---|
| BD-101 (Ditch by S. gate) | BDSW-1665 | twice background |
| Godley Rec. Center | BDWW-1666 | less than background |
| Godley Rec. Center | BDWW-1667 | less than background |

NRC notification?

May 5, 2005

- Additional samples were taken at three locations in an attempt to better define the source of the tritium in the drainage ditch.

May 9, 2005

- Due to the results of the March 24, 2005 sample and confirmatory sampling of Braidwood drainage ditch, Braidwood Station developed and began implementation of a detailed sampling and investigative plan that focused on the source of tritium. The sampling plan focused on both surface water and groundwater sample points.

May 10, 2005

- Five shallow groundwater wells (GW-1, GW-2, TW-20, OW-32 and OW-33) were sampled. These five wells are located onsite and are positioned between the drainage ditch and the Village of Godley. These samples were to provide more detailed information to samples previously collected on May 5. No tritium was detected above background concentrations in any of these five samples.

May 17, 2005

- A conference call was held with IEPA to exchange recent sample results and to discuss sampling in the Braidwood Station onsite wells (GW-1, GW-2, TW-20, OW-32 and OW-33). The IEPA reported all tritium samples as less than background, which corroborates the site's results.

- The IEPA stated they no longer requested samples of onsite wells and that the Agency would acquire four samples from residents in Godley who live along side the drainage ditch and would analyze the samples for tritium. The Agency would provide duplicate samples for Exelon tritium analyses and would notify us when the sampling was scheduled.

May 18, 2005

- A 20 drop per minute leak from the pilot valve of vacuum breaker #1 (VB-1) was identified during a walk down by engineering. A sample was acquired and sent for analysis.

May 19, 2005

- The sample of the leak catch tray at the VB-1 leak was above the IEPA standard for groundwater.

May 23, 2005

John House + myself

- Braidwood Station briefed the NRC Region 3 Inspector on the ditch tritium results. An overview of the sampling performed to date, along with the results of the sampling and a copy of the collated sample results were presented to the NRC.
- Tritium analyses performed on 5 water samples collected at Braidwood Station on May 20, 2005 were less than background except for the VB-3 Pit, BDSW-2691, tritium concentration is above background (See Attachment 15).

to page 8

April 25, 2005 OR IS IT MAY 25

- IR 328451 was generated to identify tritium levels above background in the storm water drainage ditch.
- The station began to develop a plan to understand the source of tritium. The plan was to install wells to help identify the source of the tritium and understand the hydrology and perform plume analysis studies.

June 14, 2005

- Acquired four samples from the Godley wells to satisfy the May 17 request from the IEPA.

June 20, 2005

- As part of the tritium plan, the station received the independent contractor proposal to install monitoring wells to focus on:
  - Examining the groundwater impact in the area of vacuum breaker #1 (VB-1) located south of the switchyard by installing 5 wells around VB-1, and
  - Determining the movement and direction of groundwater and its relationship to surface water on both the east and north side of the Braidwood Station property by installing 10 monitoring wells.

- This plan would determine the source of the tritium and if any groundwater was exceeding the IEPA drinking water standard of 20,000 pCi/Liter.

June 28, 2005

- The results of the four Godley well samples taken on June 14, showed no tritium levels above background.

July 22, 2005

- Exelon installed monitoring wells to investigate potential leakage around VB-1 and VB-3 that may be contributing to leakage in the storm water drainage ditch:
  - o MW-106, near the fresh water holding pond
  - o MW-107, SE corner of the switchyard near VB-1
  - o MW-108, east of VB-1 near the CW B/D line
  - o MW-109, east of the switchyard near the ditch

September 23, 2005

- Exelon pursued additional resources for expanded scope tritium investigative activities due to not finding the source of the tritium. This information was passed on to the IEPA.

October 2005

- Exelon installed monitoring wells as part of an expanded scope of the monitoring plan:
  - o MW-110, north of the meteorological tower
  - o MW-111, -112, and -113, north property line near Smiley Road

November 9, 2005

NRC notification?

- Two of the four groundwater samples collected on October 19 and October 20, 2005 from the new monitoring wells, exceeded the Off-Site Dose Calculation Manual (ODCM) Lower Limit of Detection of 2000 pCi/L. Upon this indication, Braidwood Station assembled an Exelon Special Project Team to evaluate the tritium issue.

November 22, 2005

- NOS completed the ODCM, REMP, Effluent and Environmental Monitoring Audit Report, NOSA-BRW-05-08 (AR # 287718). No issues of note were found. (See Attachment 10) Additionally, corporate governance did not uncover this issue. ***(Causal Factor 3, Missed Opportunity (does not apply to the ODCM)).***

January 15, 2006

- As this RCR was being finalized, a leak occurred on VB-7 due to failure of an internal guide and was documented on IR# 00442540. The standing water posed no radiological concern because radwaste releases had been temporarily terminated. The water was sampled for gamma and tritium and evaluated for NPDES compliance. An environmental specialist verified that the leakage did not reach runoff ditches or creeks and therefore was not a violation. An equipment apparent cause evaluation (EACE) is being performed to determine the failure and corrective actions are being tracked by ATI# 00442540.

**Analysis:**

The Root Cause Team interviewed personnel and reviewed the response procedures, regulations, historical documentation, and environmental impacts. An Event and Causal Factor (E&CF) Chart (Attachment 8) was utilized for Cause and Effect Analysis (Attachment 7), Change Analysis (Attachment 12) and Barrier Analysis (Attachment 6). Kepner-Tregoe Analysis (Attachment 9) was utilized for initial characterization.

Another root cause that was considered, was why draft procedure CSG-001, "General Action Plan For Response To Unmonitored Releases And Very Low Level Radioactivity Spills" was never implemented at Exelon. This procedure contained instructions for mitigating intrusion of low-level radioactive spills into the groundwater. There was no reason found as to why the procedure was never implemented. The reason this lack of procedure implementation was not considered as the root cause was that it did not provide overall integrated guidance for spill evaluation and mitigation. Personnel at the station would have had to recognize that a spill had the possibility of containing radioactivity and then the knowledge to enter the procedure.

Knowledge deficiency was considered as a root cause but was discounted because personnel across several departments did possess the required knowledge, however there was no integrated process or procedure to engage the proper personnel to fully address an integrated response. For example, in a number of events the station addressed the NPDES concerns but no RP individuals were engaged to address radiological concerns.

The 2000 event Root Cause Report (RCR) 38237 CAPR's were reviewed and have been effective in preventing vacuum breaker failures since 2000 through the end of 2005. The purpose of the Root Cause in 2000 was to determine the cause of those failures. RCR 38237 CAPR 1 implemented a revised preventive maintenance program for the float operated vacuum breaker valve assemblies for the CW Blowdown and Makeup Systems. This PM was developed by CA 2 and included specific intervals for inspection of valve internals and provided for periodic replacement of the valves.

This CAPR also revised the system walkdown inspection requirements, including specified frequency of walkdowns and documentation/reporting of walkdown results. Engineering has reviewed these CAPR's again and in the three years since the effectiveness review, there have been no equipment failures, which leads to the conclusion that the actions taken from the root cause report are effective in eliminating the possibility of a future vacuum breaker failure.

The RCR 38237 CAPR 2 replaced the current design vacuum breaker assembly with a surge-protected configuration. These two CAPRs were successfully implemented and an effectiveness review was performed under A/R # 00038237-08 two years after the root cause was created. The effectiveness review determined that the CAPR's were effective in eliminating the possibility of another vacuum breaker failure. ? by 2000 standard (water hammer)

CAPR 1 and 2 from above were reviewed for extent of condition. Other Exelon/Amergen Nuclear sites were contacted to determine how those plants are configured for circulating water blowdown and makeup and if they have experienced any similar problems with vacuum breaker float assembly failures. Byron and LaSalle stations were the only stations confirmed to have circulating water blowdown and makeup systems that utilize vacuum breakers in their design. For CW blowdown and makeup systems, the extent of condition is limited to Byron and LaSalle.

Byron Station replaced their fiberglass blowdown and makeup piping in 1987 with carbon steel due to a line failure associated with ground shifting. 12" Golden Anderson's model GH-7K vacuum breakers with line surge protection were installed at that time. System Engineering walkdowns are conducted annually and Operations regularly drives down the lines when they make River Screen House rounds. No vacuum breaker failures have been identified and only minor amounts of water have been discovered contained within the valve vaults.

LaSalle's Operating Department performs inspections on their circulating water blowdown and makeup systems on a semi annual basis. The inspections consist of leak checks and flushing the air release valve of any debris. The vacuum relief float is also checked and cleaned. The majority of the problems they experience are related to plugging and freezing. The smaller air release valve float is the component that has frozen and it only affected the air release and not the vacuum relief. Corrosion has also been identified as an issue on the piping from the vacuum break to the air release valve. There is no history of vacuum breaker float assembly failures at LaSalle.

There are differences in system operation among the sites. In general, LaSalle operates their system continuously, whereas Byron must cycle their blowdown system to accommodate chemical feed additions. Additionally, Byron still controls blowdown flow using the 0CW18A/B spray valves at their river screen house, thus their blowdown system is maintained full at all times. Byron's spray valves are typically throttled to 20-22% open to maintain 12-13k gpm blowdown flow. The Byron spray valves are reportedly difficult to control and require frequent maintenance to remain operable.

A review of OPEX reports did not reveal any direct correlation to the events evaluated in this root cause report. Per the OPEX reports, tritium was discovered during routine on-site and off-site environmental sampling and was associated with known active leaks. Braidwood had no known active leaks and had no increases in any our routine environmental samples.

Evaluation Methods used during the investigation process for the Root Cause.

| RC Tool | Why used | Advantages | Disadvantages overcome |
|---|---|---|---|
| **Event and Causal Factor Chart (Att 8)** | Utilized due to the complexity of the issues and actions over time. | Provide an illustration of the whole problem and contributing factors.<br><br>Works very well with barrier analysis, which became necessary during the evaluation. | While time consuming, enlisted a full-time CMO Root Cause person for the skill/experience and time to create an E&CF Chart. The large number of events verged on a CCA. However, one event was taken to represent them all and the analyses were completed utilizing that event (the 1998 event) as the template. |
| **TapRoot** | Used to assign the cause codes for individual causes of the event. | Consistent approach for more reliable cause coding. | Difficult to utilize and understand categories. Technique was used in conjunction with Trending/Coding procedure and Team input/brainstorming of causes. |
| **Barrier Analysis (Att 6)** | Used extensively, as people, physical, and administrative barriers should have prevented the issue. | Used to identify causal factors systematically, with the E&CF chart and Cause & Effect analysis to identify process weaknesses. Supports proposed corrective actions. | Utilized Team brainstorming to assure all barriers were recognized. |
| **Change Analysis (Att 12)** | Team utilized to evaluate changes in procedures and regulations. | Made for a good starting point in analysis of the E&CF chart. | Used in conjunction with Cause & Effect and Barrier analysis. |
| **Cause and Effect Analysis (Att 7)** | Found the "Why" Stair Case instrumental due to the large number of failed barriers. | This analysis method was key in finding the common/root cause used with barrier analysis. | Utilized E&CF chart and area experts in OPS, RP, Chemistry - Environmental, and other stations as well as RA and Corporate to ensure entire background was understood for this complex problem. |
| **Failure Modes and Effects Analysis** | Not Used | Not Used | Not Used |
| **K-T Problem Analysis (Att 9)** | Only able to use to a limited extent because the root cause involved many integrated procedures. | It is a rational, industry proven process that allows a focused approach to solving discrete problems. | Utilized a trained person to implement and facilitate the process. |

**Evaluation:**

| Problem Statement | Cause (describe the cause and identify whether it is a root cause or a contributing cause) | Basis for Cause Determination |
|---|---|---|
| Procedure for low level radioactivity spills not approved/ implemented & other procedures were not robust enough to ensure adequate response in all cases. | Causal Factor 1, Root Cause 1: **Procedures** - lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. | • **(Failed Barriers FB 1 -17)** (See Attachment 6) CSG-001 1990 (draft only) contained instructions regarding underground transport mechanism for tritium and directions to remediate this pathway. Procedures for responding to and assessing radiological spills are either non-existent or inadequate. There was limited guidance to acknowledge 35IAC620 requirements or subsurface transport mechanisms to provide dose to the public. Failed barriers 1-17 address lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. Due to the cross discipline teams needed to respond /document a low level radioactive leak and the lack of one procedure to integrate the response, CAPR 1 will address a multi discipline team to ensure all aspects are covered.<br>• After this root cause was identified, it was analyzed to determine if it was appropriate for this event. In other words, the team considered whether the "why" question had been asked enough to adequately resolve the problem. The team attempted to ask "why" and there is no clear/concrete documentation to explain why this 1990 procedure was not implemented **(Failed Barrier, FB-4)**. Utilizing TapRoot analysis process, the root cause is the most basic cause (or causes) that can be reasonably identified that management has control to correct and when corrected, will prevent (or significantly reduce the likelihood of) the issue recurring. In this event, management has the ability to implement integrated procedural guidance to ensure the necessary knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations is directed to ensure consistent mitigation and remediation of future events. Thus, it was concluded that the root cause statement met the criteria of the TapRoot definition and it was appropriate for this event. |
| Not all personnel possess knowledge of low level radioactivity concerns regarding environmental releases. | Causal Factor 2, **Training:** General training has no prompt to have personnel report environmental spills for assessment of radiological conditions. | • General Awareness training has no prompt to have personnel report environmental spills for assessment of radiological conditions. An example would be secondary side leakage which most personnel consider non radioactive and in reality can be radioactively contaminated. Function-specific training does not exist for either Operations or RP personnel for radiological spill response and assessment (reference Attachment 6) |
| Personnel were not aware of state regulations (example: 35IAC620) | Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Personnel were not aware of state regulations (35IAC620) to revise procedures and training for these action levels. Additionally, those who would audit the ODCM/REMP programs were also not aware that the regulatory and procedural deficiencies existed. **(See Attachment 6)** If the site had been aware of the requirement, then the site would have been driven to properly evaluate for groundwater. |

| | | |
|---|---|---|
| Events and new regulations not known by all personnel | Causal Factor 4, **Notification:** Processes and procedures for communication not well defined. | • (**FB 31**) Notice to other Site Departments when an event occurred - Did not always inform all affected parties<br>• (**FB 32**) Process lacking in formal notification to the sites of State regulation changes. |

## Extent of Condition:

| Cause being addressed | Extent of Condition Review |
|---|---|
| Causal Factor 1, Root Cause : **Procedures** - lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. | This issue applies to all Exelon Nuclear Stations. All sites produce tritium that can possibly migrate into groundwater. Pressurized Water Reactors produce a higher amount of tritium due to the usage of boron. |
| Causal Factor 2, **Training:** General training has no prompt to have personnel report environmental spills for assessment of radiological conditions. | This issue applies to all Exelon Nuclear Stations. All sites produce tritium that can possibly migrate into groundwater. Pressurized Water Reactors (PWR) produce a higher amount of tritium due to the usage of boron. |
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | All sites have the potential for contaminated leakage into groundwater. The event at Braidwood station is one example. Dresden station had a leaking underground pipe containing radioactive liquid that also resulted in groundwater contamination (reference IR 248494). There are numerous other nuclear industry events (OPEX) that resulted in groundwater contamination. For this reason, each site must assess the vulnerability of piping leaks and contaminating groundwater. This assessment is not limited to those plants that make liquid discharges. The concern is leakage into groundwater – not dose from liquid effluents to a defined outfall release point. Which is to say, that the ODCM does not direct routine measurements for leakage locations that may produce an exposure pathway.<br><br>Corporate ODCM technical support was not strong from 2001-2004. Currently, corporate assistance is available. Corporate ownership, roles, and responsibilities are not clearly understood by the station ODCM Owners. Strong technical support will be required to assist the sites by developing a plan to adequately assess the vulnerability to groundwater contamination at each site. |
| Causal Factor 4, **Notification:** Processes and procedures for communication not well defined. | This issue applies to all Exelon stations. |

**Risk Assessment:**

| Plant-specific nuclear safety risk consequence | Basis for Determination |
|---|---|
| None | There are no plant specific risks associated with this issue. There are no risks to the CW Blowdown system as a result of this issue, since the leaking (failed) vacuum breaker assembly would still function to prevent a vacuum from forming and causing damage to the CW Blowdown piping. This issue has absolutely no impact for core damage/accident mitigation. The event was reportable under Reportability Manual, SAF 1.9, News Release or Notification of Other Government Agencies. |

**Previous Events:**

The only previous event in terms of Braidwood's response to the release of a contaminant to the nearby environment would be PIF A2000-02683, Oil in North Runoff, where fuel oil from an overflowed oil separator had the potential to impact residential drinking water wells in Godley. This event is summarized as part of the discussion of events found in the search of the INPO web site.

Braidwood has had numerous leaks from the Circulating Water Blowdown piping, and two of the events resulted in significant flooding of the local areas. The previous events table contains a summary of leaks identified from records in the Corrective Action Program and the Work Control Process, including the Station's response. The majority of the below leaks were minor. However, to verify this, wells were drilled in the area of each of the Vacuum Breakers and tritium samples analyzed. No identified leaks were found to have radioactivity with the exception of VB-1, VB-2, VB-3, VB-4 and VB-7.

The INPO website was searched for Operating Experience (OPEX) using the terms tritium, release, offsite, and groundwater. Passport was also searched using similar parameters. There have been numerous events concerning releases to the environment at numerous sites. For the most part, the descriptions of the events do not discuss remediation or continuing monitoring, but rather a statement that no activity was released from the site or detected offsite.

One instance (Pickering, 1997) was found where the licensee attempted to remediate the tritium in the groundwater by flushing the ground with fire protection water. This did not reduce the tritium concentration in the groundwater.

Only one event (Waterford, 2003) reported detectable increases in offsite tritium due to a primary to secondary tube leak.

The 2000 overflow of a Braidwood oil separator was included because of its relevance in terms of impact to the public and station response.

The following are summaries of relevant events in chronological order:

| Previous Events | Previous Event Review |
|---|---|
| **INPO** | |
| Oyster Creek, 1-20-81<br><br>SER 4-81 | Condensate storage and radwaste transfer piping leaks resulted in underground release of radioactive liquid. No remediation was performed. |
| Hatch, 12-3-86, OE1905, Operating Plant Experience | 124,500 gal from a spent fuel pool leak went into the storm drain system and eventually reached a swamp area within the owner-controlled property. The water discharge resulted from a loss of air to the inflatable seals used in the transfer canal between the Units 1 and 2 Spent Fuel Pools. The area was decontaminated, and no activity was detected outside Georgia Power property. |
| Prairie Island, 5-1-92, PNO3-92-023, Elevated levels of tritium detected in onsite well | Elevated levels of tritium (concentrations of 1, 300 to 1,500 pCi/L) were detected in an on-site groundwater well. Off-site wells sampled showed no increase in levels of tritium. |
| Dresden, 10-19-94, OE7067, Cathodic Protection System Degeneration | Degraded cathodic protection system and breached wrapping of underground piping results in through-floor pitting in both contaminated condensate storage tanks and three radwaste tanks between 1992 and 1994, through-wall pitting on the HPCI test return line and a demineralized water line, and underground fire protection piping degraded in several areas. The leakage was characterized and a remediation plan to monitor the tritium plume was implemented. |
| Pickering A, 7-18-97, SER PD97184, Elevated Concentrations of Tritium in Groundwater | Since 1979, groundwater at the upgrader plant Pickering A (UPP-A) has had tritium levels in the surrounding groundwater that are above background. Several attempts have been made to reduce the tritium concentrations in the groundwater including pumping groundwater with low levels of tritium to the lake and flushing the area with fire protection water. Tritium concentrations in groundwater, however, remained constant. Increased tritium is due to spills and unplanned releases and not taking appropriate action to remediate the area after spills or discharges. |
| Braidwood, 6-25-00, PIF A2000-02683, Oil in North Runoff | Oil separator #1 overflowed into the north runoff and offsite. Root Causes were inadequate preventative maintenance of the north runoff ditch and the oil separator. A significant contributing factor was the inoperability of the oil separator high-level alarm. Remediation and off-site sampling was performed to mitigate and assess the impact to the public. |
| Limerick, 2-18-02, Event Number 352-020215-1, Tritium Identified in Normal Waste Water Holding Pond and Auxiliary Boilers | Tritium concentrations of 10000 pCi/L were detected in the normal waste holding pond. There was no plant impact, no personnel exposure, and no release above regulatory limits to the environment. Groundwater monitoring is not performed. |

| Previous Events | Previous Event Review |
|---|---|
| Salem, 9-18-02, OE15788, Spent Fuel Pool Leakage, and OE15859 Tritium Detected in Groundwater Samples from On-site Monitoring Wells (Follow-up to OE15788) | Leakage from the Unit 1 Spent Fuel Pool as a result of clogged telltale drains was found. To determine the affect of the leakage on site groundwater, 8 monitoring wells were installed as reported on 3-19-03. Tritium results were as high as 69,200 pCi/L in one sample, and positive results were found in 4 other wells. As reported on 7-25-03, sample results obtained from new wells indicate tritium concentrations of 3.5M pCi/L and 125K pCi/L. Gamma scans of samples from both locations detected no other radionuclides. There is no indication of any offsite release and there is no threat to the public or company employees. On 5-3-04, NRC Information Notice 2004-05: Spent Fuel Pool Leakage To Onsite Groundwater is issued describing the Salem event. |
| Waterford, 2-28-03, OE15894, Substantial Rising Trend in Tritium Activity Measured at Radiological Environmental Monitoring Program (REMP) Sample Location at Waterford | Primary to secondary leakage from steam generator tube/tube plug degradation resulted in an increase in secondary tritium levels and approached a reporting limit listed in the Technical Requirements Manual (TRM) for a local drainage canal. |
| Dresden, 7-31-04, CR248494, High Tritium Activity In On-Site Wells and Storm Drains | HPCI suction line had been leaking since Nov 2003. Up to 6M pCi/L was detected in monitoring wells and storm drains on site. Hydrology study shows the event does not affect residential wells near the site. Routine monitoring established for 1994 event had been discontinued. Remediation consists of quarterly monitoring of plume as it dissipates, verifying it does not migrate off site. |
| Braidwood, 12-8-04, OE19305 / OE19623, Station Challenges Effluent Quarterly Dose Limits During Unit 1 Outage | Site approaches ODCM quarterly dose limits of 7.5 mrem/unit following the A1R11 refueling outage due to failed fuel conditions. The cause of challenging the offsite dose limit is that the effluent release procedures and processes did not have limits or controls in place to account for failed fuel conditions. |
| Watts Bar, 2-8-05, OE20318, Onsite Groundwater Tritium Above Reporting Limits | 550,000 pCi/L discovered during routine onsite environmental monitoring. No tritium has been detected in water samples from offsite monitoring locations, public drinking supplies, or the Tennessee River. Source is from a Cooling Tower Blowdown Line or previous leakage from a temporary effluent line. |
| Indian Point, 9-1-05, OE21506 Spent Fuel Pool Hairline Crack | Hairline cracks in the liner of the Unit 2 spent fuel pool are found. On 10-5-05 (Event Report 42014), 21100 pCi/L of tritium was detected in monitoring well MW-111 located in the Indian Point 2 transformer yard. Other wells showed negative. The sampling that was done was part of an ongoing investigation to verify and quantify previously identified leakage, potentially from the spent fuel pool. Continued sampling discovered tritium in 6 of 9 on-site wells. |
| Haddam Neck, 10-31-05, Event 42099 | Spent Fuel Pool leakage to the site groundwater was discovered when removing soil east of the Spent Fuel Building. The quantity of water leaked is unknown. Estimates based on historic Spent Fuel Pool evaporation data indicate that the leak was small - on the order of a few gallons per day. Based on readings from down-gradient monitoring wells, there is no travel offsite. |

| **CAPSYS search using "b/d," "blowdown," "0WC0% or 0WC1%" and "vacuum" (4 searches).** | |
|---|---|
| 12-5-98 - A1998-04324, CW Blowdown Vacuum Breaker Leak – pond of water found on property, with standing water in road ditch along Smiley Rd. | AR written Monday after Southern Div. PR contacted by neighbor. Se sighted leaking vacuum breaker from the south was unaware of the "pond" to the north. Chemistry contacted environmental services. AR status changed to B1 due to possible release permit violation. This incident was initiated when (name removed) was contacted about the pooled water by a local resident. (name removed) and (name removed) investigated and noted the pool was located on station property. There was minor puddling in the adjacent ditch but this water did not run off. Environmental services was consulted and since the ponded area was restricted to station property there was no NPDES concern. The blowdown system was shut down to isolate the vacuum breaker and stop the leakage. WR 980127749 was written to repair the vacuum breaker. The work was performed over the weekend of 12/5. The station response to this event was excellent. Maintenance had this repaired in ~24 hrs. This failure had prevented the station from performing liquid releases. |
| 11-7-00 - A2000-04281, Failed Circulating Water Blowdown Vacuum Breaker Caused Unplanned Flooding Outside the Power Block - 0CW136 CW blowdown valve was found leaking past its main seat. | The valve had been in this condition for an unknown period of time, most likely several days. The ground in the nearby area is sandy and drains quickly. The ground was saturated with water. Upon the discovery of the leak operations isolated CW blowdown on the afternoon of 11/6/2000. Draining of the piping to effect the repairs was started on the morning of 11/7/2000. The 0CW135 (manual isolation to 0CW136) and the 0CW136 CW blowdown vacuum breaker valve were replaced with new valves by 1600 hrs 11/7/2000. Once a year a visual inspection of the blowdown and make up lines is performed, including the vacuum breakers. The float in question is an internal part and can not be inspected without disassembly of the valve. A degraded condition could be found by noting some leakage past the valve seats. This is the first failure of this type. A schedule of replacements will be proposed to the PHC by the system engineer to prevent reoccurrence. Extent Of Condition; the same/similar valve is used in several places on the CW make up and blowdown piping. Byron has a CW makeup and blowdown pipe, however it is not known if Byron has vacuum breakers and if so what type of vacuum breakers. A message was left for the Byron CW system engineer about this problem. |
| 11-17-00 - A2000-04389 (39223), Inadequate response to 1998 CW vacuum breaker valve leak. | The station's response to a December 1998 CW vacuum breaker valve (0CW060) failure appears to have been inadequate. No evidence can be found to documenting any follow-up sampling, surveys or reporting requirements. PIF# A1998-04324 details the station' response to the 1998 leak. This issue was discovered during the present root cause investigation for the CW vacuum breaker valve failure (0CW136). |
| 11-30-00 - A2000-04465, Slow response to implementing Event Response Guidelines/NGG Issues Management procedure. | Station was slow to implement event response guidelines, CWPI-NSP-AP-1-1, or NGG Issues Management, OP-AA-101-503, for the CW blowdown vacuum breaker failure that was discovered on 11/06/00. NGG Issues Management was not entered until 2+ days after discovery of the valve failure when rad sample results indicated detectible levels of particulate radioactivity from the spill. |

dispositioned ?

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| 6-18-01 - A2001-01806, CW B/D Valve Leaking. | Unauthorized Release Path? [#3 & 11]– 0CW060 was found seeping water from between the vacuum breaker float and the Buna-N seal. Leakage appears to be about 1 gal/2 hours. As discovered during the investigation of CR# A2000-04281, periodic maintenance of the circulating water blowdown vacuum breaker valves had not previously been up to the standards desired by the station. A campaign was initiated in Q2 2001 to repair/replace as necessary these vacuum breaker valves. When the vaults were opened, four were discovered to contain water (vaults housing 0CW060, 0CW144, 0CW075 and 0CW078). Radiological analysis of the water revealed 2 of the 4 vaults with radioactive material present in the water (0CW060 and 0CW078 showed activity). |
| 7-9-01 - A2001-02016 (56710), Weaknesses Identified in Documentation of RCR For CW Blowdown Valves. | A review of a root cause report titled "Circulating Water Blowdown Line Vacuum Breaker Failure Due To Low Stress, High Cycle Fatigue, Resulting In Flooding Of Owner Controlled Property And Discharge Outside Of NPDES Approved Path" determined that there were weaknesses associated with the report documentation (reference CR# A2000-04281 and ATI# 38237). Although the report was well written, the review identified that the description of the Corrective Actions to Prevent Recurrence (CAPRS) lacked the clarity needed for mechanical maintenance to understand the full scope of work required to execute the CAPR. Furthermore, it appears that scheduling issues were not fully considered when the due dates were set. |
| **Passport search using "blowdown or vacuum" and "0WC0% or 0WC1%" (2 searches)** | |
| 5-4-02 - 106767, Small leak identified from 0CW060 blowdown valve assembly [#3]. | 0CW060, CW blowdown vacuum breaker, was identified as having seepage from the vent on the air release valve, (air release valve is part of the entire vacuum breaker assembly but sits adjacent to the main vacuum breaker valve). Main vacuum breaker valve appeared SAT, no leakage. Water level in pit was 30" from top of manhole. No evidence of leakage outside of the manhole was noticed. Water in manhole/pit appears to be a normal condition associated with groundwater infiltration into the manhole. |
| 8-20-03 - 172376, CW Blowdown Vacuum Breaker 0CW138 has 1 gpm leak [#4]. | Main vacuum breaker seat has 1 gpm leak. Water is draining to vacuum breaker pit only no area flooding is occurring. |
| 8-27-03 - 173204, 0WX26T release with suspected leakage from 0CW138 VB [#4]. | Modification testing associated with EC336241 was performed on 8/25/03. The testing required a release to be performed from the 0WX26T release tank while blowdown flow was established at ~25,000 gpm. Seat leakage from the 0CW138 blowdown vacuum breaker most likely occurred during the time that blowdown flow was at a flow rate of 25,000 gpm. Based on field observations performed on 8/21/03 and 8/27/03 the suspected leakage from the 0CW138 during the time of the 0WX26T release was between .25 and 1 gpm, (Note: 0WS26T release occurred between 0630 and 0710 on 8/25/03, Release package L03-104.) Field observations of the 0CW138 were also performed at blowdown flowrates of between 12,000 & 14,000 gpm. These observations indicate that no leakage occurs at these lower flow rates and that the vacuum breaker appears to be open, (Note: 0CW138 open with no leakage indicates that the blowdown pipe is not completely full at the lower flow rates.) |
| 8-29-03 - 173688, Water in Vacuum Breaker Pit for breaker 0CW060 [#3]. | While performing the annual vacuum breaker surveillance we discovered water in the pit containing breaker 0CW060. WR # 00110407 was initiated. |
| 9-11-03 - 175241, 0CM138 leaking at high CW blowdown flowrates [#4]. | When CW blowdown was increased per BwOP CW-12 to approximately 22,000 gpm, 0CW138 was discovered to be leaking at 5 drops per minute. |

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| 11-17-04 - 274328, Vacuum Breaker 0CW069 Is Leaking [#8]. | While performing 0BwOS CW-A1 vacuum breaker 0CW069 was popping/leaking. The leakage was small and contained within the vacuum breaker's valve pit. Per the Limitations and Actions of the procedure the Shift Manager and RP were notified immediately. Chemistry was notified of the potential for an NPDES violation. System Engineering was contacted for guidance and it was determined that the 0CW068 valve would be maintained closed to isolate the vacuum breaker leakage. The System Engineer recommended that two adjacent vacuum breakers not be isolated with CW blowdown in operation. An EST (37096) was generated to document the abnormal position. |
| 4-25-05 - 328451, Tritium Indicated In Samples Taken From Onsite Culvert. | Two samples results from onsite property located on the downstream side of the culvert at the old A entrance gate came back from the vendor with tritium indicated on the results. Specifically, the analysis results from Environmental Inc. Midwest Laboratory (EIML) indicated results of 539 +/-121 pCi/L tritium (sampled on 03/24/05) and 582.963 +/- 112.314 pCi/L tritium (sampled on 04/07/05). |
| 5-18-05 - 336401, CW BD Vacuum Breaker 0CW058 Pilot Valve Leaking 20 DPM [#1]. | CW BD Vacuum breaker 0CW058 pilot valve leaking 20 DPM. Need WR to repair. |
| 5-24-05 - 338111, 0CW140 Blowdown Vacuum Breaker Valve Leaking From Seat [#6. | While performing ER-BR-400-101, 0CW140 blowdown vacuum breaker valve was observed to have continuous seepage of water from the valve float/seat area. The leakage is small enough to be contained within the vacuum breaker valve pit with approximately one foot of standing water in the pit. |
| 9-8-05 - 371248, NRC Questions On Previous Actions With CW B/D vacuum breakers. | During NRC debrief on 8/31/05, there was discussion regarding the CW blowdown vacuum breaker, 0CW058, leakage that was identified in May 2005 (Reference IR 336401). A previous root cause was performed for vacuum breaker failures that occurred in 2000. The NRC question is: Subsequent to 0CW058 leakage identified in May 2005, were the root cause actions reviewed for adequacy? If so, what was the conclusion? |
| 11-30-05 - 428868, Elevated Tritium Levels In On-Site Monitoring Wells. | Elevated levels of tritium have recently been identified in certain on-site groundwater sampling wells. The exact source has not been located nor has the source been determined to be active or historical. |

## Corrective Actions to Prevent Recurrence (CAPRs):

| Root Cause Being Addressed | Corrective Action to Prevent Recurrence (CAPR) | Owner | Due Date |
|---|---|---|---|
| Causal Factor 1, Root Cause: Procedures - lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. | Implement an integrated set of liquid environmental spill procedure(s) that address mitigation and remediation of those spills. | A8932CHEM | 9/20/06 |

## Corrective Actions:

| Cause Being Addressed | Corrective Action (CA) or Action item (ACIT) | Owner | Due Date |
|---|---|---|---|
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Revise the Midwest ODCM and/or program procedures to incorporate the State of IL requirement of <20,000 pCi/L of tritium for groundwater. | NCS<br>A8076CHEM | 05/29/06 |
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Clearly define to each station (extent of condition), the changes to the ODCM based on review of Illinois, Pennsylvania and New Jersey laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure fleetwide sites specific ODCM reflects and implements applicable regulations. | NCS<br>A8076CHEM | 05/29/06 |
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Revise the reportability manual for ODCM REMP/RETS reporting requirements, 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. Create additional actions as warranted. | NCS<br>A8002RAPO | 05/29/06 |
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Review the reportability manual for ODCM REMP/RETS reporting requirements, 35 IAC 611/620 to ensure that all requirements (extent of condition) are being met with respect to Groundwater Release Path, limitations, and Illinois SB241 Community Right to Know requirements. Create additional actions as warranted. | NCS<br>A8002RAPO | 05/29/06 |
| Causal Factor 3, Regulations/ Oversight: NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Submit Procedure change to revise CY-AA-170-000 and associated procedures to require audits of the ODCM at an acceptable frequency and review the need for revision to include State regulations review into Step 4.2.1 basis of the ODCM. Create additional actions as warranted to assure the ODCM is in accordance with applicable requirements. | A8932CHEM | 06/28/06 |
| Causal Factor 3, **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Review the process by which new environmental regulations are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. | NCS<br>A8015 ENV | 03/28/06 |
| Causal Factor 1, rad spill procedure(s) does not exist. | Chemistry to charter a team to ensure appropriate personnel are assigned to assist in developing the procedures necessary for responses to potential radioactive spills of liquid that may affect the environment. | A88932CHEM | 02/20/06 |

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|---|---|---|---|
| Causal Factor 4, **Notification:** Processes and procedures for communication not well defined. | Develop fleetwide environmental spill procedure(s) for response to mitigate and remediate environmental spills with the potential for radioactive release to the environment. Assign additional actions to ensure this procedure is integrated into other procedures / processes as necessary. | NCS<br>A8015 ENV | 6/20/06 |

**Effectiveness Reviews (EFRs):**

| CAPR / CA being addressed | Effectiveness Review Action | Owner | Due Date |
|---|---|---|---|
| EFR assignment for CAPR#1- Lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. | Evaluate if implemented environmental spill procedure(s) for integrated response to mitigate and remediate environmental spills with the potential for radioactivity have been challenged to determine if the CAPR was effective. If not challenged, develop a tabletop drill to challenge the CAPR and determine effectiveness. | A8932CHEM | 6/20/07 |
| MRC assignment for EFR | Present the EFR to MRC. | A8932CHEM | 6/27/07 |

## Programmatic/Organizational Issues:

| Programmatic and Organizational Weaknesses | Corrective Action (CA) or Action Item (ACIT) | Owner | Due Date |
|---|---|---|---|
| ODCM requires evaluation of groundwater pathway if credible | Evaluate the groundwater and food crop pathway per ODCM Tbl 12.5-1 Section 3.a note (6). Assign additional actions as necessary, if the pathway is credible. | A8932CHEM | 3/15/06 |
| ODCM requires evaluation of groundwater pathway if credible | Revise the Site specific portions of the ODCM to incorporate the new monitoring wells as determined by the ODCM Environmental Specialist to be credible groundwater (well water) monitoring sources into the ODCM Tbl 11-1 Section 3.a note (6) and ODCM REMP Tbl 12.5-1 Section 3a Note (6). | A8932CHEM | 3/15/06 |

| Programmatic and Organizational Weaknesses | Corrective Action (CA) or Action Item (ACIT) | Owner | Due Date |
|---|---|---|---|
| **Causal factor 2** RP Personnel not all aware of concern with CW B/D piping and condensate being tritiated water | Generate TR to analyze the level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. | A8931RP | 02/28/06 |
| **Causal Factor 2** Not all Chemistry Personnel are aware of concern with CW B/D piping and condensate being tritiated water | Generate TR to analyze the level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. | A8932CHEM | 02/28/06 |
| No shutdown precautions during a release for a leak in the Blowdown system | Ops to add precautions to BwOP CW-12, BwOP WX 526TI, & BwOP WX-501TI for release shutdown on leak to environment. | A8910OPS | 5/29/06 |
| **Causal factor 2** Not all Operations Personnel are aware of concern with CW B/D piping and condensate being tritiated water | Generate TR to analyze the level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. | A8910OPS | 02/28/06 |
| 50:75(g) (NSP-RP-6101) does not clearly address $H^3$ | RP manager to take issue to peer group to evaluate other pathways specifically underground tritium and initiate follow up ATI's for any procedure changes. | A8931RP | 5/1/06 |
| **Causal factor 2** No training on a response to a liquid radiological spill for requirements of Title 35 IAC part 620 ground water quality | Track TR#05-1721for training to evaluate and incorporate NEIT, NGET requal, for enhanced module on Rad OPEX's of this RCR. | A8961TRLS | 5/1/06 |

## Other Issues:

| Other Issues Identified During the Investigation | Corrective Action (CA) or Action Item (ACIT) | Owner | Due Date |
|---|---|---|---|
| Other Issue a, **Alarms/ Annunciators:** Initial design did not include continuous monitoring for leakage. | Review operation of the CW blowdown system and determine the optimum monitoring scope and frequency of inspection PM's and walk downs for the System. If applicable, identify gaps and create additional ATI's as required. | A8930TT | 03/24/06 |
| **Failure of pipe and valves** | Braidwood System Engineering to research and evaluate passive vacuum breaker replacement options and present findings to PHC for approval if the CW Blowdown system will be used for radwaste releases in the future. | A8930TT | 03/24/06 |
| Other Issue "a", **Alarms/ Annunciators:** Initial design did not include continuous monitoring | System Engineering to work with Design Engineering to research and evaluate viable remote monitoring instrumentation systems that can detect lower level external leakage from the blowdown system and automatically notify Braidwood Operations if the CW blowdown system will be used for radwaste releases | A8930TT | 03/24/06 |
| Other Issue "b", **Work Orders:** Work Analyst standards do not include requirements for low level radioactivity. | RP to provide information to Work Planning so that a work standard can be created for work activities that involve potentially tritiated water. This information will be used to update PM model work orders and current work orders involving potentially tritiated water. | A8931RP | 3/10/06 |
| Need a higher priority for response to low level radioactive water being released to the environment | Work Control to discuss a proposed revision of WC-AA-106 to the peer group to incorporate the need for a higher work priority for response to low level radioactive water being released to the environment. Create additional ATI's as required. | A8940WC | 5/29/06 |
| Other Issue "b", **Work Orders:** Work Analyst standards do not include requirements for low-level radioactivity. | Using the information provided by RP, create a work standard to be used for work activities that involve potentially tritiated water and update PM model work orders and current work orders involving potentially tritiated water. | A8925PLN | 4/10/06 |
| **Regulations/ Oversight:** NOS and Corporate Owner reviews did not detect ODCM not containing all applicable regulations. | Discuss this RCR with the Corporate NOS Peer Group to evaluate changing the NOS frequency auditing template standard for the ODCM Program. Document results. | A8921NOA | 03/28/06 |

**Communications Plan:**

| Lessons Learned to be Communicated | Communication Plan Action | Owner | Due Date |
|---|---|---|---|
| Elevated tritium levels in on-site monitoring wells; | Submit Preliminary NER for this event | A8932CHEM | Complete |
| Elevated tritium levels in on-site monitoring wells; | Submit preliminary NNOE for this event. | A8932CHEM | Complete |
| Blowdown line, Secondary System Condensate and other low level tritium system leaks impact to State and Federal regulations for ground/drinking water. | Interim Corrective Action<br>Create a station alignment slide that discusses the root cause and actions for station personnel when they discover liquid spills or liquid in areas where there should not be liquid. | A8932CHEM | 02/06/06 |
| Elevated tritium levels in on-site monitoring wells; Spills of liquids with low level radioactivity may impact State and Federal regulations. | Submit supplemental NER for this event. | A8932CHEM | 02/03/06 |
| Elevated tritium levels in on-site monitoring wells; Spills of liquids with low level radioactivity may impact State and Federal regulations. | Submit supplemental NNOE for this event. | A8932CHEM | 02/10/06 |

# ROOT CAUSE REPORT

## ATTACHMENTS

| # | Title | Notes |
|---|---|---|
| 1 | Circ Water Blowdown System BACKGROUND INFORMATION | |
| 2 | Interviews | |
| 3 | Summary of Applicable Regulations for Tritium Releases to the Environment | |
| 4 | Reportability Manual - Applicable Sections | LS-AA-1020 and LS-AA-1110 |
| 5 | Tritium Plume Map | |
| 6 | Barrier Analysis | |
| 7 | Cause & Effect Analysis | |
| 8 | E&CF Chart | |
| 9 | Kepner-Tregoe Analysis | |
| 10 | Off-Site Dose Calculation Manual Review | |
| 11 | Review of Exelon Hazmat spill response procedures | |
| 12 | Change Analysis | |
| 13 | Root cause charter | |
| 14 | LS-AA-125-1001, Root cause report quality checklist | |
| 15 | VB-2 and VB-3 detailed timelines | |

# Attachment 1
# Circ Water Blowdown System
# BACKGROUND INFORMATION

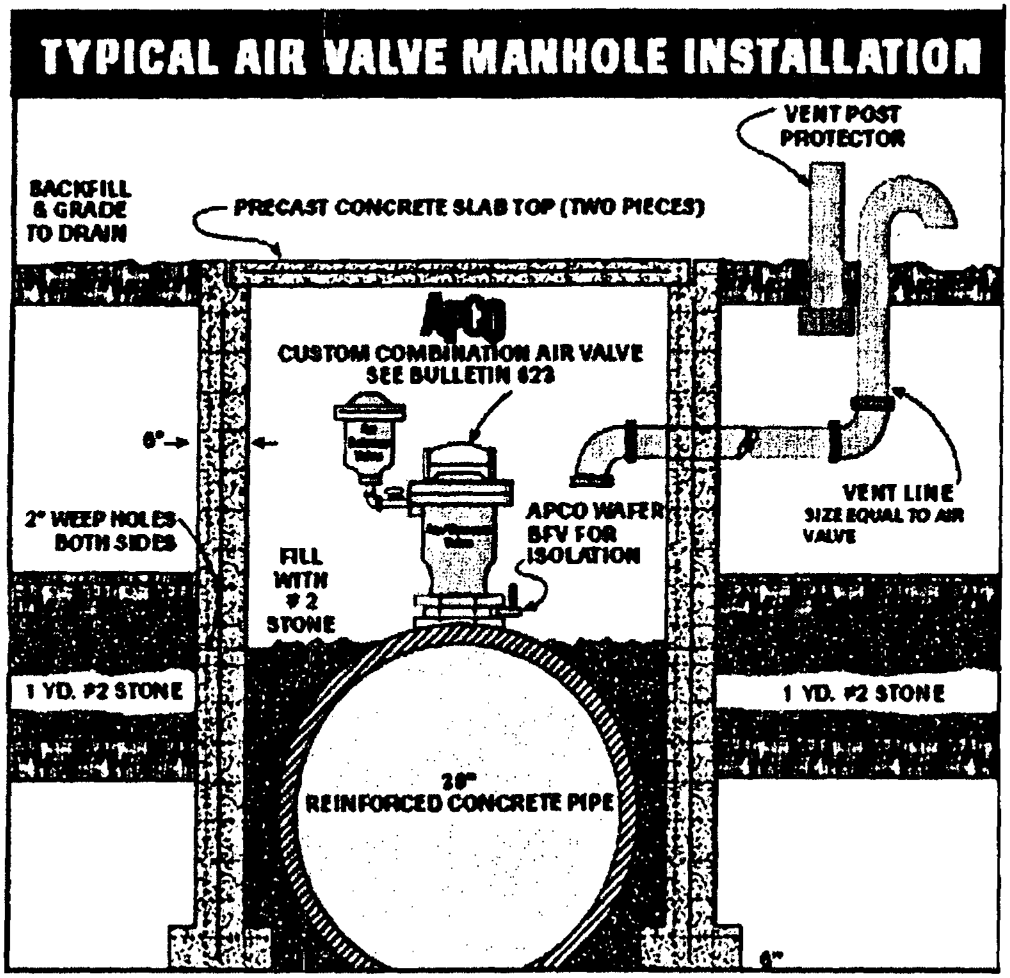
The primary function of the Circulating Water Blowdown System is to provide for lake turnover to prevent undesirable chemical buildup in the lake. The secondary function of the Circ Water Blowdown System is to provide dilution for liquid rad waste releases.

The Circulating Water Blowdown System is designed to return Cooling Lake water back to the Kankakee River. Processed fluids from the Sewage Treatment System and the Radwaste Treatment Systems discharge directly into the Circulating Water Blowdown system, where dilution occurs prior to release to the Kankakee River. The Wastewater Treatment Plant and the Demineralizer Regenerant Waste systems along with various strainer/filter backwashes are returned to the Cooling Lake and thus are indirectly returned to the Kankakee River through the Blowdown line after dilution by the Cooling Lake.

The Circ Water Blowdown system begins at the Circ Water System supply piping to the condenser. Two 24" carbon steel pipes tap off the Circulating Water supply piping (one from each unit) and combine into a 36" common header. A motor operated isolation valve (1/2CW018) is provided on each 24" line. The 6" Radwaste Treatment System discharge pipe connects to the 36" blowdown header. Downstream of the radwaste connection, the blowdown pipe is expanded to 48" prior to connection to the 3" Sewage Treatment Plant discharge pipe.

The 48" diameter blowdown pipe is reinforced concrete pipe (RCP) and runs along owner controlled property until reaching the Blowdown structure at the Kankakee River. Eleven vacuum breaker assemblies are incorporated at the high points along the 48" diameter RCP to prevent pipe implosion when the blowdown system is shut off. The 48" RCP is split and reduced to two 24" discharge pipes at the Kankakee River blowdown structure. Each 24" discharge pipe was originally equipped with a motor operated spray valve, 0CW018A/B. The entire piping network is approximately 29,000 ft long and was originally operated at about 12,000 gpm (~2.5 ft/s).

The Circ Water Blowdown system was originally designed to be maintained full and pressurized. This was accomplished through manipulation of the Blowdown Spray Valves, 0CW018A/B at the Kankakee River blowdown structure. These valves were susceptible to freezing due to their location and system operation requirements. Based on this, other maintenance issues, and parts obsolescence, these valves were eventually abandoned in the full open position in the late 1980's. To allow air release from the piping on start-up and to allow air introduction to protect against vacuum damage to the piping, vacuum breakers were installed.



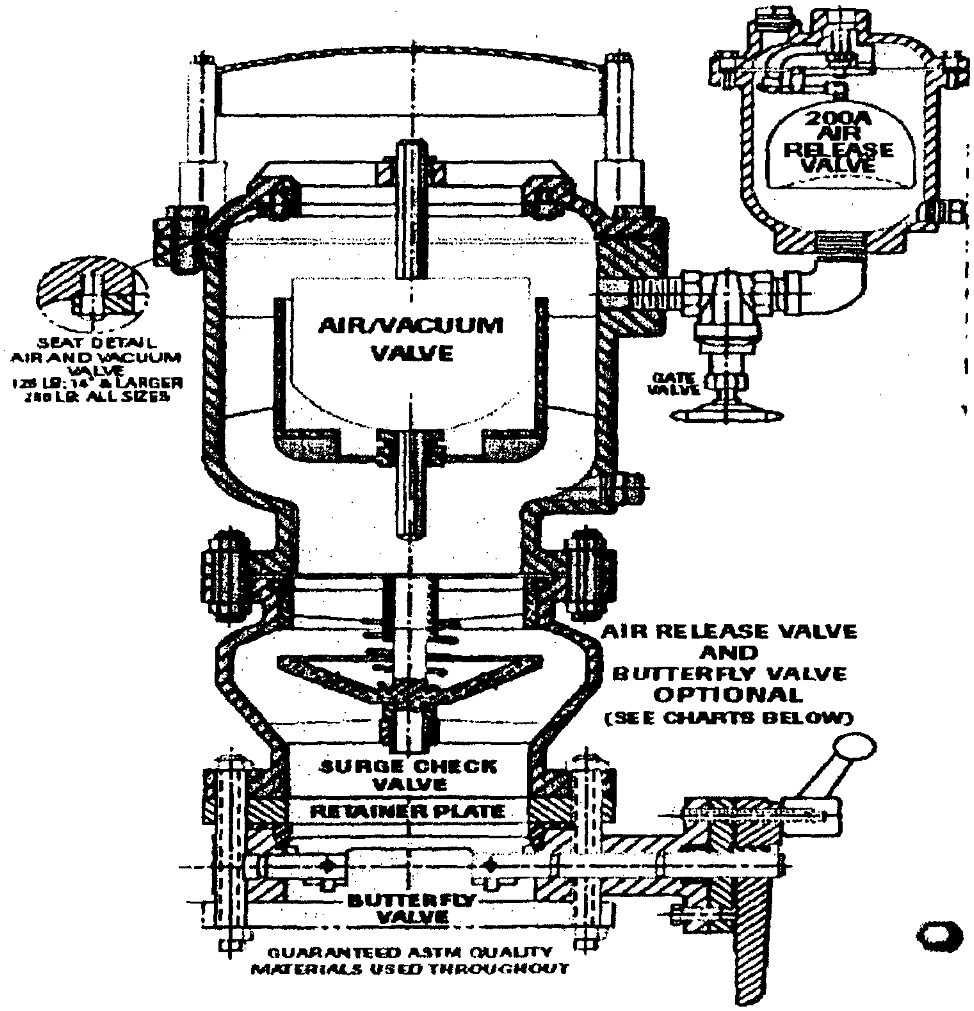

System control was transferred to the upstream motor operator isolation valves (1/2CW018) located in the turbine building. This modification caused the blowdown line to operate in a partially voided condition in various locations, depending on elevation which allowed column separation water hammer events to occur when flow rates were changed significantly, i.e.; during system start-up or shut down. Events were not initially seen because blowdown was essentially in service all the time. As a result of this modification, the blowdown system would no longer be maintained full and pressurized upon shutdown. Minimal technical review was performed on the hydraulic transient effects on the vacuum breakers from this method of operation (i.e.: surge check valves were not evaluated for system incorporation).

In 1997, the Chemical Feed System was relocated from the Turbine Building to the Lake Screen House under modification M20-0-95-003. One of the primary reasons for centralization of the Chemical Feed system to the Lake Screen

House was to reduce maintenance cost. This design change necessitated isolating the Circ Water Blowdown System on a daily basis to accommodate biocide injections into the Circ Water System, because our permits do not authorize discharge of biocide to the Kankakee River. When both units were in operation this was not an issue because partial blowdown flow was maintained from the unit not being chlorinated. The problem became apparent during outages when one unit was shut down. In this configuration, blowdown flow was stopped and started whenever the operating unit was chlorinated.

The daily requirement to isolate Circulating Water Blowdown for biocide injection, prompted the Operations Department to challenge the BwOP CW-12 procedural requirement to slowly open the 1/2CW018 valves for system start-up. BwOP CW-12 was revised to allow fast motorized operation of 1/2CW018, in lieu of slower manual throttling following short periods of system shutdown (i.e.: biocide injections).

Typical vacuum breaker:




Work history on the Circulating Water Blowdown System vacuum breakers was reviewed. There were no recorded vacuum breaker float assembly failures prior to 2000, however several instances of leaking air release valves were noted from the review. The 0CW060 air release valve was discovered leaking in 12/98. PIF # A1998-04324 was generated to address the flooding of site property and the Smiley Road ditch immediately adjacent to site property. The piping to the air release valve on the 0CW058 failed in 12/96. The complete vacuum breaker assembly including air release valve was replaced with a new assembly in 6/97. It should be noted that the 0CW058 vacuum breaker failed again on 11/20/2000 while this root cause investigation was in progress. The float assembly broke at the bowl to guide bar weld. No other significant work history was identified.

The failure of the 0CW136 float assembly was discussed with the vendor. Based on the failure description, the vendor indicated that it appeared to be consistent with the effects of a pressure surge (i.e.: water hammer). The vendor indicated that surge protection check valves should be considered for a vacuum breaker when pipe flows exceed 6 ft/s and are required when flow velocities exceed 10 ft/s. The vendor also recommended a 7-10 year PM frequency to address valve elastomer degradation. The condition was addressed by revising the operating procedure BwOP CW-12 to manually open and close the valves to slowly initiate or terminate blowdown flow.

The present circulating water blowdown system operates as follows. On system startup, the air/vacuum valve exhausts large amounts of air from the piping system until the float assembly in the air/vacuum valve rises with water level to close and seal during normal system operation. To prevent the inrushing water from causing damage to the air/vacuum valve float, a surge check valve is installed just underneath the air/vacuum valve. The surge check is a spring loaded, normally open valve, which passes air through unrestricted. When water rushes into the check valve, the disc begins to close against the spring tension and reduces the flow rate of water into the air/vacuum valve by means of throttling holes in the disc. This ensures gentle closing of the air/vacuum valve float, regardless of initial flow velocity into the valve and minimizes pressure surges. Upon system shutdown, the vacuum valve is designed to open as water level decreases. The air release valve provides two functions. The primary function is to release small amounts of entrained air that accumulates at the high points during normal system operation. If not removed, this air that would increase head loss and reduce process flow. The air release valve also facilitates earlier opening of the main air/vacuum valve on system shutdown. On shutdowns, air pockets that develop at high points may be at positive pressure, tending to hold the main air/vacuum float on its seat even though water level is below the float assembly. However, the air release valve will vent the air and allow the main air/vacuum valve to open as soon as water level drops. Each vacuum breaker is provided with a butterfly isolation valve to facilitate vacuum breaker maintenance.

Modification of 2001-2003 changed the design of the air / vacuum valve assembly to a slow closing design with the use of a surge protector valve in-line. This modification protects the air / vacuum valves from pressure surges experienced during water hammer events.

Modification of 2003 installed CW Blowdown Booster Pumps to increase the blowdown flow rate for improving lake chemistry. With increased flow rates during booster pump operation the volume of voided blowdown line may decrease, closing previously open air / vacuum valves under lower flow conditions. Start up and shut down procedures for the booster pumps specify flow / pump increase / decrease ramp rates to minimize potential column separation water hammer pressure surges.

Modification of 2005 installed a de-chlorination modification to allow continuous operation of the Blowdown System while performing unit chlorinations. This modification allowed blowdown to be in-service essentially all the time, reducing the potential for air / vacuum valves leaks caused by system flow rate changes.

No closing comment on the relevance of these modifications

# Attachment 2
# Interviews

**Interview Sheet**
**Braidwood Tritium Issue**

Operations Training Personnel: 11/06/05

Non- Licensed Operator (NLO) Training:

Q: What Lesson Plan is used to train NLOs for Radioactive Spills in the environment?
A: Historically, all NLOs where trained and qualified as Radiological Clean-up Techs with Radioactive clean-up training before they could enter NLO training. NGET & HazMat Spill Training are the currently implemented training classes that provide information that an NLO would use to respond to a spill.

Q: Is there an expectation for leaks from the CW Blowdown Vacuum Breakers?
A: Immediately Isolate/Mitigate, Secure the area, Notify the Shift (Main Control Room), Notify RP.

Licensed Operator Training [Initial (ILT) & Requalification (NSO)]:

Q: What Lesson Plan is used to train NSOs/Shift Managers for IRs that involve Radioactive Spills in the environment?

A: Reportability Manual Training with emphasis on recent changes to the operability Manual. Simulator scenarios are postulated as tests, with the Shift Managers, Unit Supervisors correctly characterizing the event per LS-AA-1020 and LS-AA-1110.

Q: Is there an expectation for leaks from the CW Blowdown Vacuum Breakers?
A: Review against Reportability Manual. However, if the blowdown was done per procedure, the radioactivity should be acceptable for the environment, as that is where it is being sent, the Kankakee River.

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## FIELD SUPERVISOR

**Interview questions**

1. *Two years ago, what would you do as (FS when you were informed) / (NLO when you noted) Circ Water blowdown vacuum valve leakage?*

   Send NLO out to investigate, shutdown CW blowdown and inform Shift Manager.

2. *Today, what would you do as (FS when you were informed) / (NLO when you noted) Circ water blowdown vacuum valve leakage?*

   Same actions as above, plus inform the Environs Group and take water samples.

3. *Is there any reportability requirements when a vacuum breaker leaks? (Not asked of this interviewee.)*

4. *When doing the CW blowdown vacuum breaker surveillance, how often do you see the valve leaking? (Not asked of this interviewee.)*

5. *Are there any other times, other than doing vacuum breaker surveillances, when you may observe leakage from the valves? (Not asked of this interviewee.)*

6. *What were the old blowdown rates before the booster pumps were installed?*

   Single unit blowdown 8K gpm. Both units 14K gpm.

7. *What are the typical flow rates with both booster pumps running?*

   25K-26K gpm

## FIELD SUPERVISOR

**Interview questions**

1. *Two years ago, what would you do as (FS when you were informed) / (NLO when you noted) Circ Water blowdown vacuum valve leakage?*

   Knew it would be an NPDS issue and would try and stop the leak ASAP. Would contact SM and Chemistry for evaluation of NPDS issue.

2. *Today, what would you do as (FS when you were informed) / (NLO when you noted) Circ water blowdown vacuum valve leakage?*

   Would stop leak ASAP. Inform SM and Chemistry. Would be concerned with tritium release potential.

3. *Is there any reportability requirements when a vacuum breaker leaks? (Not asked of this interviewee.)*

4. *When doing the CW blowdown vacuum breaker surveillance, how often do you see the valve leaking? (Not asked of this interviewee.)*

5. *Are there any other times, other than doing vacuum breaker surveillances, when you may observe leakage from the valves?*

   BwOP CW12 was changed in 2002 to inspect for leakage if flow changes outside limit occurs.

6. *What were the old blowdown rates before the booster pumps were installed? (Not asked of this interviewee.)*

7. *What are the typical flow rates with both booster pumps running? (Not asked of this interviewee.)*

## SHIFT MANAGER

**Interview questions**

1. *Two years ago, what would you do as (FS when you were informed) / (NLO when you noted) Circ Water blowdown vacuum valve leakage?*

   Would have checked reportability manual and taken actions to stop leak.

2. *Today, what would you do as (FS when you were informed) / (NLO when you noted) Circ water blowdown vacuum valve leakage?*

   Recognizes tritium issue and would try to stop leak and notify correct people.

3. *Is there any reportability requirements when a vacuum breaker leaks? (Not asked of this interviewee.)*
4. *When doing the CW blowdown vacuum breaker surveillance, how often do you see the valve leaking? (Not asked of this interviewee.)*
5. *Are there any other times, other than doing vacuum breaker surveillances, when you may observe leakage from the valves? (Not asked of this interviewee.)*
6. *What were the old blowdown rates before the booster pumps were installed? (Not asked of this interviewee.)*
7. *What are the typical flow rates with both booster pumps running? (Not asked of this interviewee.)*

## NLO

**Interview questions**

1. *Two years ago, what would you do as (FS when you were informed) / (NLO when you noted) Circ Water blowdown vacuum valve leakage?*

   Always reported any leakage to FS.

2. *Today, what would you do as (FS when you were informed) / (NLO when you noted) Circ water blowdown vacuum valve leakage?*

   Recognizes tritium issue – action would be the same, report leakage to FS.

3. *Is there any reportability requirements when a vacuum breaker leaks? (Not asked of this interviewee.)*

4. *When doing the CW blowdown vacuum breaker surveillance, how often do you see the valve leaking? (Not asked of this interviewee.)*

5. *Are there any other times, other than doing vacuum breaker surveillances, when you may observe leakage from the valves? (Not asked of this interviewee.)*

   He spent time with FIN team fixing the valves. Had several time they found leakage and reported it to FS and wrote IR's.

6. *What were the old blowdown rates before the booster pumps were installed? (Not asked of this interviewee.)*

7. *What are the typical flow rates with both booster pumps running? (Not asked of this interviewee.)*

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# Braidwood Circ Water Blowdown Issues and Questions

## QUESTIONS FOR SYSTEM ENGINEERS

1. **How many circulating water (CW) system owners have there been since circulating water blowdown system start-up? Five (5)**

2. **How often were/are the BD vacuum breakers inspected? Are there any predefines?**
   System Engineer # 1 – Never. No predefines.
   System Engineer # 2 – Twice per year. No predefines. Not documented except in system log.
   System Engineer # 3 – Twice per year undocumented. 2X per year after 2001, documented.
   System Engineer # 4 – Once per year by system engineering under PMID# 79293-01. Once per year by Ops under PMID# 98197-01. Replace each vacuum breaker every 10 years under PMID# 39012-01.

   Which system engineer is right, since all the answers are different? Why do we care what some engineers think about this, if their answers are not correct? There must be a right answer to the question.

3. **What was / is the historical response to finding standing water on the right-of-way or inside a vacuum breaker valve pit?**
   System Engineer # 1 – Never found any water.
   System Engineer # 2 – Wrote work request to repair. If standing water, MMD usually repaired within days.
   System Engineer # 3 – Wrote a work request and an IR. Repairs were often delayed months.
   System Engineer # 4 – Write a work request and an IR if it involves a component.

4. **What is the current response of work planning to a BD leak work request?**
   Per cycle planner, prior to the tritium "issue" a work request for the blowdown line or its components was assigned a "C" priority. Now, the planner refers to SC-AA-106, attachment 1, which is the priority screening check list. Item #16 has the planner refer to EN-AA-103-0002. This procedure has not been used yet, since a blowdown component has not failed since the tritium "issue" came up. It would probably be assigned a B1 priority.

5. **Was / is the system engineer aware of rad waste in the blowdown water and any limits or requirements if BD leakage is found?**
   System Engineer # 1 – Not aware of radwaste.

*System Engineer # 2 – Knew from systems training, however no commitments or procedures were known for addressing system leakage.*

**System Engineer # 3 – Was aware of radwaste. IR was directed to System Engineer # 6 and RP who filled out the 10CFR50.75.**

System Engineer # 4 – System Engineer # 4 is aware of the minimum blowdown requirements necessary to start a rad release, however he does not know any activity limits placed on the blowdown effluent.

6. **What modifications have been done on the BD system since starting operation? When were these modifications done?**

System Engineer # 1 – None.

*System Engineer # 2 – Howell/Bunger spray valves at river blowdown house were abandoned in place in the open position because no repair parts were available. (1/2CW218A/B?)*

**System Engineer # 3 – Circulating water chlorination injection was moved to the lake screen house (1997?). Because of this, blowdown valves inside the station (1/2CW018) were closed when that unit was chlorinated in order to prevent chlorine from entering the blowdown system. During an outage, isolation of the running unit's CW018 valve stopped blowdown flow. When opened again (15 seconds) a pressure pulse was sent down the blowdown line and was recorded to reflect as many as 13 times. Raw water on the carbon steel studs combined with the water hammer events, caused the VB1(?) to fail and fall to the bottom of the valve vault. Surge protectors were installed on each of the vacuum breakers to prevent water hammer. The most recent modification was the addition of blowdown booster pumps to increase max flow from 14,000 to 24,000 gpm.**

System Engineer # 4 – Dechlorination modification added near vacuum breaker 01.

7. **When did the water hammer events occur on the BD line?**

System Engineer # 1 – N/A

*System Engineer # 2 – N/A*

**System Engineer # 3 – Events occurred in 1997 after the chlorination mod was installed. Because of rapid closure of isolation valves 1/2CW018, water column separation and resultant water hammer occurred.**

System Engineer # 4 – System Engineer # 4 is not aware of any water hammer events since he has had the system.

8. **Was there an engineering evaluation for maximum pipeline pressure as a result of the water hammer? If not, why not?**

System Engineer # 1 – N/A

*System Engineer # 2 – N/A*

**System Engineer # 3 – No. Follow up action items did not include an evaluation.**
System Engineer # 4 - No

9. **Do we know of any potential OEM integrity problems with the concrete pipe?**
System Engineer # 1 – Did not know of any problems.

*System Engineer # 2 – Got a call from a lawyer about a class action lawsuit against Interpace Pipe for defective pipe. Issue was raised and design engineering took an action to look into it. System Engineer # 5 wrote up proposed action plan if a leak was ever identified. No further action was taken.*
System Engineer # 3 – Yes, he is familiar with Interpace pipe and the manufacturing defects. Quality issue in regards to material used for pre-stressing wire used around pipe. A different material than specified was used that was more susceptible to corrosion. Pipe is constructed with concrete layer inside of relatively thin steel pipe. Concrete layer on outside of steel pipe with wire on outside of outer concrete layer to pre-stress pipe. Third layer of concrete covers the wire.

Although Braidwood has not identified any failures of the piping someone should look into the piping failures at LaSalle in their make-up / blowdown piping and see if the same type pipe was used and what was the failure mechanism. (Reference IR 00435146 for review of this issue.) LaSalle probably has higher pressures at least in the make-up piping due to a greater elevation difference between the river and cooling lake.
Byron also has a greater elevation difference. The same design was used for make-up and blowdown at Byron and Braidwood and System Engineer # 2 remembers having to de-stage the Braidwood CW Make-up pumps because of the lower pressure required for make-up.

System Engineer # 4 – System Engineer # 4 is familiar with issue, however he doesn't know any details.

10. **How many sewage treatment (ST) system owners have there been since circulating water blowdown system start-up? Two (2) [known]**

11. **What external leakage issues have there been on ST? When? What were the remediation actions?**
System Engineer # 6 – The ST discharge check valve has failed in the past and allowed CW blowdown to backup into the sewage treatment system. However, this backup was into the 5000 gallon Clearwater storage tank. To the best of

System Engineer # 6's memory, ST has never overflowed into a drain sewer. Additionally, all sewers inside the fence flow into the north ditch, not into the creek east of the plant.

**12. What Pipe Integrity Verification plans are there, and was an analysis of peak pressure due to column separation water hammer performed?**

The Tritium Response Team is working on determining the current piping integrity using an acoustic monitor that will be sent down the pipe under flow and pressure conditions to acoustically determine if there are piping leaks. The team is also looking into some kind of testing like Eddy Current to determine the integrity of the wire used for pre-stressing the piping. There was no analysis of the water column separation induced water / air hammer events caused by closing the 1(2)CW018 valves electrically to determine peak pressures generated inside the piping. During the CW BD Booster Pump installation modification testing the pressure seen at pressure gage 0PI-CW027 was 37.1 psig which when corrected for elevation sets the highest pressure in the 48" concrete piping at 28 psig. The original piping was designed for 110 psig.

**13. Locate drawing to show configuration of how release line and blowdown piping are connected.**

A walkdown was performed, verifying that the release piping is connected to the top of the CW B/D piping. Hypothesis is that low release rate warm water with high tritium concentration enters top of blowdown pipe and due to relatively laminar flow and temperature striation does not mix with cold blowdown flow. When air / vacuum release valves fail they are located on the top of the blowdown pipe and allow high tritium concentration water to leak out.

There has been some conjecture that the warmer liquid radwaste would remain stratified in the blowdown line and result in higher concentrations of tritium at the top of the pipe and thus at the vacuum breakers. I had an engineer calculate Reynolds number to determine whether flow is laminar or turbulent. The result of that calculation determined that we have turbulent flow and the 2 streams will be fully mixed within a few pipe diameters. Also, the radwaste line enters the blowdown pipe (45 degrees) between the top and horizontal. Conclusion; the waste streams are fully mixed before they leave the plant.

**14. Is CW, specifically Blowdown application covered by the maintenance rule program or SHIP to monitor failures and corrective actions?**

The Circulating Water system, specifically the Blowdown portion, is not in the scope of the Maintenance Rule Program. The system is monitored through the System Health Indicator Program (SHIP).

flow / pump increase / decrease ramp rates to minimize potential column separation water hammer pressure surges.

Modification- (2005) Installed de-chlorination modification to allow continuous operation of the blowdown system while performing unit chlorinations. This modification returned blowdown to be in service essentially all the time reducing the potential for air / vacuum valves leaks caused by system flow rate changes.

**Radiation Protection Personnel Interviews**
**Questions surrounding the 1998 and 2000 CWBD leak**

None of the individuals from the Radiation Protection department were aware of the 1998 CWBD leak. No specific reason could be found for the RP organization not going to the leak site and reviewing the magnitude of the leak. The RP Technical Mgr that directed that the water from the 2000 leak be recovered, stated that had he known about the 1998 event he would have recommended the same action. The following RP personnel were interviewed:

Previous RP Manager
Previous RP Technical Mgr
Previous Off-Site Dose Calculation Manual (ODCM) Specialist
Previous site Health Physicist
Current RP FLS

The System Engineer originated the IR and stated that he recalled that he and the Site Environmental Specialist had discussed the 1998 leak in the RP Office area with someone from RP, but cannot recall details of the discussion. The System Engineer believed the RP person used words similar to "we would review the leak" and possibly "adding the leak to the list of 10CFR50.75(g) sites". No further actions were taken since the leak did not enter the public and RP was aware of the leak for evaluation.

The Site Environmental Specialist could not recall any information other than what was in the body of the IR.

The fact that the RP organization did not remediate the spill in 1998 was a missed opportunity to reduce the magnitude of the tritiated water leakage.

---

1 root cause for all 3 incidents?

## Response to Tritium sampling decisions made in 2000

-----Original Message-----**From:** (Name Removed) **Sent:** Thursday, December 22, 2005 10:48 AM
**To:** (Name Removed)
**Subject:** Requested Root Cause Information

(Name Removed):

As requested by (Name Removed) on December 22, 2005, I am providing information from (Name Removed - VP)'s information that was given to me by (Name Removed) when he resigned from Exelon.

a separate one

Info below relates to the 2000 Vacuum Breaker # 2 leak.
VP (Name Removed) was the assigned Issues Manager per OP-AA-101-503.
CRA calculated the length of time that tritiated water would reach resident wells and the answer was 15 years. – it would take care of it through the 50.75(g) process
Four groundwater monitoring wells were installed by CRA only to determine groundwater levels, flow rate and flow direction.
Decision tree put together by RP suggested that well monitoring requirements were either (1) residents or (2) drill own wells.
Talking points prepared stated that:

(b)(5)

- We are pumping water out of the trench to dispose of it properly.
  - License conditions allows us to discharge this material to the designated release point to the Kankakee River, not to the land or ditch.
  - Water in the ditch, although within release limits, was slightly above drinking water standards.
  - Removing water reduces chance of it entering the water table.

(Name Removed) was Corporate RPM at the time of the event.
(Name Removed), RP was consultant to VP (Name Removed).
(Name Removed) was the Site RP Manager at the time of the event.
January 18, 2001 memo from (Name Removed) to (Name Removed), (Name Removed - Corporate RPM), (Name Removed - RP), (Name Removed) and (Name Removed) documented NRC comments on the November 2000 blowdown line leak as follows:

- NRC comment was that the root cause report focused mainly on engineering aspects (failure analysis) and not much on recovery aspects.

Who was it? Steve? RP inspector?

- NRC comment was that it appeared that we did not sample any offsite soil or nearby drinking water wells. (We did not sample these locations by coconscious decision process, referring to decision tree). (Name Removed), NRC said that he understood our logic but thought it would be good to see negative results from these locations to support future cleanup, i.e., decommissioning.

- Some of the recovery aspects to be addressed in the 50.75 (g) report which will include a dose assessment by Millennium Services.

Knowledgeable here, but didn't follow-thru because of not

# Maintenance & Work Control Interviews

WC-AA-106 Work Screening and Processing

Procedure WC-AA-106 (Work Screening and Processing) does not have any given priority to known radiological leak that can enter the outside water table that are above the EPA ground and drinking water standards. Therefore that is why any vacuum breaker leak on the blowdown line has always been considered a "C" priority work request in the past. The station has took it upon itself to now code all of these leaks as a B2 's in the future per WC-AA-106 Attachment 1, item 19, (Equipment failure or malfunction that requires additional sampling or increases personnel exposure by a factor of two). Work Control stated there is no specific item that applies to leaks, and recommends the procedure be revised.

Verification of Byron issues on the blowdown valves show they are coded as "C" priorities. History shows their valves have had the possibility of leaks over several years prior to being repaired. Byron's history is quite small on the number of leaks.

This is considered a ***failed barrier*** due to the lack of direction in the procedure for leaks.

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# Predefines for Walkdown of CW BD lines

- PMID#00079293-01 every 12 months by Engineering (1/11/95)
  Last completed 6/30/05 WO#00698662
  Work instructions: Perform ER-BR-400-101 CW Blowdown/Makeup Vacuum breaker annual inspection
  - IR#336401 on 0CW058 leaking.
  - IR#338111 on 0CW066 leaking.

- PMID# 00098197-01 every 12 months by Operations (5/15/01)
  Last completed 11/14/05 WO# 00769127
  Work instructions: PERFORM 0BWOS CW-A1
  - IR# 00398085 on 0CW124 leaking.

Verified both procedures er-br-400-101 (unit common circulating water system blowdown and makeup vacuum breaker valve annual inspection) and 0bwos cw-a1 (unit common circulating water system blowdown and makeup vacuum breaker valve annual inspection) procedures are like for like. The only difference is in 0BwOS CW-A1 was the isolation valves are operated for testing. Both predefines are performed yearly at this time. System Engineering's predefined was initiated in 1/11/95 and was originally a semi-annual predefine that was switched to annual in 1996. Operations predefine was started in 5/15/01 due to the Root Cause A2000-04281 corrective actions under action tracking item 38237. Currently, as of September 2005, a walkdown is being performed monthly. Engineering will determine the appropriate frequency for the walkdown
Both procedures ER-BR-400-101 and 0BwOS CW-A1 state to contact Radiation Protection immediately if any leaks are discovered in the CW Blowdown system. Leaking CW Blowdown Vacuum Breakers shall be treated as possible NPDES violation and potentially contaminated (water/soil). The procedures lack in knowledge the requirements of Title 35 IAC part 620 for ground water quality, specifically State Tritium concentration limits. These procedures do not account for the spill entering the ground water source and potentially affecting drinking water of nearby wells. ***(Failed Barrier)***

# Chemistry/ODCM Interviews

In November of 2000, four monitoring wells (BMW-1-4) were installed near the vacuum breaker and the Circulating Water Blowdown (CWB) line by an environmental contractor following the 2000 vacuum breaker # 2 valve failure. The purpose of these monitoring wells installed to a depth of 15 ft. was to determine the impact of the CWB leak hydraulic gradient, groundwater elevations, and the groundwater velocity rate. Documents obtained from the environmental contractor showed through calculations that the groundwater originating at the vacuum breaker would take approximately 15 years to reach the property line located approximately 800 feet away.

In an e-mail message between the environmental contactor and the Corporate Environmental Department there is a discussion as to why the wells are required. The e-mail states there is a concern that two private homes are located within about 1000 feet of the vacuum breaker valve and that water has accumulated in a culvert near one of the homes. It is also inferred that the real concern is to manage tritium from the spill that has been analyzed at 2.5 E-05 uCi/ml near the culvert and concentration of the spill at the vacuum breaker to be 5.0 E-05 uCi/ml ant that these concentrations are right at or above the drinking water standard of 20,000 pCi/L. The email also discussed that legal council was sought and it was determined that there was no NPDES concern because waters of the state were not affected. There are no further documents that indicate that any additional water samples were taken from these wells and analyzed for tritium. No further wells were installed or groundwater analysis performed until summer of 2005.

*

**Regarding the statements found that implied 50% of the lake samples were greater than the release units:**

PIF A2000-01743, "Failure to Crisply Execute CW Vacuum Breaker Replacement Work Window" discusses difficulties encountered while setting up for the replacement of several CW blowdown vacuum breakers. In the case of repair of systems outside the Radiologically Controlled Area, the system would be sampled and analyzed to Unconditional Release criteria to demonstrate the lack of radiological activity to facilitate repair without further encumbering radiological controls.

Per the PIF, "Discussion with the Chemist indicated that about 50% of the lake sample tritium levels exceed the Unconditional Release Level limits." Because a "lake sample" discussed in this context would concern the lake water in the blowdown piping, this is a plausible assumption. Liquid Radwaste discharges are released via this piping on a routine basis. Although the lake blowdown water is not radiologically contaminated when it initially enters the system, the water becomes contaminated when mixed with liquid radwaste discharges, and would remain so until adequate blowdown volume reduces the concentrations by dilution. Because most discharges last several hours, and several more hours would be needed to flush the pipe, the characterization that the water in the blowdown piping would not meet Unconditional Release criteria half of the time is valid.

This needs much further explanation or, if not relevant, should be removed. I assume this is talking about the unconditional release criteria from the RCA, which is not the same as the criteria for allowed releases to the environment. ~~Most readers will not understand~~ this and it will be a source of needless confusion. Why is worth discussing here?

~ content

Like any system that contains radioactive fluids, even on a sporadic basis, it is reasonable to assume that Unconditional Release criteria would not be met part of the time. The Unconditional Release criteria are much lower than the Maximum Permissible Concentrations allowed by 10CFR20 for discharge of effluents to the environment. There is no indication that the event described in this PIF resulted in exceeding any regulatory criteria. This is not an issue in the context of regulatory limits for liquid effluent discharges.

- opinion?
- relevant?
- 1 person?

You have a question, who an answer

# Attachment 3
# Summary of Applicable Regulations for Tritium Releases to the Environment

TITLE 35: ENVIRONMENTAL PROTECTION

SUBTITLE F: PUBLIC WATER SUPPLIES

CHAPTER I: POLLUTION CONTROL BOARD

PART 620

GROUNDWATER QUALITY

Class I: Potable Groundwater

e) Beta Particle and Photon Radioactivity

1) Except due to natural causes, the average annual concentration of beta particle and photon radioactivity from man-made radionuclides shall not exceed a dose equivalent to the total body organ greater than 4 mrem/year in Class I groundwater. If two or more radionuclides are present, the sum of their dose equivalent to the total body, or to any internal organ shall not exceed 4 mrem/year in Class I groundwater except due to natural causes.

2) Except for the radionuclides listed in subsection (e)(3), the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalent must be calculated on the basis of a 2 liter per day drinking water intake using the 168-hour data in accordance with the procedure set forth in NCRP Report Number 22, incorporated by reference at in Section 620.125(a).

3) Except due to natural causes, the average annual concentration assumed to produce a total body or organ dose of 4 mrem/year of the following chemical constituents shall not be exceeded in Class I groundwater:

| Constituent | Critical Organ | Standard (pCi/L) |
|---|---|---|
| Tritium | Total body | 20,000.0 |
| Strontium-90 | Bone marrow | 8.0 |

(Source: Amended at 26 Ill. Reg. 2662, effective February 5, 2002)

ODCM

### A.2.2 Liquid Effluent Concentrations Requirement

**Requirement**
One method of demonstrating compliance to the requirements of 10CFR20.1301 is to demonstrate that the annual average concentrations of radioactive material released in gaseous and liquid effluents do not exceed the values specified in 10CFR20 Appendix B, Table 2, Column 2. (See 10CFR 20.1302(b)(2).) However, as noted in Section A.5.1, this mode of 10CFR20.1301 compliance has not been elected. (does it exist

As a means of assuring that annual concentration limits will not be exceeded, and as a matter of policy assuring that doses by the liquid pathway will be ALARA; RETS provides the following restriction:

"The concentration of radioactive material released in liquid effluents to unrestricted areas shall be limited to ten times the concentration values in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402."

This also meets the requirement of Station Technical Specifications and RETS.

### A.2.4 Tank Overflow

**Requirement**
To limit the consequences of tank overflow, the RETS/Technical Specifications may limit the quantity of radioactivity that may be stored in unprotected outdoor tanks. Unprotected tanks are tanks that are not surrounded by liners, dikes, or walls capable of holding the tank contents and that do not have tank overflows and surrounding area drains connected to the liquid radwaste treatment system. The specific objective is to provide assurance that in the event of an uncontrolled release of a tank's contents, the resulting radioactivity concentrations beyond the unrestricted area boundary, at the nearest potable water supply and at the nearest surface water supply, will be less than the limits of 10CFR20 Appendix B, Table 2; Column 2.

The Technical Specifications and RETS may contain a somewhat similar provision. For most nuclear power stations, specific numerical limits are specified on the number of curies allowed in affected tanks.

### A.2.5 Operability and Use of the Liquid Radwaste Treatment System

**Requirement**
The design objectives of 10CFR50, Appendix I and RETS/Technical Specifications require that the liquid radwaste treatment system be operable and that appropriate portions be used to reduce releases of radioactivity when projected doses due to the liquid

effluent from each reactor unit to restricted area boundaries exceed either of the following (see Section 12.3 of each station's RETS or Technical Specifications);

- 0.06 mrem to the total body in a 31 day period.
- 0.2 mrem to any organ in a 31 day period.

### A.2.6 Drinking Water

Five nuclear power stations (Braidwood, Dresden, LaSalle, Quad Cities, and Zion) have requirements for calculation of drinking water dose that are related to 40CFR141, the Environmental Protection Agency National Primary Drinking Water Regulations. These are discussed in Section A.6.

## A.6 DOSE DUE TO DRINKING WATER (40CFR141)

The National Primary Drinking Water Regulations, 40CFR141, contain the requirements of the Environmental Protection Agency applicable to public water systems. Included are limits on radioactivity concentration. Although these regulations are directed at the owners and operators of public water systems, several stations have requirements in their Technical Specifications related to 40CFR141.

### A.6.1 40CFR141 Restrictions on Manmade Radionuclides

Section 141.16 states the following (not verbatim):

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A-0, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of drinking 2 liter of water per day. (Using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, "NBS Handbook 69 as amended August 1963, U.S. Department of Commerce.). If two or more radionuclides are present, the sum of their annual dose equivalents to the total body or any organ shall not exceed 4 millirem/year.

TABLE A-0
AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

| Radionuclide | Critical Organ | pCi / liter |
|---|---|---|
| Tritium | Total body | 20,000 |
| Strontium-90 | Bone marrow | 8 |

LIQUID EFFLUENTS

12.3.1 Concentration
Operability Requirements

12.3.1.A The concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) shall be limited to 10 times the concentration values in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402, for radionuclides other than dissolved or entrained noble gases. For dissolved or entrained noble gases, the concentration shall be limited to $2x10^{-4}$ microCurie/ml total activity.

Applicability: At all times

Action:

1. With the concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS exceeding the above limits, immediately restore the concentration to within the above limits.

Surveillance Requirements

12.3.1.B.1 Radioactive liquid wastes shall be sampled and analyzed according to the sampling and analysis program of Table 12.3-1.

12.3.1.B.2 The results of the radioactivity analysis shall be used in accordance with the methodology and parameters in the ODCM to assure that the concentrations at the point of release are maintained within the limits of 12.3.1.A.

Bases

12.3.1.C This section is provided to ensure that the concentration of radioactive materials released in liquid waste effluents to UNRESTRICTED AREAS will be less than 10 times the concentration values in Appendix B, Table 2, Column 2 to 10CFR20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water in UNRESTRICTED AREAS will result in exposures within: (1) the Section II.A design objectives of Appendix I, 10CFR50, to a MEMBER OF THE PUBLIC, and (2) the limits of 10CFR20.1301.
This section applies to the release of radioactive materials in liquid effluents from all units at the site.
The required detection capabilities for radioactive materials in liquid waste samples are tabulated in terms of the lower limits of detection (LLDs). Detailed discussion of the LLD, and other detection limits can be found in HASL Procedures Manual, HASL-300 (revised annually), Currie, L.A., "Limits for Qualitative Detection and Quantitative Determination - Application to Radiochemistry," Anal. Chem. 40, 586-93 (1968), and Hartwell, J.K., "Detection Limits for Radioanalytical Counting Techniques," Atlantic Richfield Hanford Company Report ARH-SA-215 (June 1975).

## TABLE 12.3-1

## RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

| LIQUID RELEASE TYPE | SAMPLING FREQUENCY | MINIMUM ANALYSIS FREQUENCY | TYPE OF ACTIVITY ANALYSIS | LOWER LIMIT OF DETECTION (LLD)[1] ($\mu$Ci/ml) |
|---|---|---|---|---|
| 1. Batch Release Tanks[2] | P Each Batch | P Each Batch | Principal Gamma Emitters[7] | $5x10^{-7}$ |
| | | | I-131 | $1x10^{-6}$ |
| | P One Batch/M | M | Dissolved and Entrained Gases (Gamma Emitters) | $1x10^{-5}$ |
| | P Each Batch | M Composite [3] | H-3 | $1x10^{-5}$ |
| | P Each Batch | Q Composite [3] | Gross Alpha | $1x10^{-7}$ |
| | | | Sr-89, Sr-90 | $5x10^{-8}$ |
| | | | Fe-55 | $1x10^{-6}$ |
| 2. Continuous Releases [4] | Continuous[5] | W Composite[5] | Principal Gamma Emitters[7] | $5x10^{-7}$ |
| | | | I-131 | $1x10^{-6}$ |
| a. Circulating Water Blowdown | M Grab Sample | M | Dissolved and Entrained Gases (Gamma Emitters) | $1x10^{-5}$ |
| b. Waste Water Treatment Discharge to Circulating Water Discharge | Continuous[5] | M Composite[5] | H-3 | $1x10^{-5}$ |
| | | | Gross Alpha | $1x10^{-7}$ |
| c. Condensate Polisher Sump Discharge | Continuous[5] | Q Composite[5] | Sr-89, Sr-90 | $5x10^{-8}$ |
| | | | Fe-55 | $1x10^{-6}$ |

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

| LIQUID RELEASE TYPE | SAMPLING FREQUENCY | MINIMUM ANALYSIS FREQUENCY | TYPE OF ACTIVITY ANALYSIS | LOWER LIMIT OF DETECTION (LLD)[1] (μCi/ml) |
|---|---|---|---|---|
| 3. Continuous Release[4] Essential Service Water Reactor Containment Fan Cooler (RCFC) Outlet Line | W[6] Grab Sample | W[6] | Principal Gamma Emitters[7] | $5x10^{-7}$ |
| | | | I-131 | $1x10^{-6}$ |
| | | | H-3 | $1x10^{-5}$ |
| | | M[6] | Dissolved and Entrained Gases (Gamma Emitters) | $1x10^{-5}$ |
| 4. Continuous Surge Tank Vent-Component Cooling Water Line[8] | None | None | Principal Gamma Emitters[7] | $5x10^{-7}$ |
| | | | Dissolved and Entrained Gases (Gamma Emitters) | $1x10^{-5}$ |
| | | | I-131 | $1x10^{-6}$ |

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

(1) The LLD is defined, for purposes of these sections, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separations:

$$LLD = \frac{4.66 s_b}{E \times V \times 2.22 \times 10^6 \times Y \times \exp(-\lambda \Delta t)}$$

Where:

LLD = the lower limit of detection (microCuries per unit mass or volume),

$s_b$ = the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (counts per minute),

E = the counting efficiency (counts per disintegration),

V = the sample size (units of mass or volume),

$2.22 \times 10^6$ = the number of disintegrations per minute per microCurie,

Y = the fractional radiochemical yield, when applicable,

$\lambda$ = the radioactive decay constant for the particular radionuclide ($sec^{-1}$), and

$\Delta t$ = the elapsed time between the midpoint of sample collection and the time of counting (sec).

Typical values of E, V, Y, and $\Delta t$ should be used in the calculation.

Alternative LLD Methodology

An alternative methodology for LLD determination follows and is similar to the above LLD equation:

$$LLD = \frac{(2.71 + 4.65\sqrt{B}) \times Decay}{E \times q \times b \times Y \times t\,(2.22 \times 10^6)}$$

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

Where:

B = background sum (counts)

E = counting efficiency, (counts detected/disintegration's)

q = sample quantity, (mass or volume)

b = abundance, (if applicable)

Y = fractional radiochemical yield or collection efficiency, (if applicable)

t = count time (minutes)

$2.22X10^6$ = number of disintegration's per minute per microCurie

$2.71 + 4.65\sqrt{B} = k^2 + (2k \sqrt{2} \sqrt{B})$, and k = 1.645.

(k=value of the t statistic from the single-tailed t distribution at a significance level of 0.95 and infinite degrees of freedom. This means that the LLD result represents a 95% detection probability with a 5% probability of falsely concluding that the nuclide present when it is not or that the nuclide is not present when it is.)

Decay = $e^{\lambda\Delta t}$ $[\lambda RT/(1-e^{-\lambda RT})]$ $[\lambda T_d/(1-e^{-\lambda Td})]$, (if applicable)

$\lambda$ = radioactive decay constant, (units consistent with $\Delta t$, RT and $T_d$)

$\Delta t$ = "delta t", or the elapsed time between sample collection or the midpoint of sample collection and the time the count is started, depending on the type of sample, (units consistent with $\lambda$)

RT= elapsed real time, or the duration of the sample count, (units consistent with $\lambda$)

$T_d$ = sample deposition time , or the duration of analyte collection onto the sample media, (units consistent with $\lambda$)

The LLD may be determined using installed radioanalytical software, if available. In addition to determining the correct number of channels over which to total the background sum, utilizing the software's ability to perform decay corrections (i.e. during sample collection, from sample collection to start of analysis and during counting), this alternate method will result in a more accurate determination of the LLD.

It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

(2) A batch release is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed to assure representative sampling.

(3) A composite sample is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen that is representative of the liquids released.

(4) A continuous release is the discharge of liquid wastes of a nondiscrete volume, e.g., from a volume of a system that has an input flow during the continuous release.

(5) To be representative of the quantities and concentrations of radioactive materials in liquid effluents, samples shall be collected continuously whenever the effluent stream is flowing. Prior to analyses, all samples taken for the composite shall be thoroughly mixed in order for the composite sample to be representative of the effluent release.

(6) Not required unless the Essential Service Water RCFC Outlet Radiation Monitors RE-PR002 and RE-PR003 indicates measured levels greater than $1x10^{-6}$ μCi/ml above background at any time during the week.

(7) The principal gamma emitters for which the LLD specification applies include the following radionuclides: Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, and Ce-141. Ce-144 shall also be measured, but with an LLD of 5E-06. This list does not mean that only these nuclides are to be considered.
Other gamma peaks that are identifiable, together with those of the above nuclides, shall also be analyzed and reported in the Radioactive Effluent Release Report pursuant to Section 12.6.2, in the format outlined in Regulatory Guide 1.21, Appendix B, Revision 1, June 1974.

(8) A continuous release is the discharge of dissolved and entrained gaseous waste from a nondiscrete liquid volume.

12.3.2 Dose

Operability Requirements

12.3.2.A The dose or dose commitment to a MEMBER OF THE PUBLIC from radioactive materials in liquid effluents released, from each unit, to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) shall be limited:

1. During any calendar quarter to less than or equal to 1.5 mrems to the whole body and to less than or equal to 5 mrems to any organ, and

2. During any calendar year to less than or equal to 3 mrems to the whole body and to less than or equal to 10 mrems to any organ.

Applicability: At all times.

Action:

1. With the calculated dose from the release of radioactive materials in liquid effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days, pursuant to 10CFR50 Appendix I, Section IV.A, a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions that have been taken to

reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits.

Surveillance Requirements

12.3.2.B Cumulative dose contributions from liquid effluents for the current calendar quarter and the current calendar year shall be determined in accordance with the methodology and parameters in the ODCM at least once per 31 days.

Bases

12.3.2.C This section is provided to implement the requirements of Sections II.A, III.A and IV.A of Appendix I, 10CFR50. The Operability Requirements implement the guides set forth in Section II.A of Appendix I. The ACTION statements provide the required operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in liquid effluents to UNRESTRICTED AREAS will be kept "as low as is reasonably achievable." The dose calculation methodology and parameters in the ODCM implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I be shown by calculational procedures based on models and data, such that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated.

The equations specified in the ODCM for calculating the doses due to the actual release rates of radioactive materials in liquid effluents are consistent with the methodology provided in Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents For the Purpose of Evaluating Compliance with 10CFR50, Appendix I" Revision 1, October 1977 and Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.
This section applies to the release of radioactive materials in liquid effluents from each reactor at the site. When shared Radwaste Treatment Systems are used by more than one unit on a site, the wastes from all units are mixed for shared treatment; by such mixing, the effluent releases cannot accurately be ascribed to a specific unit. An estimate should be made of the contributions from each unit based on input conditions, e.g., flow rates and radioactivity concentrations, or, if not practicable, the treated effluent releases may be allocated equally to each of the radioactive waste producing units sharing the Radwaste Treatment System. For determining conformance to Operability Requirements, these allocations from shared Radwaste Treatment Systems are to be added to the releases specifically attributed to each unit to obtain the total releases per unit.

12.3.3 Liquid Radwaste Treatment System

Operability Requirements

12.3.3.A The Liquid Radwaste Treatment System shall be OPERABLE and appropriate portions of the system shall be used to reduce releases of radioactivity when the projected doses due to the liquid effluent, from each unit, to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) would exceed 0.06 mrem to the whole body or 0.2 mrem to any organ in a 31-day period.

Applicability: At all times.

Action:

1. With radioactive liquid waste being discharged without treatment and in excess of the above limits and any portion of the Liquid Radwaste Treatment System not in operation, prepare and submit to the Commission within 30 days, pursuant to 10CFR50 Appendix I, Section IV.A, a Special Report that includes the following information:

   a. Explanation of why liquid radwaste was being discharged without treatment, identification of any inoperable equipment or subsystems, and the reason for the inoperability,

   b. Action(s) taken to restore the inoperable equipment to OPERABLE status, and

   c. Summary description of action(s) taken to prevent a recurrence.

Surveillance Requirements

12.3.3.B.1 Doses due to liquid releases from each unit to UNRESTRICTED AREAS shall be projected at least once per 31 days in accordance with the methodology and parameters in the ODCM when the Liquid Radwaste Treatment System is not being fully utilized.

12.3.3.B.2 The installed Liquid Radwaste Treatment System shall be considered OPERABLE by meeting Sections 12.3.1.A and 12.3.2.A.

Bases

12.3.3.C The OPERABILITY of the Liquid Radwaste Treatment System ensures that this system will be available for use whenever liquid effluents require treatment prior to release to the environment. The requirement that the appropriate portions of this system be used when specified provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable". This section implements the requirements of 10CFR50.36a, General Design Criterion 60 of Appendix A to 10CFR50 and the design objective given in Section II.D of Appendix I to 10CFR50.

The specified limits governing the use of appropriate portions of the Liquid Radwaste Treatment System were specified as a suitable fraction of the dose design objectives set forth in Section II.A of Appendix I, 10CFR50, for liquid effluents.

This section applies to the release of radioactive materials in liquid effluents from each unit at the site. When shared Radwaste Treatment Systems are used by more than one unit on a site, the wastes from all units are mixed for shared treatment; by such mixing, the effluent releases cannot accurately be ascribed to a specific unit. An estimate should be made of the contributions from each unit based on input conditions, e.g., flow rates and radioactivity concentrations, or, if not practicable, the treated effluent releases may be allocated equally to each of the radioactive waste producing units sharing the Radwaste Treatment System. For determining conformance to Operability Requirements, these allocations from shared Radwaste Treatment Systems are to be added to the releases specifically attributed to each unit to obtain the total releases per unit.

**Table 2-1**
**Regulatory Dose Limit Matrix**

| REGULATION | DOSE TYPE | DOSE LIMIT(s)[3] (quarterly) | (annual) | ODCM EQUATION |
|---|---|---|---|---|
| **Liquid Releases:** | | | | |
| 10CFR50 App. I[3] | Whole (Total) Body Dose (per reactor unit) | 1.5 mrem | 3 mrem | A-17 |
| | Organ Dose (per reactor unit) | 5 mrem | 10 mrem | A-17 |
| Technical Specifications | The concentration of radioactivity in liquid effluents released to unrestricted areas | Ten (10) times the concentration values listed in 10CFR20 Appendix B; Table 2, Column 2, Table C-6 of ODCM Appendix C for Noble Gases | | A-21 |
| **Total Doses [1]:** | | | | |
| 10 CFR 20.1301 (a)(1) | Total Effective Dose Equivalent [4] | 100 mrem/yr | | A-25 |
| 10CFR20.1301 (d) and 40CFR190 | Total Body Dose | 25 mrem/yr | | A-25 |
| | Thyroid Dose | 75 mrem/yr | | A-25 |
| | Other Organ Dose | 25 mrem/yr | | A-25 |
| **Other Limits [2]:** | | | | |
| 40CFR141 | Total Body Dose Due to Drinking Water From Public Water Systems | 4 mrem/yr | | A-17 |
| | Organ Dose Due to Drinking Water From Public Water Systems | 4 mrem/yr | | A-17 |

[1] These doses are calculated considering all sources of radiation and radioactivity in effluents.

[2] These limits are not directly applicable to nuclear power stations. They are applicable to the owners or operators of public water systems. However, the RETS of some of the Exelon Nuclear power stations require assessment of compliance with these limits. For additional information, see Section A.6 of Appendix A.

[3] Note that 10CFR50 provides design objectives not limits.

[4] Compliance with 10CFR20.1301(a)(1) is demonstrated by compliance with 40CFR190. Note that it may be necessary to address dose from on-site activity by members of the public as well.

## Attachment 4
## Reportability Manual Review - LS-AA-1020 and LS-AA-1110

1.

Various documents were reviewed to determine the expected reporting requirements for an event such as discovering radiologically contaminated water leaking from a plant system onto the ground within the owner-controlled area.

LS-AA-1020 Radiological Decision Tree was reviewed. The Liquid Release or Spill portion of the tree references SAF 1.9, News Release or Notification of Other Government Agency. SAF 1.9 requires NRC notification for any event related to the health and safety of the public or onsite personnel, or protection of the environment requiring a news release or notification of another government agency. One example described is the inadvertent release of radioactively contaminated materials. Since the vacuum breaker leaks (spills) were perceived as on site, the leak would not be characterized as a release per the Off-Site Dose Calculation Manual. Since the leak was on site, there was no perceived health or safety risk to the public. A review of several Incident Reports (IR's) indicates that these leaks were not considered a public risk since the leaks were on site. These IR's also reasonably concluded that NPDES violations did not occur and therefore EPA notification was not required. Based on the nature of the leak, there was no safety or health risk to on site personnel. Therefore, it was reasonable to conclude that these events were not reportable per SAF 1.9.

The Liquid Release or Spill portion of the Radiological Decision Tree also references RAD 1.1, Events Involving Byproduct, Source or Special Nuclear Material that Cause or Threaten to Cause Significant Exposure or Release. One of the reporting requirements concerns the release of radioactive material inside or outside the restricted area, but is not reportable if the location is not normally stationed during routine operations. Since personnel would not normally be stationed at the vacuum breakers, reporting is not required.

RAD 1.4, Liquid Effluent Release requires reporting when radioactive material is present at levels greater than 10 times applicable limits. The piping leaks were within the restricted areas and therefore were not considered an effluent release. Migration of contaminated groundwater off site should be considered an effluent release, but was not considered. To date, measurable tritium concentrations in ground water off site are within 10 times applicable limits. The event is not reportable per RAD 1.4.

RAD 1.8, Effluent Release was not considered applicable since a release normally occurs at the unrestricted area boundary. Therefore, reportability per RAD 1.8 was not considered. Off site release via groundwater was not considered. Based on the measured tritium results off site, the requirements described in RAD 1.8 have not been exceeded and therefore, reportability per RAD 1.8 is not required.

RAD 1.21, Release of Radionuclides, requires reporting when the limits of 40 CFR 302 are exceeded. For tritium, the 40 CFR 302 limit is 100 Curies released within a 24-hour period. Review of effluent release data indicates that the 100-curie limit is not normally challenged during radioactive releases. However, per discussion with plant personnel, there was no evaluation of the 100-curie limit during the vacuum breaker leak events.

RAD 1.22, Release of Hazardous Substances (including radionuclides) is not applicable based on the RAD 1.21 discussion.

The other sections of the Liquid Release or Spill portion of the Radiological Decision Tree do not apply.

The other sections of the Radiological Decision Tree were reviewed and do not apply.

LS-AA-1020 Environmental decision tree was also reviewed. The Other Significant Event section was reviewed. ENV 3.26 Unusual or Important Environmental Events requires reporting of any event that did or could have significant environmental impact. It is reasonable that a blow-down water spill on site would not have a significant environmental impact and therefore notification would not be made. However, potential groundwater contamination and migration to public wells was not considered.

The other sections of the Environmental Decision Tree were reviewed and would not apply.

40 CFR 141.16 states that the average annual tritium concentration shall not exceed 20,000 pCi/L in a community drinking water system. A community drinking water system is defined in the regulation as a public water system that serves at least 15 year round residents. The reportability manual appropriately references 40CFR141.

35 IAC 620 has the same 20,000 pCi/L limit and definition of community drinking water system as described in 40CFR141.16. However, 35 IAC 620 does not limit the tritium concentration to community drinking water. This Illinois standard limits tritium concentration in "Class I: Potable Resource Water," which is defined, in part, as water located 10 feet or more below the surface that is capable of potable use. Per discussion with Conestoga-Rovers & Associates and the Exelon Hydrologist, on site groundwater at Braidwood station is classified as Class I: Potable Resource Water in accordance with 35 IAC 620. Therefore, any tritium leakage into the groundwater on site could potentially be reportable per the requirements of 35 IAC 620. Tritium analysis results at VB-1 on 5/27/05 were 51295 pCi/L. This sample was physically at the vacuum breaker and, to date, groundwater samples around VB-1 indicate tritium concentrations $\leq$ 1194 pCi/L – significantly less than the 20,000 pCi/L limit.

The Reportability Manual does not reference the ODCM Radiological Environmental Monitoring Program (REMP) reporting requirements. The ODCM REMP specifies reporting requirements of various radionuclides, including tritium, in Table 12.5-2.

The Reportability Manual was reviewed for references to the various drinking water and ground water standards. There is appropriate reference to 40 CFR 141 and 35 IAC 611. However, there were not sufficient references to 35 IAC 620 or 630. Based on this review, there was inadequate knowledge of the requirements of 35 IAC 620 and the transport of radioactivity offsite via the groundwater pathway.

## Recommendations

Review 35 IAC 620 requirements to determine whether there are reportability requirements that need to be included in the Reportability Manual

Train personnel on the transport of radioactivity off site via the groundwater pathway.

## References

Braidwood Off-Site Dose Calculation Manual Revision 7

LS-AA-1020, Reportability Reference Manual, Revision 8

LS-AA-1110, Reportable Event SAF, Revision 6

LS-AA-1120, Reportable Event Radiation (RAD), Revision 3

LS-MW-1310, Reportable Event SAF, Revision 3

LS-MW-1340, Reportable Event, ENV, Revision 4

LS-AA-1400, Event Reporting Guidelines, Revision 2

LS-MW-1340, Reportable Events, ENV, Revision 4

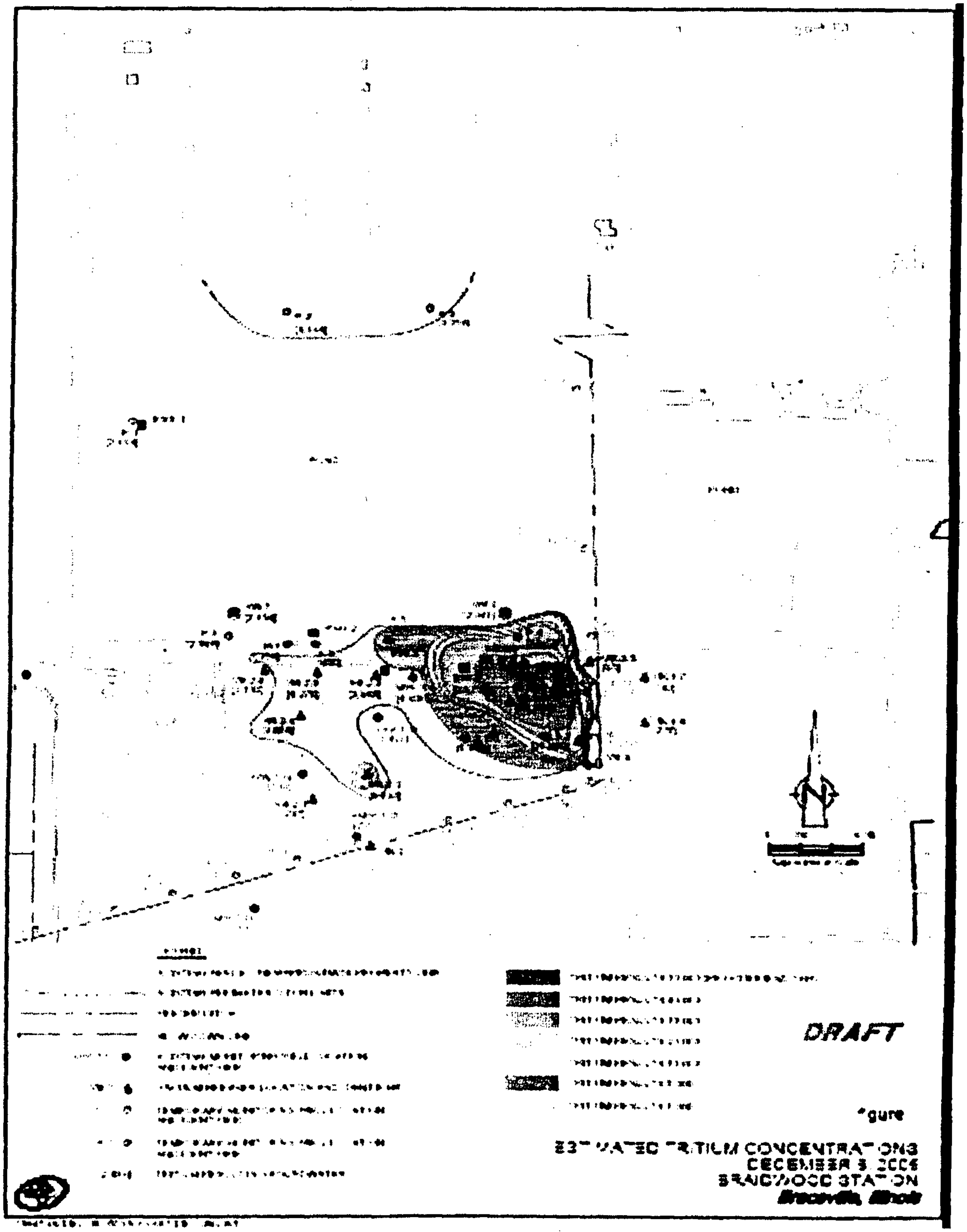
40 CFR 302, Designation, Reportable Quantities, and Notification

40 CFR 141, National Primary Drinking Water Regulations

35 IAC 611, Primary Drinking Water Standards

35 IAC 620, Groundwater Quality

Attachment 5 - Tritium Plume Map



# Attachment 6

## Barrier Analysis

| Failed or ineffective barrier | How Barrier Failed | Why Barrier Failed | Corrective action to Restore Barrier to Effectiveness |
|---|---|---|---|
| **Procedures** | CF 1 | | See CAPR 1 |
| **BwAP 750-4**<br><br>**Failed Barrier 1 (FB 1)**<br>- | - Hazmat was not entered<br><br>- Procedure does not prompt radiological response | Lack of knowledge of Title 35 IAC part 620 ground water quality | Implement an integrated set of liquid environmental spill procedure(s) that address mitigation and remediation of those spills.<br><br>See Training Failed Barrier actions |
| **BwAP1100-16 (FB 2)**<br>- | - Hazmat was not entered<br><br>- Procedure does not prompt radiological response | Lack of knowledge of Title 35 IAC part 620 ground water quality | Implement an integrated set of liquid environmental spill procedure(s) that address mitigation and remediation of those spills.<br><br>See Training Failed Barrier actions |
| **NSP-RP-6101 (FB 3)**<br>- | 50:75(g) does not clearly address $H^3$ | Lack of knowledge of Title 35 IAC part 620 ground water quality | RP manager to take issue to peer group to evaluate other pathways (specifically underground tritium).<br><br>See Training Failed Barrier actions |
| **RP-AA (FB 4)** | - No guidance for low level spills | Lack of knowledge of Title 35 IAC part 620 ground water quality | Implement an integrated set of liquid environmental spill procedure(s) that address mitigation and remediation of those spills. |
| Rad spill procedure does not exist. | - CSG-001 1990 draft only | Unknown | - Chemistry to charter a team to develop/revise appropriate procedures to respond to potential radioactive spills of liquid that may affect the environment. Team to include RP/CH/OP/RA/NGG. The team shall consider reportability manual revision, new OA, EN, and RP procedures. Team to review Barrier Analysis of RCR 428868. |

| | | | |
|---|---|---|---|
| **WC-AA-106** Attachment 1 implies a "B2" if increased sampling **(FB 5)** | WC called issues "C", not recognizing that sampling for tritium would be required | Lack of knowledge of Title 35 IAC part 620 ground water quality | - See Training Failed Barrier actions<br>- Work Control to discuss a proposed revision of WC-AA-106 to the peer group to incorporate the need for a higher work priority for response to low level radioactive water being released to the environment. Create additional ATI's as required. |
| **BwOA** (Rad spill procedure does not exist) **(FB 6)** | No guidance for low level spills | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Chemistry to charter a team to develop/revise appropriate procedures to respond to potential radioactive spills of liquid that may affect the environment. Team to include RP/CH/OP/RA/NGG. The team shall consider reportability manual revision, new OA, EN, and RP procedures. Team to review Barrier Analysis of RCR 428868. |
| **LS-AA-1020 & 1110** Reportability Manual **(FB 7)** | Does not reflect ODCM REMP/RETS reporting requirements | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Reg Assurance to review the reportability manual for ODCM REMP/RETS reporting requirements, 35 IAC 611/620 to ensure that all requirements (extent of condition) are being met with respect to Groundwater Release Path, limitations, and Illinois SB241 Community Right to Know requirements. Create additional actions as warranted. |
| **LS-AA-1020 & 1110** Reportability Manual **(FB 8)** | Does not reflect 35 IAC 620 Groundwater Tritium Release Path, 20,000 pCi/L limitations | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Corporate Reg Assurance to revise the reportability manual for ODCM REMP/RETS reporting requirements, 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. Create additional actions as warranted. |
| **LS-AA-1020 & 1110** Reportability Manual **(FB 9)** | ENV 3.26 does not clearly warn of tritium ground water release path | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Corporate Reg Assurance to revise the reportability manual for ODCM REMP/RETS reporting requirements, 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. Create additional actions as warranted. |
| **LS-AA-1020 & 1110** Reportability Manual **(FB 10)** | RAD 1.21, 100Ci tritium 24h release limitation not checked | Lack of knowledge of tritium amounts released | - See training barrier actions. |

| | | | |
|---|---|---|---|
| **<u>LS-AA-1020 & 1110</u>** Reportability Manual **<u>(FB 11)</u>** | SAF 1.9 New Right to Know legislation not reflected. | No program for review and promulgation of new laws. | - Corporate Environmental to review the process by which new environmental regulations are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. |
| **<u>ER-BR-400-101,</u>** Engineering Walkdown PM Procedure **<u>(FB 12)</u>** | No precaution for tritium ground water concern | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Chemistry to charter a team to ensure appropriate personnel are assigned to assist in developing the procedures necessary for responses to potential radioactive spills of liquid that may affect the environment. |
| **<u>0BwOS CW-A1</u>** OPS Walkdown PM Procedure **<u>(FB 13)</u>** | No precaution for tritium ground water concern | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Chemistry to charter a team to ensure appropriate personnel are assigned to assist in developing the procedures necessary for responses to potential radioactive spills of liquid that may affect the environment. |
| **<u>EN-AA-</u>**Environmental procedures **<u>(FB 14)</u>** | No guidance for rad spills that can get to drinking water supplies | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Clearly define to each station (extent of condition), the changes to the ODCM based on review of Illinois, Pennsylvania and New Jersey laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure fleet wide sites specific ODCM reflects and implements applicable regulations.<br>- See training barrier actions |
| **<u>BwOP CW-12</u>** **<u>(FB 15)</u>** | No shutdown precautions during a release for a leak in the blowdown system | Lack of knowledge of Title 35 IAC part 620 ground water quality. | - Ops to add precautions to BwOP CW-12, BwOP WX 526TI, & BwOP WX-501TI for release shutdown on leak to environment. |
| **<u>BwOP WX-526TI,</u>** **<u>(FB 16)</u>** | No shutdown precautions during a release for a leak in the blowdown system | Lack of knowledge of Title 35 IAC part 620 ground water quality | - See training failed barrier<br>- Ops to add precautions to BwOP CW-12, BwOP WX 526TI, & BwOP WX-501TI for release shutdown on leak to environment.<br>- See training failed barrier |
| **<u>BwOP WX-501TI</u>** **<u>(FB 17)</u>** | No shutdown precautions during a release for a leak in the blowdown system | Lack of knowledge of Title 35 IAC part 620 ground water quality | - Ops to add precautions to BwOP CW-12, BwOP WX 526TI, & BwOP WX-501TI for release shutdown on leak to environment.<br>- See training failed barrier |

| **Alarms/ Annunciators** | OTHER ISSUE "a" | | |
|---|---|---|---|
| Leak detection on vacuum breakers **(FB 18)** | Only performed annually at the time of the 1998 event. Recently performed on semi-annual basis. Currently (Since Sept. 2005) performed monthly | Not often enough to detect leaks. System has inherent suspended materials in the CW, which can cause the valves to stick open, allowing tritiated water to be released. Vacuum Breakers are spread over 4+ miles in neighbors fenced, live-stocked property. | Braidwood System Engineering to review operation of the CW Blowdown system and determine the optimum monitoring scope and frequency of inspection PM's and walk downs for the System. If applicable, identify gaps and create additional ATI's as required.<br><br>Braidwood System Engineering to research and evaluate passive vacuum breaker replacement options and present findings to PHC for approval if the CW Blowdown system will be used for radwaste releases in the future. |
| Alarms and annunciators **(FB 19)** | Did not alarm | Do not exist | See Leak detection on vacuum breakers failed barrier – see FB 18 above. |
| **Piping/Valves equipment failures (FB 20)** | Water hammer events | Changed BwOP-CW12 and created a water hammer issue | BwOP CW12 revised to mitigate water-hammer – revision 14. **(completed, 01/19/01)**<br><br>Braidwood System Engineering to research and evaluate passive vacuum breaker replacement options and present findings to PHC for approval if the CW Blowdown system will be used for radwaste releases in the future. |

| | | | |
|---|---|---|---|
| **Training** | CF-2 | | |
| NEIT, NGET & NGET requal **(FB 21)** | No training on a response to a liquid radiological spill for requirements of Title 35 IAC part 620 ground water quality. | Did not know Title 35 IAC part 620 ground water Tritium concentration limits | Track TR#05-1721for training to evaluate and incorporate NEIT, NGET requal, for enhanced module on Rad OPEX's of this RCR. |
| Initial License Training & Licensed Operator requalification training **(FB 22)** | No Environmental spill training for low level radioactive liquids | Did not know Title 35 IAC part 620 ground water quality | Ops to generate a TR to analyze the level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. |
| Certification of RP/HP **(FB 23)** | Lack of cert guide for low level radioactive liquid spills | Did not know Title 35 IAC part 620 ground water quality. | RP to generate a TR to analyze the level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. |
| **Regulations/ Oversight** | CF-3 | | |
| ODCM requires evaluation of ground water pathway if credible **(FB 24)** | Braidwood has demonstrated a credible pathway | Did not know Title 35 IAC part 630 ground water tritium concentration limits | Chemistry to evaluate the groundwater and food crop pathway per ODCM Tbl 12.5-1 Section 3.a note (6). Assign additional actions as necessary, if the pathway is credible. |
| ODCM requires evaluation of ground water pathway if credible **(FB 25)** | Braidwood has demonstrated a credible pathway | Did not know Title 35 IAC part 630 ground water Tritium concentration limits | Braidwood ODCM Owner to evaluate the ground water monitoring requirements by wells as shown in ODCM Tbl 11-1 Section 3.a note (6) against the five wells currently monitored. Create additional CAs to revise the ODM to reflect proper monitoring of the know tritium in ground water per ODCM REMP Tbl 12.5-1 Section 3a Note (6). |
| Title 35 IAC part 611 ground water quality **(FB 26)** | ODCM does not reflect state ground water requirements | Did not know Title 35 IAC part 611 ground water quality | Corporate Environmental to review the process by which new environmental regulations are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. |

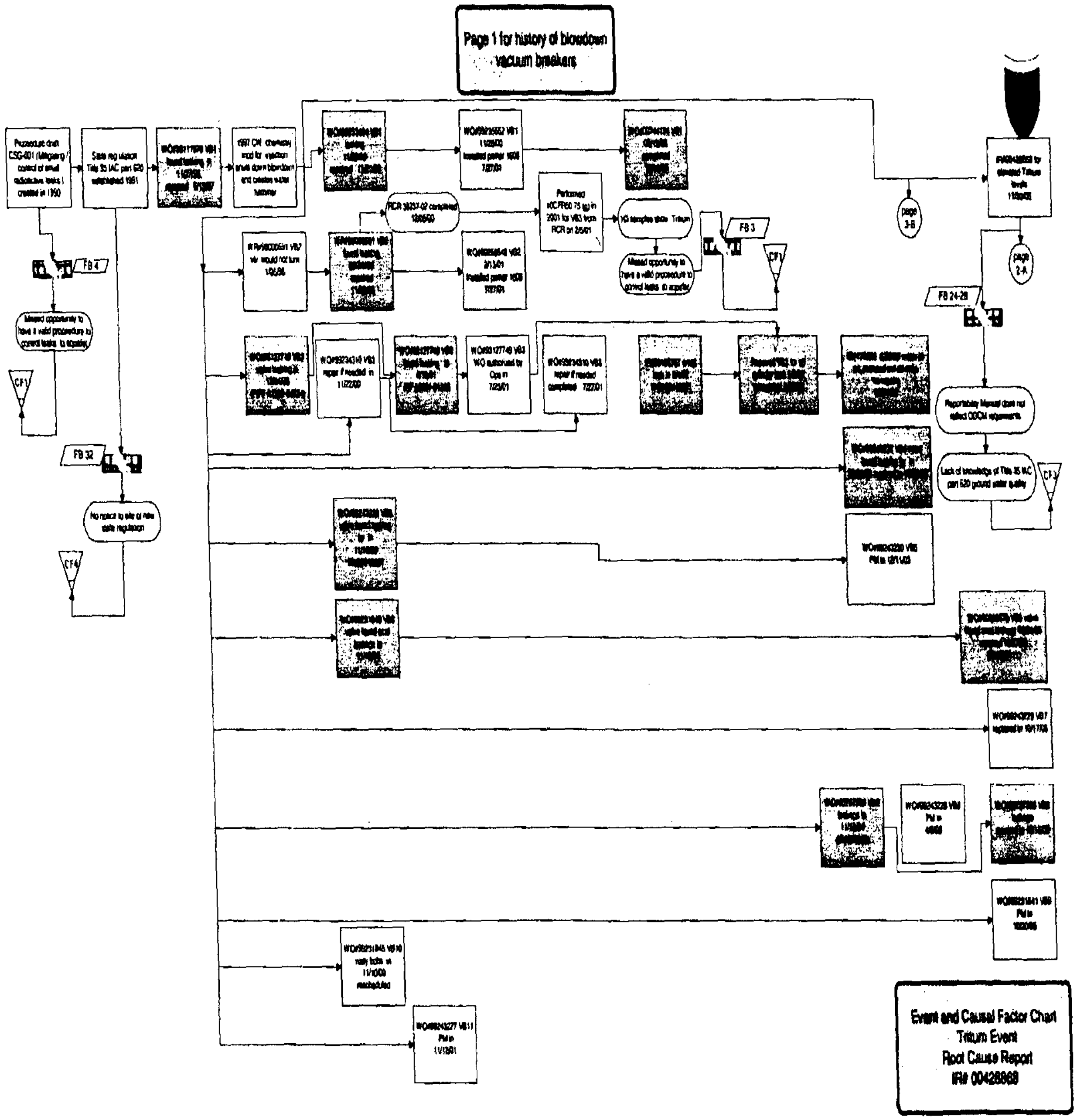
| | | | |
|---|---|---|---|
| Title 35 IAC part 620 ground water quality **(FB 27)** | ODCM does not reflect state ground water requirements. | Did not know Title 35 IAC part 620 ground water quality. | Corporate Chemistry to revise the Midwest ODCM and/or program procedures to incorporate requirement of <20,000 the State of IL pCi/L of tritium for groundwater. |
| Title 35 IAC part 630 ground water Tritium concentration limits **(FB 28)** | ODCM does not reflect state ground water requirements. | Did not know Title 35 IAC part 630 ground water Tritium concentration limits | Corporate Chemistry to revise the Midwest ODCM and/or program procedures to incorporate the State of IL requirement of <20,000 pCi/L of tritium for groundwater. |
| Corporate Over-sight CY-AA-170-000, CY-AA-170-100, CY-AA-170-1000, CY-AA-170-200, CY-AA-170-2000, CY-AA-170-2000, CY-AA-170-300, CY-AA-170-3100. **(FB 29)** | Did not uncover 2 missing State statutes or the state groundwater tritium concentration issue. | Corporate audits did not check program to sufficient detail | Chemistry to submit procedure change to revise CY-AA-170-000 and associated procedures to require audits of the ODCM at an acceptable frequency and review the need for revision to include State regulations review into Step 4.2.1 basis of the ODCM. Create additional actions as warranted to assure the ODCM is in accordance with applicable requirements. |
| **NOS Audit NOSA-BRW-05-08 (AR # 287718)** November 22, 2005 **(FB 30)** | Did not uncover 2 missing State statutes or the state groundwater tritium concentration issue | NOS Audit plan did not check program to sufficient detail, not verifying ODCM met applicable state regulations | Discuss this RCR with the Corporate NOS Peer Group to evaluate changing the NOS frequency auditing template standard for the ODCM Program. Document results. |
| **Notification** | CF-4 | | |
| Notice to other Site Departments when an event occurred **(FB 31)** | Did not always inform all affected parties | No procedure to assure consistent approach to leaks/spills | Corporate Environmental to develop an integrated set of liquid environmental spill procedure(s) that address mitigation and remediation of those spills. |
| Notice to sites of new State Regulation **(FB 32)** | Sites not informed of new Illinois SB241, Community Right to Know | Program not robust | Review the process by which new environmental regulations are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. |

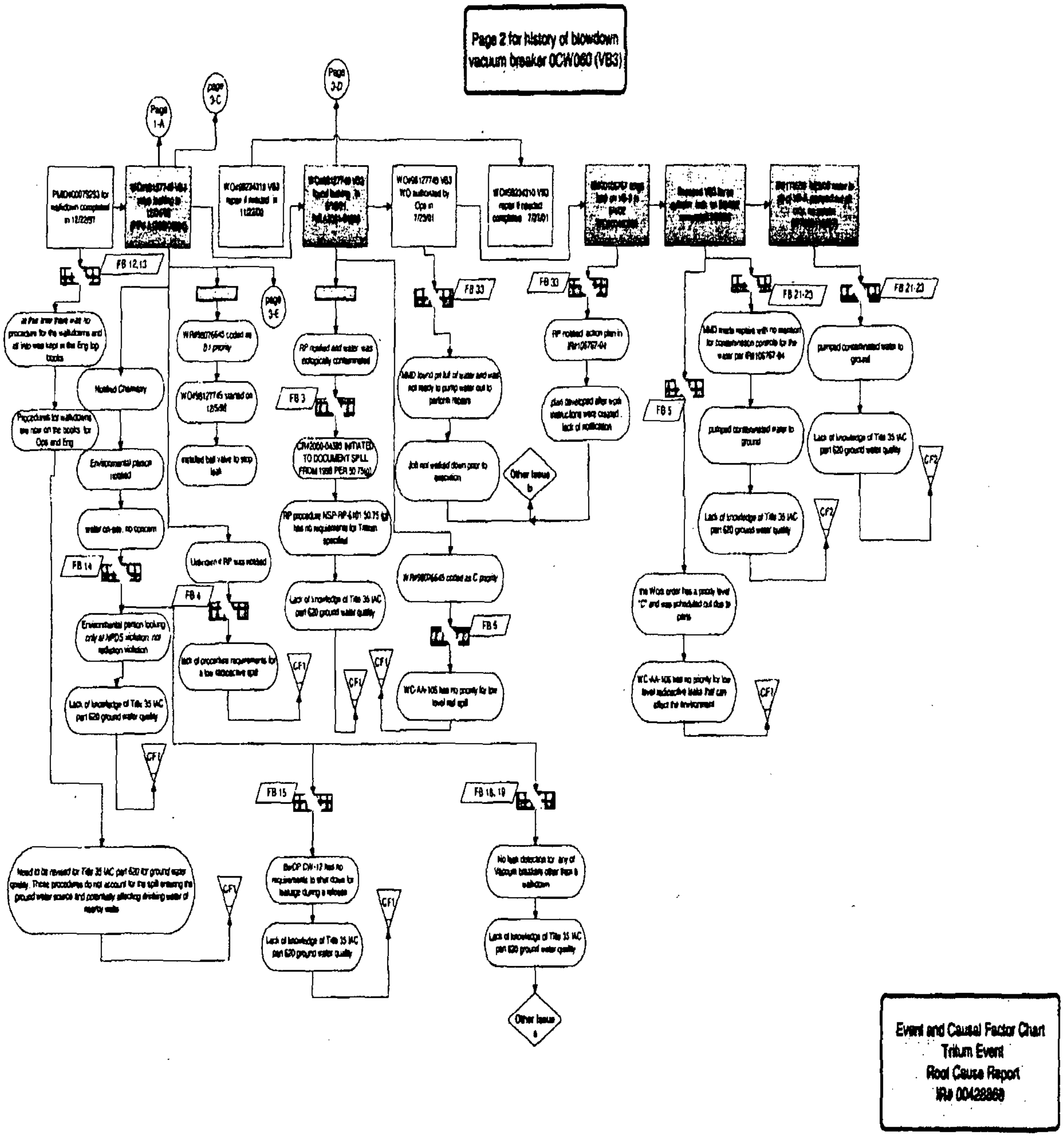
| Work Orders | OTHER ISSUE "b" | | |
|---|---|---|---|
| Model PM work orders and current work orders for B/D vacuum breakers **(FB 33)** | Failed to have RP sampling of leaks and how to properly dispose of liquids not in work order instructions. | Did not know Title 35 IAC part 620 ground water quality | - RP to provide information to Work Planning so that a work standard can be created for work activities that involve potentially tritiated water. This information will be used to update PM model work orders and current work orders involving potentially tritiated water.<br>- Using the information provided by RP, create a work standard to be used for work activities that involve potentially tritiated water and update PM model work orders and current work orders involving potentially tritiated water. |

## Attachment 7 - Cause & Effect Analysis

| Effect / Symptom | Why | Cause / Reason |
|---|---|---|
| Tritium found off site | | Inadequate response |
| Inadequate response | | Personnel not aware of the B/D water Tritium exceeding ground water limits |
| Personnel not aware of the B/D water Tritium exceeding limits | | Personnel not aware of the IEPA tritium limit requirements for ground water |
| Personnel not aware of the IEPA tritium limit requirements for ground water | | Knowledge deficiency |
| Knowledge deficiency | | No procedural guidance for ground water spills |

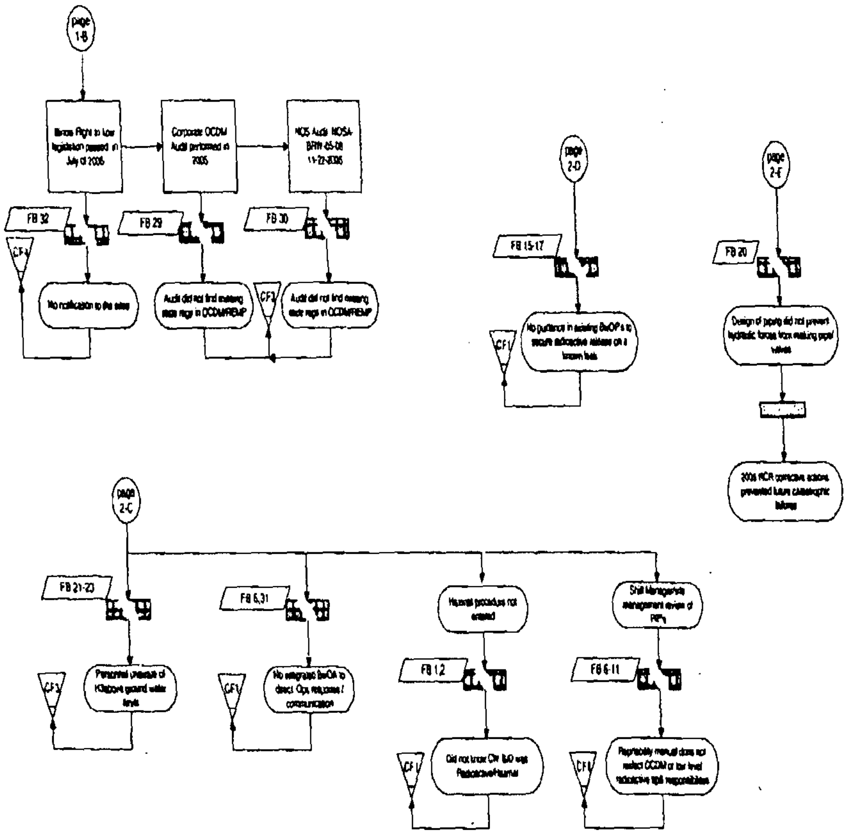
# Attachment 8 - E&CF Chart





Page 2 for history of blowdown vacuum breaker 0CW060 (VB3)
Page 1-A
page 3-C
Page 3-D
FB 12,13
FB 33
FB 21-23
FB 3
FB 14
FB 4
FB 5
FB 15
FB 18, 19
Other Issue b
Other Issue a
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF1
CF2
Event and Causal Factor Chart
Tritium Event
Root Cause Report
IR# 00428869

Page 3 for history of blowdown vacuum breakers




Event and Causal Factor Chart
Tritium Event
Root Cause Report
IR# 00428988

# Attachment 9
## Kepner Tregoe

[redacted]

**List threats and opportunities** — **Separate and clarify concerns** — **Consider current impact, future impact, and time frame**

*What deviations are occurring? What decisions need to be made? What plans should be implemented?*

*What changes are anticipated? What opportunities exist? What bothers us about...?*

*What do we mean by...? What exactly is...? What else concerns us about...?*

*What evidence do we have...? What different deviations, decisions, or plans are part of this concern?*

*What is the current impact on people, safety, etc.? Which concern is most serious?*

*What is the deadline? When do we need to start? Which concern will be hardest to resolve later?*

*What will be the future impact? Which concern is getting worse quicker?*

| Concerns | Concerns | Current Impact | Future Impact | Time Frame |
|---|---|---|---|---|
| Detectable Tritium Off-site | Detectable Tritium Off-site | Public concerned | Tritium potentially reaching drinking water | being determined |
| | | Regulators concerned | Adverse regulatory environment | being determined |
| Public NPDES Reapproval concerns | Detectable Tritium Off-site | Public concerned | Tritium potentially reaching drinking water | being determined |
| | | Regulators concerned | Adverse regulatory environment | being determined |

# Attachment 9
# Kepner Tregoe

[redacted] [redacted] [redacted]

### Determine analysis needed

*Do we have a deviation? Is cause unknown?*
*Do we need to know cause to take meaningful action?*
*Do we need to make a choice?*
*Do we have an action or plan to protect (enhance)?*

### Determine help needed

*What needs to be done and when?*
*Who will document our process*
*and results?*

| Highest Priority | Process | Action Needed | Who Does What and When |
|---|---|---|---|
| ☑ | PPA | Mitigation of Tritium in water | Braidwood Station to determine corrective actions |
| ☐ | Select | Mitigation of Public perception | Braidwood Station to determine corrective actions |
| ☐ | Select | | |
| ☑ | Select | Mitigation of Tritium in water | Braidwood Station to determine corrective actions |

# ATTACHMENT 10

# OFF-SITE DOSE CALCULATION MANUAL REVIEW

## ODCM Reporting Requirements

Reporting requirements described in the Braidwood Off-Site Dose Calculation Manual (ODCM) were reviewed.

The reporting requirements for the Radiological Environmental Monitoring Program (REMP) are specified in the Braidwood ODCM section 12.5.1. Table 12.5-2 lists REMP reporting levels for tritium and other radionuclides that are monitored in various types of samples obtained. These ODCM required reporting requirements are not listed in the Reportability Manual.

The Braidwood ODCM REMP drinking water tritium concentration reporting requirements are consistent with the requirements of 40 CFR 141 and 35 IAC 620. However, per ODCM Section 12.5.1, reportability is based on a quarterly average. 40 CFR 141 and 35 IAC 620 reportability are based on an annual average – the ODCM reportability is conservative and consistent with the recommendations in NUREG 1301 Section 3.12.1.

There is no mention of 35 IAC 611 or 35 IAC 620 requirements in the Braidwood ODCM.

To date, measured tritium concentrations are less than the reporting criteria described in the ODCM.

## State Legislation

The requirements of 35 IAC 620 are not described in the ODCM and station personnel were not aware of these requirements. As a result, Braidwood's historical response to vacuum breaker leakage was inadequate.

In 2005, Illinois passed SB241, which became effective on July 25, 2005. This legislation states that if the Illinois Environmental Protection Agency (IEPA) makes a determination that groundwater poses a threat of exposure above Class I groundwater standards (35 IAC 620), then public notification is required. The IEPA does not require conclusive evidence of exceeding a standard. The notification can be based on modeling that demonstrates a trend towards exceeding a standard.

While this legislation does not require site reporting and does not change daily operation, it does impact the site because public notification can be made based on groundwater contaminant concentrations that are below reportable thresholds. There is no mechanism in place for site technical expertise to be made aware of new legislation such as Illinois SB241.

REMP Monitoring

Braidwood ODCM Table 12.5-1 section 3.a, Ground / well water specifies that samples from two sources are required only if they are likely to be affected. Note (6) of ODCM Table 12.5-1 clarifies that groundwater samples shall be taken when this source is tapped for drinking or irrigation purposes in areas where the hydraulic gradient or recharge properties are suitable for contamination. Per discussion with Conestoga-Rovers & Associates and the Exelon Hydrologist, on site groundwater at Braidwood meets the above criteria. There are drinking water wells in close proximity of the site that could be affected.

Review of Braidwood ODCM Table 11-1 section 3.a, Ground / well water indicates that there are (5) drinking water wells currently being monitored. However, there are no specific groundwater sample locations. This requirement should be reviewed to determine if the well samples described in Table 11-1 meets the intent of groundwater monitoring and to modify the REMP to include specific shallow groundwater monitoring.

Braidwood ODCM Table 12.5-1 Section 3.a and note (6) to the table discusses the need for groundwater monitoring when the irrigation pathway is a credible pathway. The hydraulic gradient at Braidwood indicates that shallow wells could become contaminated. ODCM Section 4.3 states that the only liquid pathways used are the potable water and fish ingestion pathways. The irrigation to food crop pathway should be evaluated.

Monitoring for other nuclides

40 CFR 141 and 35 IAC 620 specify limits on radionuclides other than tritium. As part of Braidwood's recovery plan, gamma-emitting fission and activation products as well as other beta-emitting nuclides (Strontium-89, and Strontium-90). To date, the gamma-emitting nuclide analytical results indicate normal background levels. Strontium-89 and Strontium-90 results are not available at this time.

ODCM Oversight

ODCM ownership was transferred from Radiation Protection (RP) to Chemistry at Braidwood in 2003 without transferring the ODCM specialist and the associated expertise of the program. At other stations, the ODCM specialist transferred from RP to Chemistry, thus maintaining continuity and expertise.

As part of Exelon alignment, the corporate support for the ODCM program was eliminated in the 2001-2002 time frame. From 2002-2005, there was no corporate ODCM support to assist the sites. In early 2005, a Corporate Chemistry specialist was given collateral duty of overseeing the implementation of several ODCM-related vendor contracts. Since that time, this collateral duty has evolved. But, there is no defined responsibilities or procedures. The position is evolving over time, but is still a collateral duty.

Corporate technical assistance for off-normal situations such as abnormal releases to groundwater supply could help mitigate such an event in a timely manner and reduce the environmental impact.

## Recommended Actions

Review the ODCM REMP reportability requirements to determine whether these requirements should be included in the Reportability Manual.

Review ODCM RETS reportability requirements to determine whether the reportability requirements not currently in the Reportability Manual should be in the Reportability Manual.
Determine whether state specific requirements such as 35 IAC 611 or 35 IAC 620 should be in the ODCM.

Evaluate Braidwood ODCM REMP requirements to determine if groundwater monitoring wells should be included in the REMP per ODCM Table 12.5-1 Section 3.a. and note (6) to that table.

Evaluate Braidwood ODCM REMP irrigation pathway based on ODCM Table 12.5-1 Section 3.a and note (6) to that table. This evaluation will include an evaluation of the groundwater pathway for off site dose considerations.

Corporate Chemistry should clearly define the role of the corporate ODCM technical support.

Corporate RP/Chemistry should develop a plan/procedure to assist the sites' vulnerability to groundwater contamination/spills.

Corporate Licensing should develop a method to communicate new legislation (such as Illinois SB241) to the site technical expertise.

Based on the lack of knowledge concerning 35 IAC 620 and Illinois legislation SB241, all applicable environmental legislation should be reviewed to determine other requirements exist that current processes do not address. Scope should be expanded as required based on this review.

## References

Braidwood Off-Site Dose Calculation Manual Revision 7

NUREG 1301, Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors, Generic Letter 89-01 Supplement 1, April 1991

40 CFR 141, National Primary Drinking Water Regulations

35 IAC 611, Primary Drinking Water Standards

35 IAC 620, Groundwater Quality

Exelon Environmental Regulatory Group (EERG) White Paper: Illinois Right-to-Know Legislation – PA094-0314

## ATTACHMENT 11

# Review of Exelon Hazmat spill response procedures

In general, there is no spill response procedure, which would acknowledge the subsurface water transport mechanism from on-site to off-site locations. The three documents reviewed were a draft procedure circulated in 10/16/90, "General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills", BwAP 750-4, "Hazardous Material Spill Response", and BwAP 1100-16, "Fire/Hazardous Materials Spill and/or Injury Response", and NSP-RP-6101, "10CFR50.75(g)(1) Documentation Requirements".

The most significant barrier deficiencies noted was that the 1990 draft procedure, which was circulated, did provide recognition of reviewing hydrology and dose to the public from radiological contamination of ground water. Additionally, the procedure to document the spill for 10CFR50.75(g)(1) requirements for decommissioning prompts to perform a potential dose impact to the public from the spill, but does not require any specific pathway (i.e. subsurface migration of contaminants to drinking water).

| Procedure | Relevant Content | Barrier Analysis |
|---|---|---|
| Draft Procedure CSG-001, "General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills"<br><br>Circulated as a Draft procedure 10/16/90. No record of this becoming an actual procedure.<br><br>This procedure contains information relevant to the underground water dose pathway to the public now being evaluated. Not implementing this procedure was a missed opportunity to erect a barrier to recognize | The draft procedure contained pertinent information about:<br>• For situations involving subsurface contamination, corrective action may mean the preparation of a submittal pursuant to the Il Adm. Code 340.3020 and 10CFR20.302 requesting the in-place disposal of subsurface contamination.<br>• Environment – refers to any surface water, ground water, sanitary or storm sewers, soil, land surface, or subsurface strata and vegetation.<br>• Subsurface contamination and hydrology concerns<br>• Reviewing to ensure the spill is not in excess of Reportable Quantity quantities in 40CFR302 App | Significant missed opportunity to erect a barrier.<br><br>This procedure would have prompted recognition of dose impacts from the contamination of ground water and supporting hydrology issues.<br><br>Would have provided an opportunity for all former ComEd power plants to |

| Procedure | Relevant Content | Barrier Analysis |
|---|---|---|
| | B or 40CFR355 App A<br>• Required evaluation of exposure pathways from infiltration and contamination of ground water. | recognize the potential issue. |
| BwAP 750-4, "Hazardous Material Spill Response" | In general, site personnel would not consider entry into the hazmat spill procedure for a water spill.<br>The procedure contains the following pertinent information:<br>• The procedure references Hazardous Materials as listed in 40CFR302.4, which lists many chemicals, but not radioactive material. The intent of this reference is to ensure that a "Reportable Quantity" has not been spilled on the ground. The absence of radioactive materials from the list in the procedure does not preclude someone from looking for radioactive material in 40CFR302.4, but the procedure does not offer a clear barrier to trip recognition of a radioactive material spill as a hazmat event per this procedure. Even if radioactive materials was clearly on the Reportable Quantity list, the RP organization does not have a procedure documenting additional required actions.<br>• The procedure states, "Spills containing radiologically contaminated material shall be reported to the Radiation Protection Dept. | Minor missed barrier.<br><br>Missing this barrier was of no consequence. The RP organization did not have subsequent procedures to respond to the subsurface transport issues, which are of issue today. |
| BwAP 1100-16, "Fire/Hazardous Materials Spill and/or | The hazmat procedure does not contain information to specify actions that might direct specific | Minor missed barrier. |

| Procedure | Relevant Content | Barrier Analysis |
| --- | --- | --- |
| Injury Response" | radiological actions to minimize the significance of a similar event. The procedure essentially defers radiological spills to the RP organization. The procedure contains the following radiological information:<br>• Notify Rad Protection to dispatch personnel to the fire/spill area for radiation detection and first aid purposes. | Missing this barrier was of no consequence. The RP organization did not have subsequent procedures to respond to the subsurface transport issues which are of issue today. |
| NSP-RP-6101, "10CFR50.75(g)(1) Documentation Requirements" | This procedure is intended to provide the following information as required from the regulation:<br>• 10CFR50.75(g)(1) Records of spills or other unusual occurrences involving the spread of contamination in and around the facility, equipment, or site. These records may be limited to instances when significant contamination remains after any cleanup procedures or when there is reasonable likelihood that contaminants may have spread to inaccessible areas as in the case of possible seepage into porous materials such as concrete. These records must include any known information on identification of involved nuclides, quantities, forms, and concentrations.<br>• The actual procedure requires addressing:<br>o Concentrations of involved radionuclides<br>o Quantities of material(s) | Significant Missed barrier<br><br>The procedure requires an assessment of potential dose to the public from the remaining radioactive material, but does not prompt for the pathway of subsurface migration through ground water to drinking water. |

| Procedure | Relevant Content | Barrier Analysis |
|---|---|---|
| | o Forms of material(s), (e.g. solubility and permeability of the contaminant)<br>o Description of the event<br>o Impact of the remaining radioactive material on the health and safety of the public<br>o Affected areas<br>• The procedure prompts to perform a potential dose impact to members of the public, but it does not describe pathways to be analyzed (i.e. subsurface migration of contaminants to drinking water). The general absence of tools to calculate the specifics of subsurface transport mechanisms may have prompted actual measurements through the drilling of wells to sample water or sample existing off-site wells. | |

# Attachment 12
# Change Analysis

(The information contained in the change analysis attachment was inadequate to use effectively and was therefore not utilized as an input to this root cause report.)

Incident Title: Corporate ownership for ODCM eliminated

| Factors That Influence Performance | Interview Questions | Successful Performance | Failed Performance | Change? | Causal Factor? |
|---|---|---|---|---|---|
| "What?" – Lack of Guidance Lost depth of knowledge | Questioned Corporate personnel as to whether or not there is existing ownership on stations ODCM. | Dedicated Corporate owner for all sites ODCM oversight. | Corporate support for the ODCM program was eliminated. From 2002-2005, there was no corporate ODCM support to assist the sites. | Yes | Potentially |
| "When?" – 2001-2002 time frame. | | | | | |
| "Where?" – Cantera/Downers Grove | | | Corporate office. | | |
| "How?" – No turnover information | | | As part of Exelon realignment. | | |
| "Who?" – What positions? Corporate | | | Unknown. | | |
| Special Conditions- Laws have been changing. Best in Fleet manning. | | | | | |
| Procedures- Change management procedure (followed?) | | | | | |
| Training- Not performed for | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| those assuming | | | | | |
| Communications | | | | | |
| Management Expectations | | | | | |

Incident Title: – Right to Know (RTK) Legislation changed Regulators approach to handling potential concerns.

| **Factors That Influence Performance** | **Interview Questions** | **Successful Performance** | **Failed Performance** | **Change?** | **Causal Factor?** |
|---|---|---|---|---|---|
| "What?" – Right to Know (RTK) Legislation changed Regulators approach to handling potential concerns. | | Plan in place to cope with changing regulation. | Increased Regulatory focus and resultant impact not fully realized by corporation. | | |
| "When?" -Became law on 7/25/2005. | | Prior to becoming law. | | | |
| "Where?" – All Illinois sites | | | | | |
| "How?" – Illinois passed SB241, which included both community right-to-know (RTK) and unilateral administrative order (UAO) provisions | | | | | |
| "Who?" – Generally known amongst Corporate and Environmental personnel. | | | | | |
| Special Conditions- None | | | | | |
| Procedures- None | | | | | |
| Training- None | | | | | |
| Communications- Corporate wrote white paper. | | | | | |
| Management Expectations- Never let this happen again. | | | | | |

Analyses will also be utilized. To accomplish a timely report delivery, support will be required as noted above in Engineering, Hydrology, Maintenance, Operations, Off-Site Dose Assessment, and Technical Writing.

**Interim Corrective Actions:**

An Issues Management Team has been formed to manage the recovery.
Additional Sampling will be performed and analyzed to fully define the affected areas.
The discharge piping will be reviewed for integrity. Remediation plans will be developed and implementation initiated. Communications will be maintained with Exelon, Regulatory personnel, the public, and INPO.

**Root Cause Report Milestones:**

| | | |
|---|---|---|
| 1. | Event Date | (11/30/05) |
| 2. | Screening Date | (12/07/05) |
| 3. | Completion of Charter (2 Days from MRC) [-03] | (12/09/05) |
| 4. | Status Briefing for Charter [-14] | (12/14/05) |
| 5. | Two Week Update & Draft RCR for Reviews [-07] | (12/21/05) |
| 6. | MRC Update & Draft RCR for Reviews [-08] | (12/28/05) |
| 7. | CAPCo Reviews of RCR [-15] | (12/29/05) |
| 8. | Collegial Reviews of RCR [-15] | (12/29/05) |
| 9. | MRC Update & Draft RCR for Reviews [-09] | (01/04/06) |
| 10. | Sponsoring Manager Report Approval [-14] | (01/04/06) |
| 11. | Root Cause delivered to MRC | (01/06/06) |
| 12. | Review by MRC [-05] | (01/13/06) |
| 13. | Final Root Cause Investigation Due Date [-04] | (01/13/06) |

| | | |
|---|---|---|
| **Prepared By:** | Tom Leffler, Root Cause Qualified Investigator | 12/09/05 |
| | (Name) | (Date) |
| **Approved By:** | Janice Kuczynski Chemistry Manager | 12/09/05 |
| | (Sponsoring Manager) | (Date) |

# ATTACHMENT 14
## Root Cause Report Quality Checklist



| A. | Critical Content Attributes | YES | NO |
|---|---|---|---|
| 1. | Is the condition that requires resolution adequately and accurately identified? | X | |
| 2. | Are inappropriate actions and equipment failures (causal factors) identified? | X | |
| 3. | Are the causes accurately identified, including root causes and contributing causes? | X | |
| 4. | Are there corrective actions to prevent recurrence identified for each root cause and do they tie DIRECTLY to the root cause? AND, are there corrective actions for contributing cause and do they tie DIRECTLY to the contributing cause? | X | |
| 5. | Have the root cause analysis techniques been appropriately used and documented? | X | |
| 6. | Was an Event and Causal Factors Chart properly prepared? | X | |
| 7. | Does the report adequately and accurately address the extent of condition in accordance with the guidance provided in Attachment 3 of LS-AA-125-1003, Reference 4.3? | X | |
| 8. | Does the report adequately and accurately address plant specific risk consequences? | X | |
| 9. | Does the report adequately and accurately address programmatic and organizational issues? | X | |
| 10. | Have previous similar events been evaluated? Has an Operating Experience database search been performed to determine whether the problem was preventable if industry experience had been adequately implemented? | X | |

| B. | Important Content Attributes | | |
|---|---|---|---|
| 1. | Are all of the important facts included in the report? | X | |
| 2. | Does the report explain the logic used to arrive at the conclusions? | X | |
| 3. | If appropriate, does the report explain what root causes were considered, but eliminated from further consideration and the bases for their elimination from consideration? | X | |
| 4. | Does the report identify contributing causes, if applicable? | X | |
| 5. | Is it clear what conditions the corrective actions are intended to create? | X | |
| 6. | Are there unnecessary corrective actions that do not address the root causes or contributing causes? | X | |

| | | | |
|---|---|---|---|
| 7. | Is the timing for completion of each corrective action commensurate with the importance or risk associated with the issue? | X | |
| **C.** | **Miscellaneous Items** | | |
| 1. | Did an individual who is qualified in Root Cause Analysis prepare the report? | X | |
| 2. | Does the Executive Summary adequately and accurately describe the significance of the event, the event sequence, root causes, corrective actions, reportability, and previous events? | X | |
| 3. | Do the corrective actions include an effectiveness review for corrective actions to prevent recurrence? | X | |
| 4. | Were **ALL** corrective actions entered and verified to be in Action Tracking? | X | |
| 5. | Are the format, composition, and rhetoric acceptable (grammar, typographical errors, spelling, acronyms, etc.)? | X | |

# Attachment 15

## Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2)
## Event Timeline

### Vacuum Breaker #3 (VB-3)

December 1997

- VB-3 was inspected with no leakage noted.

December, 3 to 4, 1998

- VB-3 was discovered leaking, due to catastrophic water hammer failure of the air vent valve line ***(See RC38237-02)***. The Problem Identification Form (PIF) for this event (A1998-04324) was closed to no concern, based on the water being contained on-site and personnel not aware of the tritium concern ***(Causal factor 2)***. The PIF stated that the water was in the ditch, which Exelon owns. PIF A1998-04324 stated the repair was completed within 24 hours (12/05/1998) under WR 98076645 and WO 98127749. This section of ditch is blocked at both ends. The size/amount of leakage was not recorded due to a lack of monitoring instrumentation **(Other Issue "a")**, but was estimated to be similar to the VB-2 leakage at approximately 3 million gallons over a 30-day period. No integrated spill response procedure was in place to ensure adequate station response. ***(Causal Factor 1, Root Cause )***

December 5,1998

- Revision 0 of Work Order (WO) 98127749 states: "Butterfly valve gear box stripped & air release valve laying in bottom of the pit. Installed nipple and ball valve into vacuum breaker water shooting out. Closed ball valve and reinstalled air release valve until parts can be purchased and taken Out of Service (OOS) for 3 to 4 days to allow for draining of header."

November 15, 2000

- Condition Report (CR) A2000-04389 was written which stated the 1998 response was inadequate, as a result of Root Cause Report (RCR) 38237/CR A2000-04281. CR A2000-04389 resulted in an action to Radiation Protection to perform a radiological evaluation under 10CFR50.75(g).

June 18, 2001

- CR A2001-01806 found VB-3 leaking. WC-AA-106 did not have tritium concerns integrated into the work prioritization. At this time, there was no guidance in the CW B/D procedures to secure radiological releases when known leaks were discovered. ***(Causal Factor 1, Root Cause)***

  Note: Little to no information could be found in PIF's or WR/WO's for this event. Therefore, little data could be retrieved by the Root Cause Team (RCT) other than from personnel interviews.

July 21, 2001

- CR A2000-04389's 10CFR50.75(g) Radiological Assessment Report was completed based on samples obtained in April 2001. The spill site was inadequately characterized, due to the lack of groundwater assessment for tritium concentrations. Therefore, the evaluation erroneously concluded that there was no further action required. (Attachment 11) ***(Causal Factor 1, Root Cause)***

July 23, 2001

- Revision 2 of WO 98127749 to repair VB-3 is authorized for work by Operations. The WO comments stated that leaking water prevented work completion. The WO did not contain precautions regarding tritium leakage, due to ATI 106767-04 comments not being incorporated into the WO. ***(Other Issue "b")***

December 2001

- VB-3 was inspected with no leakage noted.

May 4, 2002

- VB-3 pilot (air release) valve seat was discovered leaking.

May 20, 2002

- Revision 2 of WO 98127749 to repair the isolation valve for VB-3 was completed, with no mention of radiological controls for the water discovered in the vacuum breaker pit. ***(Causal factor 2)***

August 29, 2003

- Water was found in the VB-3 valve pit during walkdown surveillance. WR#00110407 and IR#173688 were written.

March 17, 2005

- The IEPA commenced an investigation into high tritium in a Radiological Environmental Monitoring Program well (the Hutton well, elevated, but within specification). Follow-up sampling to this issue was commenced.

April 19, 2005

- VB-3 pilot (air release) valve seat repair was completed. Leakage was not recorded. A leak rate of 20 drops per minute was assumed. This leakage was the result of raw water debris preventing the seat from closing. Cycling of the valve during normal operation typically clears this type of leakage. In this case, the valve was replaced. The current PM program inspects the valve twice a year to identify these problems and correct them.

November 30, 2005

- Issue Report (IR) 428868 reports tritium concentrations from what appears to be the area of the 1998 spill, have migrated off-site with a potential to affect the public via tritiated groundwater. ***(EVENT)***

**Vacuum Breaker 2 (VB-2)**

December 1996

- VB-2 was inspected with no leakage noted

January 1, 1998

- Leak discovered on the VB-2 pilot (air release) valve seat.

November 2000

- VB-2 pilot valve repair completed via Work Request (WR) 98000691. Leakage was not recorded. A leak rate of 20 drops per minute was assumed. This leakage was the result of raw water debris preventing the seat from closing. Cycling of the valve during normal operation typically clears this type of leakage. In this case, the valve was replaced. The current Preventative Maintenance (PM) program inspects the valve twice per year to identify and correct these problems.

November 6, 2000 ~ 14:30

- The National Pollutant Discharge Elimination System (NPDES) Coordinator received a call from the Illinois Environmental Protection Agency (IEPA) regarding standing water in a ditch adjacent to site property along the south side of Smiley Road. An area resident had reported the water and noted that the water had been present in the ditch for approximately 7-10 days prior to IEPA notification. Suspecting a faulty vacuum breaker, the NPDES Coordinator notified the Shift Manager and Outage Control Center (OCC) Director of the IEPA notification.

November 6, 2000 ~ 15:00

- The NPDES Coordinator walked down the Circulating Water Blowdown system and identified that the water was coming from a valve vault that houses VB-2. The NPDES Coordinator assessed the site and concluded that the water was confined to site property and the ditch along the south side of Smiley Road immediately adjacent to site property. The water in the ditch was confined by the resident's driveway to the west and by higher elevation to the east.

- The NPDES Coordinator notified the IEPA of his findings regarding the water source and the boundaries of the discharge. Station NPDES monitoring requirements were discussed and the IEPA concluded that no additional sampling was required and that there were no NPDES concerns since the water was contained and not discharging to 'Waters of the State'.

- The VB-2 leakage was estimated to be a maximum of 3 million gallons. This leakage was the result of water hammer, which broke the float in VB-2, exposing an 8" opening. This was caused by a change in the operation of the CW B/D line in 1997. Root Cause 38237 addressed this problem. The corrective actions have been completed to prevent a recurrence.

<u>November 6, 2000 16:00 -17:00</u>

- A meeting was held with Senior Station Management, the Shift Manager and the Operational Control Center (OCC) staff. The NPDES Coordinator briefed the attendees on the results of his field observations of the area surrounding the vacuum breaker valve. Station Management was also briefed on the discussions between the NPDES Coordinator and the IEPA. Senior Management directed the following actions be taken:
  1. Operating personnel were to evaluate water inventories and to explore potential alternate release options.
  2. Isolate the CW B/D system
  3. Make preparations to take the CW B/D system out of service, drain the piping section and replace the failed vacuum breaker valve.

- The CW B/D system was then isolated in preparation for draining and repairs. There was no discussion at this time of any need to sample for radioactivity in the water that had been discharged. The thought process was that any radioactivity in the water had been diluted per procedure and was acceptable for discharge to the environment (i.e., the Kankakee River). [This is based on Operations interviews.]

<u>November 7, 2000 ~ 0615</u>

- The Radiation Protection (RP) Manager was contacted by the Operations Manager that there was a blowdown line leak and that RP was to meet with the Chemistry Manager to look at potential alternate radioactive release paths. The reason for this request was that radioactive releases would not be possible via the blowdown system while blowdown was isolated for repairs to VB-2.

- Following this phone conversation, the RP Manager spoke with the RP Technical Superintendent and discussed the need to collect samples of available water. Included in this discussion was a conclusion that the samples should contain no radioactivity because of the belief that the spilled water was "only lake water."

November 7, 2000 ~0800

- A decision to conduct confirmatory sampling of the water leaking from the manway cover of the vacuum breaker structure was made. The sample was taken at approximately 0845 and the results of the gamma isotopic analysis indicated no quantifiable peaks found no quantifiable peaks found (NQPF), and the tritium result was less than the lower limit of detection.

November 7, 2000 ~0830

- Mechanical Maintenance Department (MMD) personnel with assistance from System Engineering pumped out the VB-2 vault back into the B/D line and began draining the blowdown piping to facilitate work on VB-2.

November 7, 2000 ~ 1130

- RP received information that the leak may have occurred for a period of 7-10 days and that the water that leaked was from the circulating water blowdown line, which carries the liquid radwaste discharges from the station to the river.

November 7, 2000 ~ 1200

- After the CW B/D line had drained sufficiently, the entire VB-2 isolation valve and vacuum breaker assembly was replaced.

November 7, 2000 ~ 1230

- A decision was made to initiate soil sampling in the vicinity of the vacuum breaker structure, and to obtain a water sample from the standing water that was onsite, but near the Smiley Road ditch.

November 7, 2000 ~1900

- The results of the samples of this day were discussed with corporate Generation Support Department (GSD) RP Manager. Corporate GSD agreed to discuss the issue with the corporate GSD General Manager.

November 7, 2000 ~1945

- The Station Manager and Site Vice-President (VP) were notified of the sample results. A total of 5 soil samples were obtained within approximately 30 feet of the vacuum breaker structure, and 2 of the 5 samples had detectable levels of radioactivity. The onsite soil sample obtained near the Smiley Road ditch was analyzed and the gamma isotopic indicated NQPF and the water analysis indicated tritium at a level of >20,000 pCi/L.

November 8, 2000~0830

- The RP Manager discussed the sample results on the morning call.

November 8, 2000 ~1400

- The RP Manager, Chemistry Manager, Regulatory Assurance Manager, Station Manager, and Site VP met to discuss the current status, next steps, and sampling for the event.

November 8, 2000 ~ 1600

- Additional onsite sampling of the standing water in the area leading to the Smiley Road ditch was performed. Four water samples were taken and results indicated tritium levels >20,000 pCi/L. No gamma isotopic activity was detected.

November 9, 2000 ~ 1000

- A conference call was held with the Site Management and Corporate Personnel to finalize and approve an Offsite Sampling Plan, a Remediation Plan, and a Communications Plan. At 1200, discussions were held with site and regional NRC personnel. At 1210, notification of the offsite release was made to Will County authorities and to the Reed Township Highway Commissioner. At 1245, RP was dispatched to obtain water samples from the Smiley Road ditch.

November 9, 2000 ~1400

- Four water samples were obtained from the Smiley Road ditch. Gamma isotopic analysis indicated and the tritium analyses ranged from 19,000 pCi/L to 25,000 pCi/L NQPF. Teledyne Isotopes Midwest Laboratory also analyzed these samples with similar results.

November 9, 2000

- The NRC Regional Office and Illinois Department of Nuclear Safety (IDNS) were notified of the Smiley Road ditch sample analyses results.

November 10, 2000 ~1100

- Pumping of the water back to the blowdown line commenced. Pumping continued using a 600 gpm pump, approximately 18 hours per day.

November 15, 2000 ~2000

- All possible water spilled from VB-2 was pumped back into the blowdown line.

November 2000

- Wells were installed in the area of the 2000 leak to characterize the local hydrology. The information gained implied that underground water in the area of VB-2 would take approximately 15 years to flow off-site. Therefore, further actions regarding radioactivity clean-up was delegated to the 10CFR50.75(g) long-term spill characterization and clean-up process, which did not sample for groundwater tritium ***(Missed Opportunity).***