4.12 PUBLIC AND OCCUPATIONAL HEALTH IMPACTS

4.12.1 Nonradiological Impacts

4.12.1.1 Public Health Impacts

The area within an 80-kilometer (km) (50-mile) radius of the License Area includes portions of six counties in northeastern Wyoming (Campbell, Converse, Johnson, Natrona, Weston Counties and a small portion of Niobrara County). The proposed Moore Ranch Project is located in southwest Campbell County. The nearest communities are Wright, a small Campbell County incorporated town located northeast on State Highway 387, and the Towns of Edgerton and Midwest, which are located in Natrona County southwest of the Moore Ranch Project on State Highway 387.

Section 3.10 discussed the population distribution for the 80 km radius around the Moore Ranch Project. Figure 3.10-1 provides the sectorial population for the 16 compass sectors in concentric rings of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70 and 80 km from the center of the proposed project. The population within 2 miles of the License Area boundary was estimated by locating occupied residences within 2 miles using 2006 aerial photos and field reconnaissance in 2007. The nearest resident is approximately 4.5 km from the proposed central plant location. The nearest sensitive receptors (e.g., schools) are in the Town of Wright, located approximately 32.2 km from the central plant location.

NUREG-1569 requires that applicants provide estimates of concentrations of nonradioactive constituents in effluents at the points of discharge and provide a comparison with natural ambient concentrations and applicable discharge standards. There are two effluents expected from the Moore Ranch Project.

- A gaseous and airborne effluent will consist of air ventilated from the plant building ventilation system and vented from process vessels and tanks. This gaseous effluent will contain radon gas as discussed below in Section 4.12.2. The gaseous and airborne effluent will not contain any non-radiological effluents. Nonradioactive airborne effluents at the Moore Ranch Project will be limited to fugitive dust from access roads and wellfield activities. Fugitive dust emissions will be minimal and dust suppressants will be used if conditions warrant their use. Air quality impacts of construction and operation of the Moore Ranch Project were discussed in detail in Section 4.6.

- The liquid effluent will be managed in the deep disposal wells. The deep disposal wells will permanently dispose of liquid wastes and will be permitted under a Class I UIC Permit issued by the WDEQ. No routine liquid environmental discharges, other than waste disposal via deep well injection, are planned and as such, no definable water related pathways for routine operations exist. There are no non-radiological impacts to public health expected due to the liquid effluents from the Moore Ranch Project.

4.12.1.2 Occupational Health Impacts

Accidents involving human safety associated with the ISR uranium mining technology typically have far less severe consequences that accidents associated with underground and open pit mining methods. In-situ mining provides a higher level of safety for employees and neighboring communities when compared to conventional mining methods or other energy related industries. Accidents that may occur would generally be considered minor when compared to other industries. Radiological accidents that might occur would typically manifest themselves slowly and are therefore easily detected and mitigated. The remote location of the Moore Ranch facility and the low level of radioactivity associated with the process combine to decrease the potential hazard of an accident to the general public.

For the purposes of estimating the potential occupational injury and illness rates for the Moore Ranch project, EMC estimates that the total site work hours for EMC employees and contractors will be 142,000 hours per year. Using the 2007 Wyoming mining industry total nonfatal occupational injury and illness rate of 2.7 from Table 3.11-1, operations at Moore Ranch could potentially result in 1.9 nonfatal occupational injuries and illnesses per year of operation.

NRC has previously evaluated the effects of accidents at conventional uranium milling facilities in NUREG–0706 and specifically at ISR uranium facilities in NUREG/CR-6733. These analyses demonstrate that, for most credible potential accidents, consequences are minor so long as effective emergency procedures and properly trained personnel are used. The proposed Moore Ranch facilities are consistent with the operating assumptions, site features, and designs examined in the NRC analyses in NUREG/CR-6733.

NUREG-0706 considered the environmental effects of accidents at single and multiple uranium milling facilities. Analyses were performed on incidents involving radioactivity and classified these incidents as trivial, small, and large. NUREG-0706 also considered transportation accidents. Some of the analyses in NUREG-0706 are applicable to ISR facilities, such as transportation accidents. NUREG/CR-6733 specifically addressed risks at ISR facilities and identified the "risk insights" that are discussed in the following sections.

4.12.1.2.1 Chemical Risk

NUREG/CR-6733 noted that the scope of the NRC mission includes hazardous chemicals to the extent that mishaps with these chemicals could affect releases of radioactive materials. Industrial safety aspects associated with the use of hazardous chemicals at Moore Ranch is regulated by the Wyoming Occupational Safety and Health Administration (OSHA).

Sulfuric Acid

Sulfuric acid may be used to split the uranyl carbonate complex from rich eluate into carbon dioxide gas and uranyl ions in preparation for precipitation using hydrogen peroxide. A 93 percent sulfuric acid solution will be stored outdoors and outside the processing plant in a cross-linked high-density polyethylene flat bottom tank. The tank will be founded in a concrete secondary containment system that is sized to hold 100% of the tank's volume plus a 25-year precipitation episode for 24 hours. The surface of the concrete containment area will be treated with an appropriate coating that could include but not be limited to an acid proof epoxy coating. No other chemicals will be stored in the sulfuric acid secondary containment area. A vent pipe will be fitted to the storage tank and will route vapors to a water bath or circulating water system. Here, acid vapors quickly react with the water to form a dilute sulfuric acid solution. The solution will then be treated with an appropriate base such as soda ash to neutralize the dilute acid solution. Alternately, the vent pipe will be fitted with a demister system to mitigate any acid vapors from releasing to the atmosphere.

In the presence of 93 percent sulfuric acid, the interior of carbon steel pipe will initially corrode to form a thin film of iron sulfate on the surface of the metal. Once formed, the iron sulfate film prevents further corrosion of the underlying material. For this reason, Schedule 80 black steel pipe with forged welding fittings will be used to transport the acid from the storage tank to the elution tanks or other points of application. Proper valving will be installed at the tank exit, both sides of the redundant pumps, and a re-routing piping arrangement down stream from the pumps will be installed to purge the exit lines to the pregnant eluant tanks and return any residual acid in the lines to the outdoor storage tank. A programmable logic control system integrated to the plant automation system will control the pump starts, flow rates, and time as it relates to volume needed. Standard operating procedures (SOPs) will be developed and operators will be trained on using these systems, both automated and manual.

NUREG\CR-6733 does not specify the size of the sulfuric acid storage tank but considers the use of a smaller 450 gallon day tank located within the plant building. EMC does not plan to use a day tank in order to mitigate this potential source for leaks and spills of sulfuric acid. The concentration of sulfuric acid fumes that are immediately dangerous to life and health (IDLH) is 15 mg/m^3. In the risk analysis from NUREG/CR-6733, a spill of 93 percent sulfuric acid was not deemed a significant inhalation hazard to workers as long as normal air dilution is available from the facility ventilation system. If the ventilation system for the Moore Ranch CPP were not operational at the time of a sulfuric acid spill, workers would be required to exit the building. This scenario is unlikely since the ventilation system design includes redundant ventilation blowers to ensure adequate ventilation at all times for the control of chemical and radioactive fumes and gases. NUREG/CR-6733 also noted that sulfuric acid reacts vigorously with ammonia, sodium carbonate, and water, all of which will be present at Moore Ranch. To minimize the potential for chemical reactions in the unlikely event of simultaneous tank leaks, the sulfuric acid storage tank will be located away from other process tanks.

The use of sulfuric acid is subject to Threshold Planning Quantities (TPQs) contained in 40 CFR Part 355, Emergency Response Plans for threshold quantities (TQs) in excess of 1,000 pounds. The Moore Ranch design includes a sulfuric acid tank with a capacity of 12,000 gallons Based on the design capacity, EMC will be subject to the Emergency Response Plan requirements.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and the environment from a release of sulfuric acid include the following:

- To minimize the potential for chemical reactions in the unlikely event of simultaneous tank leaks, the sulfuric acid storage tank will be located separately from other process tanks.

- Construction of all storage tanks, piping, and associated appurtenances will be in accordance with current industry standards.

- The acid tank will be enclosed and will employ a vapor control system on the tank vent, limiting the amount of vapors that can escape to the atmosphere.

- Daily shift inspections of plant and chemical storage facilities are conducted for early detection of potential deficiencies.

- Containment will be provided for 100 % of the total storage capacity plus a 25-year precipitation episode for 24 hours. Containment will be constructed of chemically compatible materials.

- Typically, a Concentrated Acid Work Permit will be required for maintenance work on tanks, pipes, or equipment that contains or may contain concentrated acid or to the use of concentrated acid to prepare decontamination or cleaning solutions as required by site industrial safety procedures.

- Offloading procedures will be developed and implemented to ensure proper steps and precautions are followed during offloading into bulk storage areas.

Mitigation/Accident Response

Upon detection of a release of sulfuric acid, steps will be taken to stop or limit the extent of the release that can be performed without endangering the health of the responders. EMC will develop emergency response procedures for an accidental release of sulfuric acid and employees will be trained on those procedures. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

As a minimum, an acid-rated respirator, face shield, overall or apron and gloves will be required during the cleanup of any acid spill. Additionally, eye wash stations as well as deluge type emergency showers will be located in close proximity to any areas where will be used.

Hydrochloric Acid

As an alternative to sulfuric acid discussed in the previous section, hydrochloric acid may be used to split the uranyl carbonate complex from rich eluate into carbon dioxide gas and uranyl ions in preparation for precipitation using hydrogen peroxide. A 35 percent hydrochloric acid solution will be stored outdoors and outside the processing plant in a cross-linked high-density polyethylene flat bottom tank. The tank will be founded in a concrete secondary containment system that is sized to hold 100% of the tank's volume plus a 25-year precipitation episode for 24 hours. The surface of the concrete containment area will be treated with an appropriate coating that could include but not be limited to an acid proof epoxy coating. No other chemicals will be stored in the hydrochloric acid secondary containment area. A vent pipe will be fitted to the storage tank and will route vapors to a water bath or circulating water system. Here, acid vapors quickly react with the water to form a dilute sulfuric acid solution. The solution will then be treated with an appropriate base such as soda ash to neutralize the dilute acid solution. Alternately, the vent pipe will be fitted with a demister system to mitigate any acid vapors from releasing to the atmosphere.

CPVC (chlorinated PVC) schedule 80 piping with Latharge Viton or EDPM gaskets will be used to transport the hydrochloric acid from the storage tank to the elution tanks or other points of application. Proper valving will be installed at the tank exit, both sides of the redundant pumps, and a re-routing piping arrangement down stream from the pumps will be installed to purge the exit lines to the pregnant eluant tanks and return any residual acid in the lines to the outdoor storage tank. A programmable logic control system integrated to the plant automation system will control the pump starts, flow rates, and time as it relates to volume needed. Standard operating procedures (SOPs) will be developed and operators will be trained on using these systems, both automated and manual.

Hazard Analysis Calculations:

NUREG\CR-6733 does not specify the size of the hydrochloric acid storage tank. EMC performed an analysis of the potential air concentrations of hydrochloric acid fumes using a scenario similar to that considered in NUREG\CR-6733 and applying the following specific characteristics of the Moore Ranch design:

- Flow rate of 35 percent HC1 to the process = 11.355 L/min (3 gpm)
- Volume of the process building = (200 x 140 x 24) ft^3 = 672,000 ft^3 = (672,000 x 0.02831) = 19,024 m^3.
- Process building HVAC system is designed for 3 air changes per hour.

Similar to NUREG\CR-6733, a leak in the piping system of 150 ml/min (0.04 gpm) which goes undetected for 30 min was assumed.

Volume of leak = (0.04 x 30) L = 4.5 L (1.19 gal.)

Mass of leak = 4.5 L x 1.1493 kg/L = 5.2 kg (5.2 x 10^6 mg)

Mass of HC1 in leaked solution = (5.2 x 10^6) x 0.35 = (1.82 x 10^6) mg in 30 min

In 30 minutes the building HVAC system will have performed 1.5 air change volumes of the process building = 28,536 m^3

Volume of air in which the leaked HCl can volatilize = (1 + 1.5) x 19,024 m^3 = 47,560 m^3

Concentration of HC1 vapor in process building = (1.82 x 10^6) mg/47,560 m^3 = 38.3 mg/m^3

IDLH for HCl vapor = 50 ppm = (50 x 1.52) mg/m3 = 76 mg/m3

This analysis illustrates that an HCl piping system leak at the Moore Ranch facility would have the potential to result in localized vapor concentrations of about half the IDLH value within approximately 30 min.

The use of hydrochloric acid is subject to Reporting Quantities (RQs) contained in 40 CFR Part 302.4 for quantities in excess of 5,000 pounds. Based on the design capacity, EMC will be subject to the Reporting Quantities.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and the environment from a release of sulfuric acid include the following:

- To minimize the potential for chemical reactions in the unlikely event of simultaneous tank leaks, the hydrochloric acid storage tank will be located separately from other process tanks.
- Construction of all storage tanks, piping, and associated appurtenances will be in accordance with current industry standards.
- The acid tank will be enclosed and will employ a vapor control system on the tank vent, limiting the amount of vapors that can escape to the atmosphere.
- Daily shift inspections of plant and chemical storage facilities are conducted for early detection of potential deficiencies.
- Containment will be provided for 100 % of the total storage capacity plus a 25-year precipitation episode for 24 hours. Containment will be constructed of chemically compatible materials.
- Typically, a Concentrated Acid Work Permit will be required for maintenance work on tanks, pipes, or equipment that contains or may contain concentrated acid or to the use of concentrated acid to prepare decontamination or cleaning solutions as required by site industrial safety procedures.
- Offloading procedures will be developed and implemented to ensure proper steps and precautions are followed during offloading into bulk storage areas.

Mitigation/Accident Response

Upon detection of a release of hydrochloric acid, steps will be taken to stop or limit the extent of the release that can be performed without endangering the health of the responders. EMC will develop emergency response procedures for an accidental release of hydrochloric acid and employees will be trained on those procedures. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

As a minimum, an acid-rated respirator, face shield, overall or apron and gloves will be required during the cleanup of any acid spill. Additionally, eye wash stations as well as deluge type emergency showers will be located in close proximity to any areas where will be used.

Sodium Hydroxide

Sodium hydroxide is used for pH adjustment during the precipitation process. The sodium hydroxide will be stored in a tank located in the processing plant for use in the precipitation circuit. The 50% sodium hydroxide solution will be stored in an 11,844 gallon fiberglass tank with a vent pipe routed through the roof to the atmosphere outside and above the CPP. A concrete containment berm will be constructed within the plant to contain spills to the immediate area. The berm will be constructed to a height of 6 inches. The sodium hydroxide will be transported using conventional PVC piping from the fiberglass storage vessel into the CPP precipitation tanks. Sodium hydroxide reacts vigorously with sulfuric and hydrochloric acid, one of which will also be present in the precipitation circuit.

Hazard Analysis Calculation:

NUREG\CR-6733 only considered the use of sodium hydroxide for pH control during radium removal from the barren lixiviant bleed stream using a conventional barium/radium sulfate co-precipitation process. 55-gallon drum were assumed for storage. NUREG\CR-6733 did not consider the use of bulk sodium hydroxide for pH control during precipitation, which is curious since this application is common at operating facilities. EMC has performed a hazard analysis similar to the spill scenario contained in NUREG\CR-6733 using specific design data for the Moore Ranch CPP. NUREG\CR-6733 noted that sodium hydroxide is not volatile and that a spill of 50-percent sodium hydroxide solution would not pose a significant inhalation hazard to workers.

The use of sodium hydroxide is subject to the following regulatory program:

- Reportable Quantities (RQs) for spills from the Comprehensive Environmental, Response, Compensation and Liability Act (CERCLA) in 40 CFR § 302.4 for spills in excess of 1,000 pounds.

As discussed, the Moore Ranch design includes a sodium hydroxide tank with a capacity of 11,844 gallons. Based on this design capacity, EMC will be subject to all of the aforementioned regulatory programs.

Hydrogen Peroxide

Hydrogen peroxide will be used in the precipitation phase at Moore Ranch. A 50-percent solution of hydrogen peroxide will be added to the acidified uranium-rich eluant to form an insoluble uranyl peroxide compound. Hydrogen peroxide is a strong oxidizer and is a reactive, easily decomposable compound. Its hazardous decomposition products include oxygen and hydrogen gas, heat, and steam. Decomposition can be caused by mechanical shock, incompatible materials including alkalies, light, ignition sources, excess heat, combustible materials, strong oxidants, rust, dust, and a pH above 4.0. When sealed in strong containers, the decomposition of hydrogen peroxide can cause excessive pressure to build up which may then cause the container to burst explosively.

A 50% solution of hydrogen peroxide will be stored in a horizontal aluminum pressure vessel tank with a pressure actuated relief valve installed in the vent pipe for safety. The storage tank will be located outdoors and outside the main plant. Upon relief, the vapors dissociate to water and oxygen, therefore no vapor scrubbing system is required. A containment berm will be constructed meeting 40 CFR §264.193 for spill mitigation. Hydrogen peroxide will be transported using PVC piping from the exterior storage vessel into the main plant to the precipitation tanks. Proper valves will be installed at the tank exit and both sides of the redundant pumps. A programmable logic control system integrated to the plant automation system will control the pump starts, flow rates, and time as it relates to volume needed. Standard operating procedures (SOP's) will be developed and operators will be trained on using these systems, both automated and manual. Eye wash stations as well as deluge type emergency showers will be located in close proximity to the areas where hydrogen peroxide is used.

Hazard Analysis Calculations:

NUREG\CR-6733 does not specify the size of the hydrogen peroxide storage tank, simply stating that it is typically a large tank located outdoors. EMC performed an analysis of the potential air concentrations of hydrogen peroxide using a scenario similar to that considered in NUREG\CR-6733 and applying the following specific characteristics of the Moore Ranch design:

- Flowrate of 50-percent H_2O_2 solution = 1.14 Lpm (0.3 gpm)
- Volume of the process building = (200 x 140 x 24) ft^3 = 672,000 ft^3 = (672,000 x 0.02831) = 19,024 m^3.
- Process building HVAC system is designed for 3 air changes per hour.

Similar to NUREG\CR-6733, a leak in the piping system of 0.38 LPM (0.1 gpm) which goes undetected for 10 min was assumed.

Volume of leak = (0.1 gpm x 3.7854 L/gal. x 10) = 3.7854 L.

Mass of leak = (3.7854 L x 1.1 kg/L) kg = (4.063×10^6) mg.

Mass of H_2O_2 in leaked solution = (4.063×10^6)/2 = (2.032×10^6) mg.

In 10 min., the building HVAC system will have performed (3 x 10/60) air changes = 0.5 air changes.

Volume of the process building = 19,024 m^3.

Volume of air in which the leaked H_2O_2 can volatilize = (1 + 0.5) x 19,024 m^3 = 28,536 m^3.

Concentration of H_2O_2 vapor in process building = (2.032×10^6 mg)/28,536 m^3 = 71.2 mg/m^3 or 99.7 ppm.

IDLH for H_2O_2 vapor = 75 ppm = (75 x 1.4) mg/m3 = 105 mg/m3.

As noted in NUREG/CR-6733, a hydrogen peroxide piping system leak in a process building has the potential to result in localized vapor concentrations in excess of the IDLH value of 75 ppm within several minutes. A leak in a confined space has the potential to generate lethal concentrations of vapor at an even faster rate. EMC will incorporate recommendations concerning materials of construction for tanks and piping systems and the use of local ventilation with explosion-proof fans to control vapors in the event of a leak of hydrogen peroxide. The building HVAC system is designed for 3 air changes per hour with the capacity to expand to 6 air exchanges per hour. In addition, local exhaust fans will be installed along the outer plant wall to sweep vapors and gases near the floor level.

The use of hydrogen peroxide at concentrations greater than 52 percent is subject to the following regulatory programs:

- Process Safety Management of Highly Hazardous Chemicals standard contained in 29 CFR §1910.119 for TQs in excess of 7,500 pounds; and
- Threshold Planning Quantities (TPQs) contained in 40 CFR Part 355, Emergency Response Plans for threshold quantities (TQs) in excess of 1,000 pounds.

As discussed in Section 2, the Moore Ranch design includes the use of hydrogen peroxide at a concentration of 50 percent contained in a hydrogen peroxide tank with a capacity of 10,000 gallons. With the design hydrogen peroxide concentration and capacity, EMC will not be subject to the aforementioned regulatory programs.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and the environment from a release of hydrogen peroxide include the following:

- To minimize the potential for chemical reactions in the unlikely event of simultaneous tank leaks, the hydrogen peroxide storage tank will be located separately from other process tanks.

- Construction of all storage tanks, piping, and associated appurtenances will be in accordance with current industry standards.

- The hydrogen peroxide tank will be enclosed, limiting the amount of vapors that can escape to the atmosphere.

- Daily shift inspections of plant and chemical storage facilities are conducted for early detection of potential deficiencies.

- A containment will be constructed meeting 40 CFR §264.193 for spill mitigation and will be constructed of chemically compatible materials.

- Offloading procedures will be developed and implemented to ensure proper steps and precautions are followed during offloading into bulk storage areas.

Mitigation/Accident Response

Upon detection of a release of hydrogen peroxide, steps will be taken to stop or limit the extent of the release that can be performed without endangering the health of the responders. EMC will develop emergency response procedures for an accidental release of hydrogen peroxide and employees will be trained on those procedures. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

Oxygen

Oxygen presents a substantial fire and explosion hazard. The design and installation of the oxygen storage facility is typically performed by the oxygen supplier and meets applicable industry standards. The oxygen will be delivered to Moore Ranch by truck and stored on site under pressure in a cryogenic tank in liquid form. The oxygen will be allowed to evaporate and will be added to the barren lixiviant upstream of the injection manifold.

The oxygen storage system will consist of 30-ton bulk liquid oxygen pressure vessel(s) at each wellfield. The tanks will be supplied and maintained by the liquid oxygen supplier. All oxygen deliveries and tank fillings are performed by the tank supplier. Gaseous oxygen, formed by the air heated evaporators, is then routed via low carbon steel piping that has been properly degreased from the bulk storage tank to individual header houses. After entering the header house the oxygen supply line is routed into the barren lixiviant using a single injection port and mixed with the lixiviant along a common manifold. Oxygen saturated lixiviant is metered from the common manifold and routed to the individual injection wells. Oxygen saturation pressure is a function of the water head or pressure above the uranium bearing sands. Totally enclosed fan cooled (TEFC) motors, solenoids, valves, pressure gauges, exhaust ventilation systems and alarm safety devices are included in the design for accident mitigation.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and safety from a release of oxygen include the following:

- The design and installation of underground and above-ground gaseous oxygen piping at Moore Ranch including material specifications, velocity restrictions, location and specifications for valves, and design specifications for metering stations and filters will be in accordance with industry standards contained in CGA G-4.4.
- Header houses will be equipped with an exhaust ventilation system to reduce the risks of O_2 accumulation in case of a leak.
- Oxygen monitoring will be conducted prior to entry into confined spaces where oxygen buildup could occur.
- Normally closed solenoids will reduce the risk of O_2 leaks in the lixiviant injection piping.

Combustibles such as oil and grease will burn in oxygen if ignited. EMC will ensure that all oxygen service components are cleaned to remove all oil, grease, and other combustible material before putting them into service. Acceptable cleaning methods are described in CGA G-4.1.

Mitigation/Accident Response

EMC will develop procedures that implement emergency response instructions for a spill or fire involving oxygen systems.

Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Reporting

Carbon Dioxide

The primary hazard associated with the use of carbon dioxide is concentration in confined spaces, presenting an asphyxiation hazard. Bulk carbon dioxide facilities are typically located outdoors and are subject to industry design standards. Floor level ventilation and carbon dioxide monitoring at low points will be performed to protect workers from undetected leaks of carbon dioxide within the central plant.

The carbon dioxide storage system will consist of one 50-ton bulk liquid carbon dioxide pressure vessel tank supplied and maintained by the carbon dioxide supplier. The tank will be located outdoors and outside the main plant. All carbon dioxide deliveries and tank fillings will be performed by the supplier. Gaseous carbon dioxide is routed via carbon steel piping from the bulk storage tank to both the production and injection main lines.

EMC will incorporate recommendations concerning materials of construction for tanks and piping systems and the use of ventilation to control vapors in the event of a leak of carbon dioxide. The building HVAC system is designed for 3 air changes per hour with the capacity to expand to 6 air exchanges per hour. In addition, local exhaust fans will be installed along the outer plant wall to sweep vapors and gases near the floor level.

Sodium Carbonate and Sodium Chloride

Sodium carbonate and sodium chloride are primarily inhalation hazards. Soda ash and carbon dioxide will be used to prepare sodium carbonate for injection in the wellfield. Sodium carbonate and sodium chloride are also used for regeneration of ion exchange resin. Dry storage and handling systems will be designed to industry standards to control the discharge of dry material.

A 26 percent sodium chloride saturated solution will be created from pure salt solids transferred using aluminum piping into two 15,230 gallon vertical flat bottom reinforced fiberglass tanks with a vent pipe vented through the roof to the atmosphere outside and above the main plant. Water is pumped into the storage tanks using PVC piping and the salt dissolves until solution saturation is achieved.

A 32 percent soda ash saturated solution will be created from dense soda ash solids transferred into a 16,920 gallon vertical flat bottom reinforced fiberglass tank with a vent pipe vented through the roof to the atmosphere outside and above the main plant. Hot water is pumped using copper pipe into the storage tank and the soda ash dissolves until solution saturation is achieved. Solution temperature is maintained at a minimum of 95 °F to avoid solids precipitation of the soda ash solution.

All piping from both systems to the eluate system will be conventional PVC. Proper valving will be installed at the tank exits and both sides of the redundant pumps. A programmable logic control system integrated to the plant automation system will control the pump starts, flow rates, and time as it relates to volume needed. Standard operating procedures (SOPs) will be developed and operators will be trained on using these systems, both automated and manual.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and the environment from a release of sodium carbonate include the following:

- To minimize the potential for chemical reactions in the unlikely event of simultaneous tank leaks, the sodium carbonate storage tank will be located separately from other process tanks with incompatible chemicals.

- Dry storage and handling systems will be designed to industry standards to control the discharge of dry material.

- All tanks are enclosed limiting the amount of dust that can escape to the atmosphere.

- Daily shift inspections of plant and chemical storage facilities are conducted for early detection of potential deficiencies.

- Bulk storage facilities will be located inside of the satellite plant providing full containment of released materials.

- Offloading procedures will be developed and implemented to ensure proper steps and precautions are followed during offloading into bulk storage areas.

Mitigation/Accident Response

Upon detection of a release, steps will be taken to stop or limit the extent of the release that can be performed without endangering the health of the responders. EMC will develop emergency response procedures for an accidental release of sodium carbonate and employees will be trained on those procedures. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

Sodium Sulfide

Sodium sulfide may be used as a reductant during groundwater restoration. Sodium sulfide is corrosive and will cause severe eye and skin burns. Routes of entry into the body include inhalation, ingestion, and contact with the skin. Under low pH conditions, sodium sulfide can react with water to liberate hydrogen sulfide gas.

Accident Prevention

Prevention methods utilized to minimize potential impacts to human health and the environment from a release of sodium sulfide include the following:

- Sodium sulfide can be flammable and contact with heat, flame, or other sources of ignition will be avoided.
- Sodium sulfide will be stored separately from incompatible chemicals.
- Construction of all storage tanks, piping, and associated appurtenances will be in accordance with current industry standards.
- All tanks are enclosed limiting the amount of dust and vapors that can escape to the atmosphere.
- Daily shift inspections of plant and chemical storage facilities are conducted for early detection of potential deficiencies.
- Containment will be provided for 100% of the total storage capacity of the largest tank within the secondary containment area. The containment area will be constructed of chemically compatible materials.
- Offloading procedures will be developed and implemented to ensure proper steps and precautions are followed during offloading into bulk storage areas.

Mitigation/Accident Response

Upon detection of a release of sodium sulfide, steps will be taken to stop or limit the extent of the release that can be performed without endangering the health of the responders. EMC will develop emergency response procedures for an accidental release of sodium sulfide and employees will be trained on those procedures. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

4.12.1.2.2 Facility Areas Where Fumes or Gases May Be Generated

A description of the areas in the proposed plant facility where radiological gases or air particulate could be generated is contained in Section 6.2 and are shown in Figure 6.2-1 as monitoring locations.

Other potential sources of non-radiological fumes or gases can result from use of process related chemicals. The potential sources of non-radiological fumes or gases are minimal in the ion exchange process area since the mining solutions contained in the process equipment are maintained under a positive pressure. The area within the plant facility with the greatest potential to generate non-radiological fumes or gases is the precipitation area. As described in Section 2.2, the primary chemicals used in the precipitation area are sulfuric or hydrochloric acid, hydrogen peroxide, and sodium hydroxide. A description of the preventive/mitigative controls and monitoring for each of these potential chemical fumes is provided in the following list:

Sulfuric or Hydrochloric Acid Fumes

Sulfuric or hydrochloric acid fumes may be generated from leaks in acid piping and process tanks contained within the central plant precipitation area. Preventive/mitigation measures include construction of all storage tanks, piping, and associated appurtenances in accordance with current industry standards, all tanks are enclosed limiting the amount of vapors that can escape to the atmosphere, and daily shift inspections of plant and chemical storage facilities are conducted. Monitoring may be conducted using colorimetric tubes if it is believed that acid fumes may be present in an area.

Typically, a Concentrated Acid Work Permit will be required for maintenance work on tanks, pipes, or equipment that contains or may contain concentrated acid or to the use of concentrated acid to prepare decontamination or cleaning solutions as required by site industrial safety procedures. Employees who may be exposed to concentrated sulfuric or hydrochloric acid must wear chemical goggles and face shield, chemical suit, and acid resistant gloves. A respirator with an acid cartridge is necessary when fumes may be encountered. An emergency eyewash station will also be maintained near the precipitation area in case an employee comes into contact with sulfuric or hydrochloric acid.

Hydrogen Peroxide Fumes

Hydrogen peroxide fumes may be generated from leaks in piping and process tanks contained within the central plant precipitation area. Preventive/mitigation measures include construction of all storage tanks, and associated piping in accordance with current industry standards; all tanks are enclosed limiting the amount of vapors that can escape to the atmosphere; and daily shift inspections of plant and chemical storage facilities are conducted.

Hydrogen peroxide will be stored in bulk storage vessel located outside of the building away from any organics or other incompatible substance. Rubber gloves and face shield should be worn when there is any possibility of contact with this chemical. In the event of a spill, ample quantities of water will be used to dilute the spill. An emergency eyewash station will also be maintained near the precipitation area in case an employee comes into contact with hydrogen peroxide.

If any of the potential fumes described above are detected, then building ventilation in the process equipment area will be accomplished by the use of the HVAC system that draws in fresh air and sweeps the plant air out to the atmosphere.

In addition to the fumes described above in the plant area, the potential exists for buildup of carbon dioxide or oxygen gases may also occur in confined spaces such as headerhouses if carbon dioxide and oxygen lines are present. Procedures will require monitoring for these gases in confined spaces or basements where these gases may be present prior to employees conducting work in these areas.

4.12.2 Public Radiological Impacts

EMC is proposing to develop a uranium in-situ recovery facility with a production and restoration flow of approximately 3000 and 500 gallons per minute (gpm) respectively. An assessment of the radiological effects of the Moore Ranch Project must consider the types of emissions, the potential pathways present, and an evaluation of potential consequences of radiological emissions.

The project will use fixed bed pressurized down flow ion exchange columns to separate uranium from the pregnant production fluid and to treat restoration solutions. The uranium contained in the eluant from the production ion exchange columns will be precipitated and subsequently vacuum dried.

In addition to ion exchange treatment, the groundwater restoration process will also use reverse osmosis to remove the dissolved solids. Liquid waste disposal will be via direct deep well injection. No evaporation ponds are planned at this time.

The facility could receive uranium-loaded ion exchange resin from various satellite facilities around the region in the future. An average of 6 resin transfers per day from these satellite facilities is anticipated.

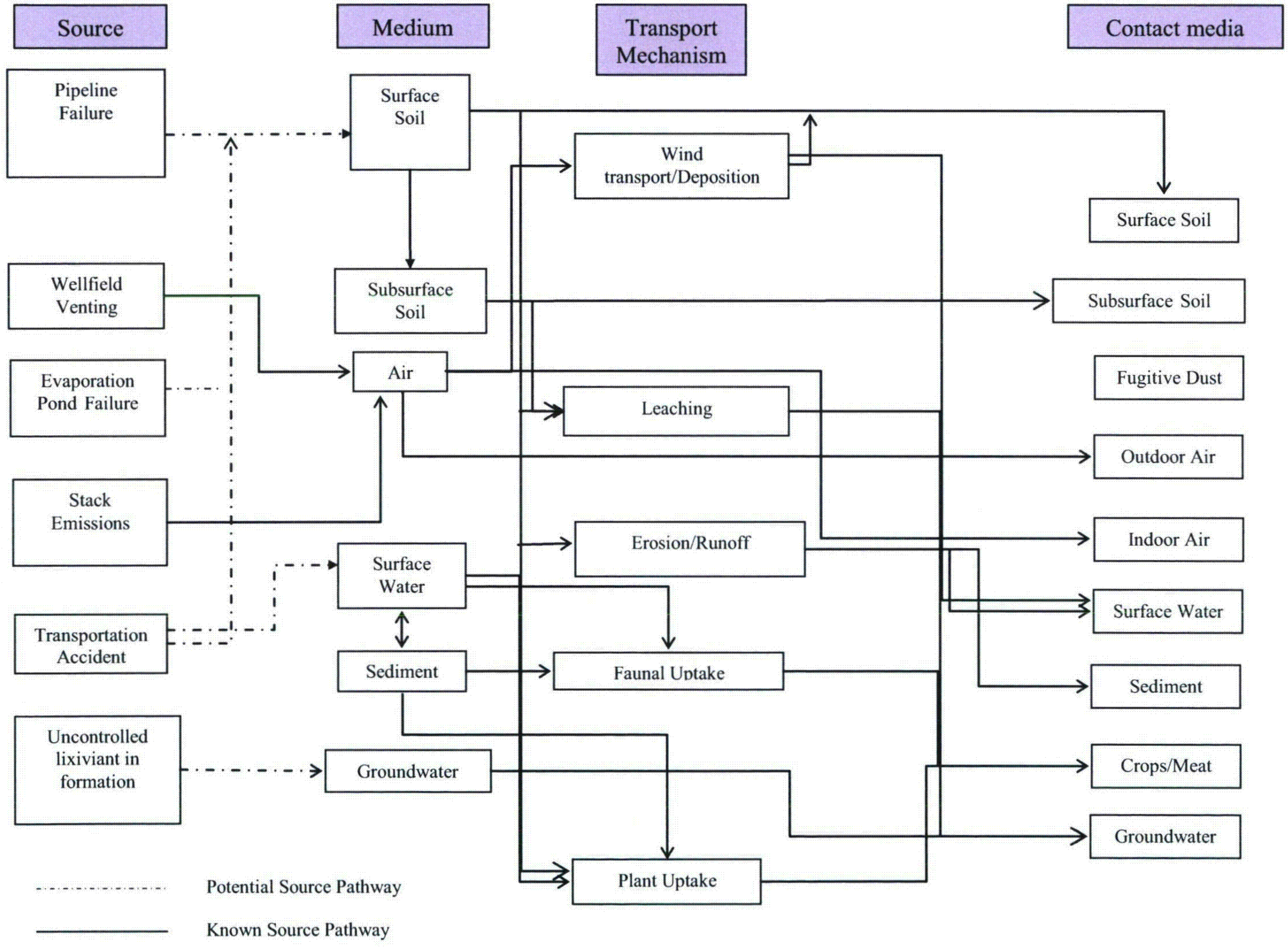
Since the drying and packaging operation is conducted under vacuum, the only expected routine emission at the facility will be radon-222 gas. Radon-222, a decay product of radium-226, is dissolved in the lixiviant as it travels through the ore to a production well where it is brought to the surface. The concentration of radon-222 in the production solution and estimated releases are calculated using the methods found in USNRC Regulatory Guide 3.59. The details of and assumptions used in these calculations are found in Section 4.12.2.3.

MILDOS-AREA is used to model radiological impacts on human and environmental receptors (e.g. air and soil) using site specific radon-222 release estimates, meteorological and population data, and other parameters. The estimated radiological impacts resulting from routine site activities will be compared to applicable public dose limits as well as naturally occurring background levels.

4.12.2.1 Exposure Pathways

Figure 4.12-1 presents exposure pathways from all potential sources at the Moore Ranch facility. The predominant pathways for planned and unplanned releases are identified. As mentioned earlier, atmospheric radon-222 is expected to be the predominant pathway for impacts on human and environmental media. Impacts of radon-222 releases can be expected in all quadrants surrounding the facility, the magnitude of which is driven predominantly by wind direction and atmospheric stability. As a noble gas, radon-222 itself has very little radiological impact on human health or the environment. Radon-222 has a relatively short half-life (3.2 days) and its decay products are short lived, alpha emitting, nongaseous radionuclides. These decay products have the potential for radiological impacts to human health and the environment. As Figure 4.12-1 shows, all exposure pathways, with the possible exception of absorption, can be important depending on the environmental media impacted. All of the pathways related to air emissions of radon-222 are evaluated by MILDOS-AREA. Output from MILDOS-AREA simulations is provided in Appendix C.

Figure 4.12-1 Human Exposure Pathways for Known and Potential Sources from the Moore Ranch Area



Pathway

Contact media	Ingestion	Inhalation	Direct Exposure	Absorption
Surface Soil	**X**		**X**	
Subsurface Soil	X		**X**	
Fugitive Dust	**X**	**X**	X	X
Outdoor Air		**X**	X	
Indoor Air		X	X	
Surface Water	X			X
Sediment				
Crops/Meat	**X**			
Groundwater	**X**			

x Predominant Path

4.12.2.2 Exposures from Water Pathways

The mining solutions in the ore zone will be controlled and adequately monitored to ensure that migration does not occur. The overlying aquifers will also be monitored.

The primary method of waste disposal at the facility will be by deep well injection. The deep well(s) will be completed at a depth greater than 6,000 feet and will be isolated geologically from underground sources of drinking water. The well(s) will be constructed under a permit from the Wyoming Department of Environment Quality (WDEQ) and all requirements of the Underground Injection Control (UIC) program for Class I wells will be met.

The uranium ion exchange, precipitation, drying and packaging facilities will be located on curbed concrete pads to prevent any liquids from entering the environment. Solutions used to wash down equipment drain to a sump and are either pumped back into the processing circuit or to the disposal well. The pads will be of sufficient size to contain the contents of the largest tank in the event of a rupture.

No routine liquid environmental discharges, other than waste disposal via deep well injection, are planned and as such, no definable water related pathways for routine operations exist.

4.12.2.3 Exposures from Air Pathways

The only source of radionuclide emissions is radon-222 released into the atmosphere through a vent system in the main plant area or from the wellfields. As shown in Figure 4.12-1, atmospheric releases of radon-222 can result in radiation exposure via three pathways; inhalation, ingestion, and direct exposure. The Total Effective Dose Equivalent (TEDE) to nearby residents in the region around the facility was estimated using MILDOS-AREA.

4.12.2.3.1 Source Term Estimates

The source terms used to estimate radon-222 releases from the facility include three well fields in production, one restoration well field, new well field development, operation of the central process plant, and resin transfers from neighboring satellite processing facilities. The parameters used to characterize and estimate releases are provided in Table 4.12-1.

Table 4.12-1 Parameters used to estimate and characterized source terms at the Moore Ranch In-Situ Recovery facility.

Parameter	Value	Unit	Source
Average Ore Grade	0.1	%	Application
Ore radium-226 Concentration	282	pCi g^{-1}	Reg. Guide 3.59
Mined Area	3.12E+05	m^2 y^{-1}	Application
Average Lixiviant Flow	1.14E+04	L m^{-1}	Application
Average Restoration Flow	1.89E+03	L m^{-1}	Application
Operating days per year	365	days	
Ore formation thickness	6.1	meters	Application
Ore formation porosity	0.2	NA	Application
Ore formation rock density	2.65	g cm^{-3}	Application
Average residence time for lixiviant	7	days	Application
Average residence time for restoration solutions	35	days	Application
Average mass of ore material in mud pit	1.02E+07	g	Estimate based on planned activities
Number of mud pits generated per year	300	NA	Estimate based on planned activities
Storage time in mud pits	14	days	Estimate based on planned activities
Radon-222 emanating power	0.2	NA	Reg. Guide 3.59
Radon-222 release rates	0.1	y^{-1}	Estimate based on process
Resin Porosity	0.4	NA	NUREG 1569
Ion Exchange Column Volume	1.42E+04	L	Estimate based on planned activities
Number of Resin Transfers per day	6	NA	Estimate based on planned activities
Stack Height	16	m	Application
Stack Diameter	0.3	m	Application
Stack Velocity	11	m s^{-1}	Application

Production Releases

Currently EMC plans to have up to three wellfield areas at Moore Ranch that could potentially be mined concurrently. The potential radon-222 releases from the production well fields were estimated using methods described in Regulatory Guide 3.59 as follows:

Radon released (equilibrium condition) to production fluid from leaching is calculated using Equation 1:

$$G = R\rho E \frac{(1-p)}{p} x10^{-6} \qquad \text{(Equation 1)}$$

Where:

G = radon released (Ci/m^3)
R = radium content of ore (pCi/g)
E = emanating power
ρ = rock density (g cm^{-3})
p = formation porosity

The yearly radon released to the production fluid is calculated using Equation 2:

$$Y = 1.44 GMD(1 - e^{-\lambda t}) \qquad \text{(Equation 2)}$$

Where:

Y = yearly radon released to production fluid (Ci yr-^{1})
G = radon released at equilibrium (Ci m^{-3})
M = lixiviant flow rate (L min^{-1})
D = production days per year (d)
λ = radon-222 decay constant (d^{-1})
t = lixiviant residence time
1.44 = unit conversion factor

Using Equations 1 and 2 and the parameters in Table 4.12-1, the yearly radon released to production fluid is 2563 Ci yr^{-1}. Regulatory Guide 3.56 assumes all the radon-222 that is released to the production fluid is ultimately released to the atmosphere, which is the case for ion exchange columns operating at atmospheric pressure in an open system and is an appropriate conservative assumption for this type of ion exchange system. In cases where pressurized downflow ion exchange columns are used and wellfields are operated under pressure, the majority of radon released to the production fluid stays in solution and is not released. The radon which is released is from occasional well field venting for sampling events, small unavoidable leaks in well field and ion exchange equipment, and maintenance of well field and ion change equipment. For this reason, an estimated annual release of 10% of the radon-222 in the production fluid from the wellfields and an additional 10% in the ion exchange circuit was assumed. Given this assumption, the annual radon-222 released from production in the wellfield and at the central plant facility is 256 and 230 Ci yr^{-1}, respectively. For purposes of MILDOS-AREA model simulations, the wellfield release of 256 Ci yr^{-1} was distributed in proportion to the size of the two proposed wellfields at the site.

Restoration Releases

Radon-222 releases resulting from wellfield restoration activities were estimated in the same manner as the production activities above (i.e., using Equation 2) but modified for the lower restoration flow rate and the longer restoration fluid residence time, both of which are listed in Table 4.12-1. The estimate of a 10% release in the well field and treatment facility results in releases of 59 and 53 Ci yr^{-1} respectively. For purposes of the MILDOS-AREA model simulations, the wellfield release of 59 Ci yr^{-1} was distributed equally among the three proposed well fields at the site.

New Well Field Releases

Radon-222 releases resulting from new wellfield development activities were estimated using methods described in NUREG-1569 as follows:

$$Rn_{nw} = EL[Ra]TmNx10^{-12} \qquad \text{(Equation 3)}$$

Where:

Rn_{nw} = Radon-222 release rate from new well field (Ci yr^{-1})
E = emanating power
[Ra] = concentration of radium-226 in ore (pCi g^{-1})
L = decay constant of radon-222
T = storage time in mud pit (d)
m = average mass of ore material in the pit (g)
N = number of mud pits generated per year
10^{-12} = unit conversion factor (Ci pCi^{-1})

Using Equation 3 and the parameters in Table 4.12-1, the yearly radon released from new wellfield development is 0.43 Ci yr^{-1}. For purposes of the MILDOS-AREA model simulations, the new wellfield release was assumed to occur at the central plant location.

Resin Transfer Releases

Radon-222 releases resulting from resin transfers from neighboring satellite facilities were estimated using methods described in NUREG-1569 as follows:

$$Rn_x = 3.65x10^{-10} F_i C_{Rn} \qquad \text{(Equation 4)}$$

Where:

Rn_x = Radon release rate from resin transfers (Ci yr^{-1})
F_i = water discharge rate from resin unloading (L d^{-1})
C_{Rn} = Steady state radon-222 concentration in process water (pCi L^{-1})
$3.65x10^{-10}$ = unit conversion factor (Ci pCi^{-1})(d yr^{-1})

The steady state radon-222 concentration in process water (C_{Rn}) can be estimated from the following expression:

$$C_{Rn} = \frac{Y * 1.9E6}{M} \qquad \text{(Equation 5)}$$

Where:

C_{Rn} = Steady state radon-222 concentration in process water (pCi L^{-1})
Y = yearly radon released to production fluid (Ci yr-^{1})
M = lixiviant flow rate (L min^{-1})
1.9E6 = unit conversion factor (pCi Ci^{-1})(yr min^{1})

The water discharge rate from resin unloading (Fi) can be estimated from the following expression:

$$F_i = N_i * V_i * P_i$$
(Equation 6)

Where:

F_i = water discharge rate from resin unloading (L d^{-1})
N_i = Number of resin transfers per day
V_i = volume of resin in transfer (L)
P_i = porosity of resin

Using Equations 4-6 and the parameters in Table 4.12-1, the yearly radon released from resin transfers from satellite facilities development is 5.3 Ci yr^{-1}. This estimate assumes the ore grade mined at the satellite facilities would yield the same radon concentration in production fluid as the Moore Ranch facility. For purposes of the MILDOS-AREA model simulations, the resin transfer release was assumed to occur at the central plant location.

Radon-222 Release Summary

A summary of estimated radon-222 releases from the Moore Ranch Facility is presented in Table 4.12-2. The source coordinates in Table 4.12-2 are relative to the main plant area.

Table 4.12-2 Estimated Radon-222 Releases (Ci yr^{-1}) from the Moore Ranch Facility

Location	X (km)	Y (km)	Production	Restoration	Drilling	Resin Transfer	Total
Well Field 1	-0.42	0.07	85.3	20	0	0	105.3
Well Field 2	0.89	-0.53	85.3	20	0	0	105.3
Well Field 3	0.47	-0.64	85.3	20	0	0	105.3
Main Plant Stack	0	0	230	53	0	5.3	288.3
New Well Field	0	0	0	0	0.43	0	0.43
Total			486	113	0.43	5.3	604.7

4.12.2.3.2 Receptors

The receptors used in the MILDOS-AREA simulations are presented in Table 4.12-3 and include the property boundary in 16 compass directions, 2 residences, and the town of Wright.

Table 4.12-3 Moore Ranch Receptor Names and Locations

Location	X (km)	Y (km)	Distance (km)
1. Property Boundary- N	0.00	2.60	2.60
2. Property Boundary- NNE	1.09	2.63	2.85
3. Property Boundary- NE	1.96	1.96	2.77
4. Property Boundary- ENE	3.64	1.50	3.94
5. Property Boundary- E	6.71	0.00	6.71
6. Property Boundary- ESE	4.27	-1.96	5.11
7. Property Boundary- SE	2.31	-2.31	3.27
8. Property Boundary- SSE	1.19	-2.87	3.11
9. Property Boundary- S	0.00	-2.85	2.85
10. Property Boundary- SSW	-1.51	-3.64	3.94
11. Property Boundary- SW	-2.85	-2.85	4.03
12. Property Boundary- WSW	-3.02	-1.25	3.27
13. Property Boundary- W	-2.77	0.00	2.77
14. Property Boundary- WNW	-2.17	0.90	2.35
15. Property Boundary-NW	-1.42	1.42	2.01
16. Property Boundary- NNW	-1.09	2.63	2.85
17. Nearest Resident East	4.50	0.00	4.50
18. Nearest Resident South	0.00	-13.4	13.4
19. Wright	26.1	18.9	32.2

4.12.2.3.3 Miscellaneous Parameters

The metrological data used in the MILDOS-AREA model is from the Joint Frequency Distribution data presented in Section 3.6 of this Environmental Report.

The population distribution used in the MILDOS-AREA model to estimate population doses is from the demographic information presented in Section 3.10 of this Environmental Report.

4.12.2.3.4 Total Effective Dose Equivalent (TEDE) to Individual Receptors

In order to show compliance with the annual dose limit found in 10 CFR §20.1301, EMC has demonstrated by calculation that the TEDE to the individual most likely to receive the highest dose from the Moore Ranch uranium in-situ recovery operation is less than 100 mrem per year. The results of the MILDOS-AREA simulation for each receptor in Table 4.12-3 are presented in Table 4.12-4.

An evaluation of the TEDE follows:

1) The maximum TEDE of 0.8 mrem/yr, located at the northwest property boundary, is 0.8 percent of the public dose limit of 100 mrem.

2) Receptor #17 is the closest resident to the Moore Ranch facility. The estimated TEDE at this location is 0.7 mrem/yr, which is 0.7 percent of the regulatory limit.

3) The effect of the Moore Ranch operation on any potential resident is less that 1 mrem/yr.

4) Since radon-222 is the only radionuclide emitted, public dose requirements in 40 CFR part 190 and the 10 mrem/y constraint rule in 10 CFR §20.1101 do not apply.

5) Even if 100% of the radon-222 contained in restoration and production fluids were released to the atmosphere (i.e. 100% released instead of 10%), the impacts to potential residents surrounding the facility would be less than the 100 mrem public dose limit.

Table 4.12-4 Estimated Total Effective Dose Equivalent (TEDE) to Receptors near the Moore Ranch Processing Facility

Receptor	Distance from Main Plant (km)	TEDE (mrem/y)
1. Property Boundary- N	2.60	0.43
2. Property Boundary- NNE	2.85	0.32
3. Property Boundary- NE	2.77	0.34
4. Property Boundary- ENE	3.94	0.41
5. Property Boundary- E	6.71	0.45
6. Property Boundary- ESE	5.11	0.45
7. Property Boundary- SE	3.27	0.54
8. Property Boundary- SSE	3.11	0.50
9. Property Boundary- S	2.85	0.48
10. Property Boundary- SSW	3.94	0.22
11. Property Boundary- SW	4.03	0.15
12. Property Boundary- WSW	3.27	0.22
13. Property Boundary- W	2.77	0.41
14. Property Boundary- WNW	2.35	0.74
15. Property Boundary-NW	2.01	0.80
16. Property Boundary- NNW	2.85	0.46
17. Nearest Resident East	4.50	0.69
18. Nearest Resident South	13.4	0.08
19. Wright	32.2	0.03

4.12.2.3.5 Population Dose

The annual population dose commitment to the population in the region within 80 km of the Moore Ranch facility is also predicted by the MILDOS-AREA code. The results are contained in Table 4.12-5 where TEDE is expressed in terms of person-rems. For comparison, the dose to the population within 80 km of the facility due to background radiation has been included in the table. Background radiation doses are based on a North American population of 346 million and an average TEDE of 360 mrem.

The atmospheric release of radon also results in a dose to the population on the North American continent. This continental dose is calculated by comparison with a previous calculation based on a 1 kilocurie release near Casper, Wyoming, during the year 1978. The results of these calculations are included in Table 4.12-5 and also combined with dose to the region within 80 km (50 mi) of the facility to arrive at the total radiological effects of one year of operation at the Moore Ranch project.

The maximum radiological effect of the Moore Ranch operation would be to increase the TEDE of continental population by 0.000045 percent.

Table 4.12-5 Total Effective Dose Equivalent to the Population from One Year's Operation at the Moore Ranch Facility

Criteria	TEDE (person rem/yr)
Dose received by population within 80 km of the facility	0.09
Dose received by population beyond 80 km of the facility	5.3
Total Continental Dose	5.4
Background North American Dose	1.2 E8
Fractional increase to background dose	4.5 E-8

4.12.2.3.6 Exposure to Flora and Fauna

To estimate potential radiological impacts to flora and fauna, the most important pathway for exposure should be identified. Since the only planned emissions from the facility is radon-222 to the atmosphere, the most important pathway for exposure to flora and fauna is deposition of radon-222 decay products on surface water, surface soils, and vegetation. MILDOS-AREA estimates surface deposition rate as a function of distance from the source for the radon-222 decay products and calculates surface concentrations. Table 4.12-6 presents the highest surface concentrations of radon-222 decay products predicted by MILDOS-AREA over a 100 year period. Soil concentrations were calculated based on a conservative assumption of 1.5 g cm^{-3} bulk soil density.

Table 4.12-6 Highest Surface Concentrations of Radon-222 Decay Products Resulting from Moore Ranch ISR Operations

Radionuclide	Distance from site (km)	Direction	Surface Concentration (pCi/m^2)	Soil Concentration in upper 0.5 cm (pCi/g)
Polonium-218	1.5	E	25	3 E^{-3}
Lead-214	1.5	E	25	3 E^{-3}
Bismuth-214	1.5	E	25	3 E^{-3}
Lead-210	35	E	50	6 E^{-3}

Lead-210 represents the radionuclide with the highest concentration (6 E^{-3} pCi/g) which is at least an order of magnitude below most analytical laboratories detection limits. Recent site specific surface soil (0-5 cm) data (discussed in Section 6.1) show that lead-210 ranges from 1.1 to 4.6 with a mean of 2.8 ± 1.6 pCi/g. The increase in soil radioactivity projected by MILDOS over a 100-year period is insignificant compared to site specific background concentrations.

It is likely that soil re-suspension from background soils would be the predominant source of lead-210 concentration in vegetation surrounding the site since lead-210 concentrations in vegetation would be similar to that of soil.

From this evaluation, the radiological impact of operations at the Moore Ranch Project would be minimal and indistinguishable from current baseline conditions. Mitigation measures to minimize radiological impacts that were considered in the design of the Moore Ranch Project are discussed in Section 5.12.2.

4.12.2.4 Potential Radiological Accidents

The following sections discuss potential accident scenarios that could have radiological impacts. Mitigation measures to reduce or eliminate these impacts are discussed in Section 5.12.2.

4.12.2.4.1 Tank Failure

A spill of the materials contained in the process tanks at the Moore Ranch Project will present a minimal radiological risk. Process fluids will be contained in vessels and piping circuits within the central plant. The tanks at Moore Ranch will contain injection and production solutions, ion exchange resin, pregnant eluant, yellowcake, and liquid waste.

NUREG/CR-6733 analyzed the potential impacts of a failure of a yellowcake thickener resulting in a release of 20% of the contents outside the plant structure. This postulated accident scenario was based on an event at the Irigaray ISR facility in 1994. The event in question was caused by the failure of an inadequate concrete pad supporting the thickener. The subsequent release from the building was a result of the proximity of the thickener to the plant wall. NUREG/CR-6733 concluded that, based on conservative calculations of this unlikely event, the dose to the public would be below the limits in 10 CFR Part 20. The calculations resulted in a dose to an unprotected worker in excess of the exposure limits from 10 CFR Part 20 (i.e., 5 rem). However, this dose estimate was based on a number of unlikely, conservative assumptions. The scenario made the unrealistic assumption that no efforts would be made to clean up the spill, allowing the yellowcake to dry and become transportable. The dose was based on lung clearance class Y uranium, which produces the highest dose estimates. No allowance in the dose calculation was made for the use of protective equipment, including protection factors from the use of respiratory protection equipment.

NUREG/CR-6733 also assessed the potential dose from a catastrophic spill from an ion exchange column resulting in the release of the entire contents of the vessel and the resultant release of radon gas. Based on a number of assumptions, the predicted dose was 1.3 rem in a 30-minute period to a worker in the area. Any change to the Rn-222 concentration or exposure time has a linear affect on dose. For example, if the room size is doubled or the exposure time is halved, then the dose will be halved. NUREG/CR-6733 recommended that the use of ventilation or atmosphere-supplying respirators designed to protect against gases would be sufficient to mitigate doses, that unprotected personnel should evacuate spill areas near ion-exchange columns, and that ISR facilities maintain proper equipment, training, and procedures to respond to large lixiviant spills or ion-exchange column failure.

As discussed in Section 2, a concrete curb will be built around the entire central process plant building to contain spilled liquids. The curb is designed to hold 12,200 cubic feet (91,256) gallons. The largest liquid-containing vessel in the plant is the yellowcake thickener with a maximum capacity of 9,263 cubic feet (69,300 gallons). Therefore, the building curb capacity will be adequate to contain the contents of the largest tank in the plant.

NRC staff requested that EMC address the likelihood of and measures for preventing a multiple tank failure such as might occur if one failed tank fell into an adjacent tank. The next largest liquid-containing vessel in the central plant is the pregnant eluant tank with a maximum capacity of 3,079 cubic feet (23,031 gallons). Although the yellowcake thickener and the pregnant eluant tank are not adjacent to each other and would therefore not be subject to the scenario postulated by NRC staff of one tank falling into another, the "worst-case" scenario of these two liquids-containing vessels failing at the same time would cause a maximum spill volume of 12,342 cubic feet. The plant retention volume is 12,200 cubic feet within the 6 inch curbing area. Therefore, the maximum volume spilled in this unlikely scenario would slightly exceed the plant curb capacity. However, it should be noted that the cited tank capacities are based on the maximum volume and not the operating volume.

Construction of tanks and vessels will be in accordance with ASME and ASTM codes, providing sufficient liquid containment for potential releases. In addition, standard operating procedures for central processing plant operations will be used by EMC to minimize the potential of releases escaping the central processing plant primary containment systems.

There are a number of unlikely scenarios that could cause the failure of multiple tanks other than one tank falling into another tank. These primarily relate to natural disasters. For instance, an earthquake or a direct strike by a tornado could cause failures that would lead to leaks from multiple tanks. The likelihood of these events is discussed in Sections 3.3 and 3.6, respectively. The radiological impacts from these scenarios are discussed in Section 7.5.8 of the Technical Report and address the primary radiological hazard, which would be the release of yellowcake. It is possible that in the unlikely event of multiple tank failures due to a natural disaster, the plant curb may not be able to contain all of the liquid released in the plant. However, the radiological risk of such an event is minimal and is bounded by the analysis in Section 7.5.8 of the Technical Report. Spilled liquids containing radioactive material released outside the plant containment would quickly absorb into the surrounding soil and would not present a radiological risk to workers or the public beyond that discussed in Section 7.5.8 of the Technical Rreport. Any released radioactive material would be cleaned up using reclamation procedures as discussed in Section 5.1. Section 5.12.2.2 discusses mitigation measures that EMC will implement to mitigate the potential impacts radiological accidents. These mitigation measures include the preparation of spill response procedures, provisions for spill response equipment and materials, the use of protective equipment, and employees training in proper spill response methods. The following sections discuss accident prevention and mitigation/accident response measures.

Accident Prevention

The plant will be designed to control and confine liquid spills from tanks should they occur. The central plant building structure and concrete curb will contain the liquid spills from the leakage or rupture of a process vessel and will direct any spilled solution to a floor sump. The floor sump system will direct any spilled solutions back into the plant process circuit or to the waste disposal system. Bermed areas, tank containments, and/or double-walled tanks will perform a similar function for any process chemical vessels located outside the central plant building.

All tanks will be constructed of fiberglass or steel with the exception of the hydrogen peroxide storage tank, which will typically be constructed of aluminum. Instantaneous failure of a tank is unlikely. Tank failure would more likely occur as a small leak in the tank. In this case, the tank would be emptied to at least a level below the leaking area and repairs or replacement made as necessary. Other prevention methods include shift inspections of plant areas including tanks.

Mitigation/Accident Response

The Moore Ranch Central Plant will be designed in accordance with standard industry building codes and will incorporate containment adequate to contain the contents of the largest tank in the facility at a minimum. Area ventilation will be provided to control concentrations of airborne radioactive material in the central plant. Finally, EMC will prepare spill response procedures, provide spill response equipment and materials, require the use of protective equipment, and will train employees in proper spill response methods. Emergency response procedures will include instructions in the following:

- Immediate notifications
- Evacuation procedures
- Perimeter establishment
- Personal Protective Equipment requirements
- Site mitigation, neutralization, and cleanup
- Reporting

4.12.2.4.2 Plant Pipe Failure

The rupture of a pipe within the central plant will be easily detected by operating staff and can be quickly controlled. Spilled solution will be contained and managed in the same fashion as for a tank failure.

4.12.2.4.3 Wellfield Spill

The rupture of an injection or recovery line in a wellfield, or a trunkline between a wellfield and the plant, would result in a release of injection or production solution which would contaminate the ground in the area of the break.

Occasionally, small leaks at pipe joints and fittings in the wellhouses or at the wellheads may occur. Small leaks in wellfield piping typically occur in the injection system due to the higher system pressures. Until remedied, these leaks may drip process solutions onto the underlying soil. These leaks seldom result in soil contamination. Following repair of a leak, EMC will require that the affected soil be surveyed for contamination and the area of the spill documented. If contamination is detected, the soil is sampled and analyzed for the appropriate radionuclides. Contamination may be removed as appropriate.

4.12.2.4.4 Yellowcake Dryer Accident

NUREG/CR-6733 analyzed the potential effects of accidents involving yellowcake dryers by examining the scenarios analyzed in NUREG-0706. The impact analysis for the four scenarios in NUREG-0706 (i.e., fire and explosion in the yellowcake drying area, discharge valve at bottom of dryer fails open, failure of offgas treatment system on one dryer, and tornado strikes to the dryer room) were based on two yellowcake dryers, each having a capacity of 4,300 1b of yellowcake, and two yellowcake dryer feed hoppers, each with a 155 ft^3 volume. NUREG-0706 also reports an upper-limit failure rate of 5×10^{-3} per plant year. NUREG/CR-6733 notes that this frequency appears to be for a gas-fired multiple hearth dryer based on failure rates for piping used in the transmission of natural gas. NUREG/CR-6733 concludes that the failure rate for the rotary vacuum dryer is likely to be less since it is not a gas-fired unit and uses hot oil as the heating medium for drying the yellowcake. However, the analysis did not quantify the expected failure rate for a hot oil-heated vacuum dryer. A gas explosion for the Moore Ranch yellowcake dryer is not a credible scenario since the dryer is heated with hot oil, eliminating the potential for an gas explosion at the dryer.

Of the four scenarios, NUREG/CR-6733 noted that the fire and explosion scenario bounded the analysis for discharge valve failure and tornado strike. The remaining scenario, failure of the offgas treatment system, is specific to gas-fired multiple hearth dryers. For the purposes of the Moore Ranch design, use of the fire and explosion scenario will provide a bounding analysis for an accident involving a large quantity of dried radioactive material.

The Moore Ranch design includes one rotary vacuum dryer with a maximum capacity of 7,353 pounds of yellowcake. This capacity is based on an optimal dryer loading of 60 percent of the dryer capacity and 35 percent solids and 65 percent liquid by weight slurry from the filter press. The yellowcake hopper from the filter press to the dryer has a maximum capacity of 366 cubic feet of wet yellowcake. Assuming a specific gravity of wet yellowcake of 1.346, the weight of the yellowcake contained in the hopper would be 30,740 pounds. Using the 35 weight percent slurry from the filter press, the weight of yellowcake powder in the hopper would be 10,759 pounds. This results in a total of

18,112 pounds of dry yellowcake available in the hopper and dryer for dispersion in the event of a fire or explosion.

NUREG/CR-6733 assumed that approximately 50 percent of the maximum yellowcake capacity available in two dryers and two hoppers would not be converted into aerosol size particles by the fire or explosion. Assuming this same factor for the Moore Ranch scenario, 9,056 pounds of yellowcake could become airborne. The volume of the Moore Ranch dryer room is approximately 7.37×10^4 ft^3.

NUREG/CR-6733 cites studies that indicate that the maximum sustainable airborne yellowcake concentration in air is 100 mg/m^3 (6.2×10^{-6} lb/ft^3), with heavier materials dropping out within a few minutes. Under the NUREG/CR-6733 scenario of 9,500 pounds of yellowcake dispersed in a dryer room with a volume of 1.2×10^5 ft^3, the average airborne yellowcake concentration for the first ten minutes was estimated at 3.8×10^{-2} lb/ft$^{3.}$ This concentration resulted in a potential dose to a worker wearing respiratory protection (protection factor = 1,000) of 8.8 rem for the first ten minutes and 1.4 mrem for the second ten minutes after the heavier material had settled. This dose was based on Y class U_3O_8.

The average concentration of airborne uranium in the dryer room for the first ten minutes under the Moore Ranch scenario would be 6.16×10^{-2} lb/ft^3. Although this average concentration would result in a higher dose during the first ten minutes than that postulated under the NUREG/CR-6733 scenario, the uranium produced at Moore Ranch is expected to be D Class materials. This is particularly true of the 10,759 pounds contained in the hopper. For the sake of conservatism until samples of the actual Moore Ranch product can be analyzed for solubility, W Class uranium has been assumed in this application. W Class uranium would result in a dose lower than Y Class by a factor of 25. Although some of the dispersed material could be converted to Y Class depending on the temperature produced by the fire or explosion and the period of time that the material is exposed to that heat, it is clear that the dose under the Moore Ranch scenario would be less than that determined in NUREG/CR-6733.

NUREG/CR-6733 made the following recommendations due to the potentially severe consequences of a yellowcake dryer explosion:

- The checking and logging requirements contained in 10 CFR Part 40, Appendix A, Criterion 8 should be retained;
- Operators should train crews for response to an accident of this type;
- Dryer manufacturer maintenance and operations recommendations should be followed; and
- Respirators should be used in the area of the dryer when it is operating.

EMC will implement all of these recommendations at Moore Ranch.

4.12.2.4.5 Radiological Release Reporting

Reporting of releases of source or byproduct material will be consistent with the requirements of 10 CFR 20 Subpart M. These reporting requirements are discussed in detail in Section 5.2.6 of the Technical Report.

4.12.3 Occupational Radiological Impacts

The potential occupational doses for the Moore Ranch facility can be best estimated by comparison with doses actually reported for similar, operating facilities. The operating Smith Ranch Facility in Converse County, Wyoming is very similar to the planned design of the Moore Ranch Facility. Both plants employ the following elements to control worker exposure to ionizing radiation:

- The use of downflow pressurized ion exchange columns to limit the release of radon gas from the lixiviant;
- The use of vacuum dryers to minimize the potential release of dried yellowcake during packaging operation.
- The use of building ventilation systems to minimize airborne concentrations of radioactive materials during operations.

These sites are in close proximity to one another and both are subject to similar environmental conditions and are likely to involve similar industrial circumstances. Occupational dose data has been published for Smith Ranch in a site inspection report (NRC, 2009) and several ALARA audit reports (Rio Algom Mining Corporation, 2000, 2001, 2002). This published information was used to compile estimates of average maximum doses to workers at Smith Ranch for both external and predominant internal sources in the following table.

Table 4.12-7 Estimated Average Maximum Doses for Predominant Sources at Smith Ranch

Year	External (mrem/yr)	Internal from U Inhalation* (mrem/yr)	Internal from Radon** (mrem/yr)	Max Internal (inhalation only) (mrem/yr)	External + Internal (mrem/yr)	Reported Max TEDE (Mrem/yr)
1999	205	57	63	120	325	301
2000	244	21	42	63	307	583
2001	878	58	21	79	957	1080
2008	431	-	-	-	-	538
Average	440	45	42	87	530	626

Notes: * Mean annual maximum based on reported DAC-Hours and 2.5 mrem/DAC-hr
** Mean annual maximum based on reported WLM, and equilibrium ratio of 0.5, and 500 mrem/WLM (ICRP 65)

The resulting average values indicated in this table provide a reasonable estimate of expected doses to the maximally exposed worker at the Moore Ranch Facility. It is also reasonable to assume that average worker doses would be considerably less than these maximums as only a limited number of employees would be working consistently near primary source areas such as the ion exchange columns, satellite facilities, dryer area, or header house locations. Furthermore, the proposed Moore Ranch facility has been designed to take into account the ALARA principle, with increased ventilation air exchange rates, a vacuum dryer, and pressurized downflow ion exchange column design expected to significantly reduce radon concentrations in the plant.

Use of pressurized downflow ion exchange (IX) columns, and operating wellfields under pressure, will result in the majority of radon in the production fluids remaining in solution and not being released to the environment. It is estimated that only 10% of radon-222 in production fluids IX columns will be released to the atmosphere. Vessel vents from the individual IX vessels will be directed to a manifold that is exhausted outside the building. This venting will minimize employee exposures. Small amounts of radon-222 may be released via solution spills, filter changes, IX resin transfer, reverse osmosis (RO) system operation during groundwater restoration, and maintenance activities. These will be small radon gas releases, on an infrequent basis. The general exhaust system in the plant will have increased ventilation to further reduce employee exposure. Air in the central plant and other structures will be sampled for radon daughters to assure that concentration levels of radon and radon daughters are maintained as low as reasonably achievable (ALARA).

While no quantitative estimate can be made with regard to expected dose reduction associated with these ALARA-based design features, the annual Moore Ranch doses are not expected to exceed the doses reported for the Smith Ranch facility. Assuming that the average dose is approximately half of the average maximum dose (a conservative assumption given the limited number of employees that would routinely work in primary exposure areas) and that the plant will employ 40 workers, the collective occupational dose for Moore Ranch is expected to be 12.5 person-rem per year or less.

4.13 WASTE MANAGEMENT IMPACTS

4.13.1 Gaseous and Airborne Particulates

The primary radioactive airborne effluent at the Moore Ranch Facility will be radon-222 gas. Radon-222 is found in the pregnant lixiviant that comes from the wellfield into the facility for separation of uranium. The uranium will be separated from the groundwater by passing the solution through fixed bed ion exchange (IX) units operated in a pressurized downflow mode. NUREG-1910 (NRC, 2009) in section 2.7.1 notes that pressurized ion exchange systems contain most of the radon gas present in the lixiviant. In these systems, radon gas may be released during venting and resin transfer operations. The alternative to pressurized downflow ion exchange columns typically employed for ISL mining is upflow atmospheric ion exchange columns. These columns release virtually all of the radon gas present in the lixiviant. The use of pressurized downflow ion exchange columns at Moore Ranch will reduce the radon gas emissions relative to other available ion exchange technologies and represents an emission control method that reduces emissions to levels that are as low as reasonably achievable and complies with the requirements of 10 CFR Part 40, Appendix A, Criterion 8. Further, the use of these ion exchange systems coupled with tank and area ventilation systems ensures that worker exposure to radon and its progeny is maintained ALARA through the use of engineering controls.

Vessel vents from the individual IX vessels will be directed to a manifold that is exhausted to atmosphere outside the building via an induced draft fan. Venting any released radon-222 gas to atmosphere outside the plant minimizes employee exposure. Small amounts of radon-222 may be released via solution spills, filter changes, IX resin transfer, reverse osmosis (RO) system operation during groundwater restoration, and maintenance activities. These are minimal radon gas releases on an infrequent basis. The exhaust system in the plant will further reduce employee exposure. The air in the central plant and other structures will be sampled for radon daughters to assure that concentration levels of radon and radon daughters are maintained as low as reasonably achievable (ALARA).

4.13.2 Liquid Waste

As a result of in-situ recovery mining, there are several sources of liquid waste that are collected. The potential waste water sources that exist at the Moore Ranch Facility will include the following.

4.13.2.1 Liquid Process Waste

The operation of the ion exchange process generates production bleed, the primary source of liquid waste as previously discussed in Section 2.0. This bleed is routed to the deep disposal well(s) for disposal. Other liquid waste streams from the central plant include plant wash down water and bleed stream from the elution and precipitation circuits. However, these other liquid waste streams make up a very small portion of the total liquid waste stream. The anticipated liquid waste stream is non-hazardous under the Resource Conservation and Recovery Act. The anticipated water chemistry of the injected waste stream is presented in Table 4.13-1. Minor concentrations of corrosion inhibitors, scale inhibitors, and/or biocides may be used as needed to maintain the well in optimum condition. These waste streams are beneficiation wastes, exempt from RCRA regulation under the Bevill Amendment found in 40 CFR 261.4(b)(7).

Table 4.13-1 Summary of Anticipated Waste Stream Water Quality

Estimated Range of Waste Stream Water Quality		
Chemical Species	Minimum (mg/l)	Maximum (mg/l)
pH	6	9
Ammonia as Nitrogen	50	500
Sodium	150	3,000
Calcium	200	1,000
Potassium	10	1,000
Bicarbonate as HCO3	1,500	4,000
Carbonate as CO3	0	500
Sulfate	80	2,000
Chloride	200	4,000
Uranium as U3O8	1	15
Ra-226 (pCi/l)	300	3,000
TDS	4,000	15,000

4.13.2.2 Aquifer Restoration

Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The current groundwater restoration plan consists of four activities:

1. Groundwater Transfer,
2. Groundwater Sweep,
3. Groundwater Treatment, and
4. Wellfield Circulation.

Only the groundwater sweep and groundwater treatment activities will generate wastewater.

During groundwater sweep, water is extracted from the mining zone without injection, causing an influx of baseline quality water to sweep the affected mining area. The extracted water must be sent to the wastewater disposal system during this activity.

Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. A reverse osmosis (RO) unit will be used to reduce the total dissolved solids of the groundwater. The RO unit produces clean water (permeate) and brine. The permeate is injected back into the formation and the brine is sent to the wastewater disposal system. Chemical reducing agents such as sodium sulfide or biological reducing agents may also be employed during the groundwater treatment phase.

4.13.2.3 Water Collected from Wellfield Releases

This water is injection lixiviant or recovery fluids recovered from areas where a liquid release has occurred from a well or pipeline. The water will be placed into the wastewater disposal system for deep well injection.

4.13.2.4 Stormwater Runoff

A final source of water is storm runoff. Stormwater management is controlled under NPDES permits issued by the WDEQ-WQD. Facility drainage will be designed to route storm runoff water away or around the plant, ancillary building and parking areas, and chemical storage. The design of the Moore Ranch facilities and procedural and engineering controls contained in a Best Management Practices (BMP) Plan will be implemented such that runoff is not considered to be a potential source of pollution.

4.13.2.5 Liquid Waste Disposal

EMC expects that the liquid waste stream generated at the Moore Ranch Facility will be chemically and radiologically similar to the waste disposed in the current disposal wells in operation at existing ISR sites in the Powder River Basin. It is anticipated that the maximum volume of liquid waste stream for disposal will be approximately 45 gpm during normal operations and approximately 100 gpm during restoration. The average net consumptive use during the operational and restoration phases of the Moore Ranch Project was estimated at 105 gpm as discussed in Section 4.4.2.1. This waste stream will require effective disposal.

Total Radioactivity Related to Liquid Waste Disposal

As previously noted, the average consumptive use during the operational and restoration phases of the Moore Ranch project is 105 gpm. Based on the discussion of the consumptive use of groundwater contained in Section 4.4.2.1, this average flow will occur over a period of 12.5 years, resulting in a total groundwater use during the operational and restoration phases of 6.899E+8 gallons (2.61E+9 liters). Using the maximum anticipated radionuclide content for uranium and radium-226 from Table 4.13-1, the expected total radioactivity associated with uranium and radium-226 that will be disposed over the course of the Moore Ranch project is 26.5 and 7.83 Curies, respectively.

Feasible Exposure Pathways from Deep Well Injection

Deep well injection technology and the EPA and state Underground Injection Control ("UIC") Programs established by the Safe Drinking Water Act ("SDWA") (42 U.S.C. §§ 1420, et. seq.) to regulate this technology are major tools for protecting human health and the environment by preventing the endangerment of drinking water sources. A UIC permit cannot even be issued unless potential underground sources of drinking water (USDWs) are protected. The foundational assumptions of the Class I UIC program are that: (1) injected fluids will be permanently removed from the accessible environment, (2) the fate and transport of waste is well defined and understood, and (3) underground sources of drinking water will be protected. By definition, there cannot effectively be an exposure pathway for injectate to move from the injection zone and reach the public if a permit is to be granted.

The approved Wyoming UIC program must demonstrate that deep well injection facilities are maintained and operated in accordance with federal and state regulations and the UIC permits (see 40 C.F.R. §144.1(b)(1) and 40 CFR §147.2550). Consistent monitoring and enforcement assure that the wells will continue to be protective of human health and the environment. Permits allow for the injection and containment of substances within deep geological formations located thousands of feet below the Earth's surface where the injected fluids will remain isolated and contained for thousands of years, which is an effective way to protect human health and the environment, as well as underground and surface sources of drinking water.

EPA has repeatedly noted that "[w]hen wells are properly sited, constructed, and operated, underground injection is an effective and environmentally safe method to dispose of wastes" (EPA, 2001). EPA has found deep well injection to be "safer than virtually all other waste disposal practices" (EPA 1993). Implementation of EPA's current technical requirements for Class I wells, which are located at 40 C.F.R. 146, include extensive construction, monitoring, operating and reporting requirements. When wells comply with these regulations, the EPA has consistently found that "underground injection is an effective and environmentally safe alternative to surface disposal" (EPA 1999). Furthermore, the EPA has noted for Class I industrial deep wells that "there are no documented problems with the effectiveness of the UIC regulations." (55 Fed. Reg. 22,529, 22,658; June 1, 1990).

There are two potential pathways through which injected fluids can migrate to an underground source of drinking water (USDW) and present a potential exposure to the public: (1) failure of the well or (2) improperly plugged or completed wells or other pathways near the well (EPA 2001).

Contamination due to well failure may be caused by leaks in the well tubing and casing or when injected fluid is forced upward between the well's outer casing and the well bore should the well lose mechanical integrity. Internal mechanical integrity is the absence of significant leakage in the injection tubing, casing, or packer. An internal mechanical integrity failure can result from corrosion or mechanical failure of the tubular and casing materials. External mechanical integrity is the absence of significant flow along the outside of the casing. Failure of the well's external mechanical integrity occurs when fluid moves up the outside of the well due to a casing failure or improper installation of the cement. To reduce the potential threat of well failures, operators must demonstrate that there is no significant leak or fluid movement through channels adjacent to the well bore before the well is issued a permit and allowed to operate. In addition, operators must conduct appropriate mechanical integrity tests (MITs) every 5 years (for nonhazardous wells) thereafter to ensure the wells have internal and external mechanical integrity and are fit for operation. It is important to note that failure of an MIT, or even a loss of mechanical integrity, does not necessarily mean that wastewater will escape the injection zone. Class I wells have redundant safety systems to guard against loss of waste confinement.

The multi-layer construction of a Class I deep well, which is required in Wyoming, provides redundant safety features that guarantee injected wastes do not migrate from the well bore into protected aquifers due to well failure. These wells must be constructed with multiple layers of concentric tubing (made of steel or other materials designed to be compatible with the injected fluids) and cement which provides redundant layers of protection to the injection structure. This construction amounts to a pipe within a pipe within a pipe (three tubes, two layers of cement, and a fluid barrier) (EPA, 1994). Thus, "Class I wells have redundant safety systems and several protective layers to reduce the likelihood of failure. In the unlikely event that a well should fail, the geology of the injection and confining zones serves as a final check on movement of wastewaters to USDWs" (EPA 2001).

The Area of Review (AoR) is the zone of endangering influence around the well, or the radius at which pressure due to injection potentially could cause the migration of the injectate and/or formation fluid into a USDW if a conduit for flow (such as an improperly plugged well) existed. Improperly plugged or completed wells that penetrate the confining zone near the injection well could provide a pathway for fluids to travel from the injection zone to USDWs. These potential pathways are most common in areas of oil and gas exploration. To protect against migration through this pathway, wells that penetrate the zone affected by injection pressure must be properly constructed or plugged. Before injecting, operators must identify all wells within the AoR that penetrate the injection or confining zone, and repair all wells that are improperly completed or plugged before a permit is issued. Fluids could potentially be forced upward from the injection zone through transmissive faults or fractures in the confining beds which, like abandoned wells, can act as pathways for waste migration to USDWs. Faults or fractures may have formed naturally prior to injection or may be created by the waste dissolving the rocks of the confining zone. Artificial fractures may also be created by injecting wastewater at excessive pressures. To reduce this risk, injection wells are sited such that they inject below a confining bed that is free of known transmissive faults or fractures. In addition, during well operation, operators must monitor injection pressures to ensure that fractures are not propagated in the injection zone or initiated in the confining zone. It is noted that some states, including Wyoming, allow creation of artificial fractures during completion of a Class I injection well. However, such fractures must be contained within the injection zone, and the maximum operational injection pressure must be below fracture propagation pressure (e.g., the fracture cannot be extended during operations).

The 2001 EPA Risk Report discusses a study that quantitatively estimated the risk of waste containment loss as a result of various sets of events associated with Class I hazardous wells. Through a series of "event trees," the study estimated the probability that an initiating event will occur and be undiscovered, followed by subsequent events that could ultimately result in a release of injected fluids to a USDW. The study assumed that, given the redundant safety systems in a typical Class I well, loss of containment requires a string of improbable events to occur in sequence. For example, a leak develops in the packer, followed by a drop in annulus pressure that is undetected due to a simultaneous malfunction of the pressure monitoring system, followed by a leak in the long string casing between the surface casing and the upper confining layer, resulting in a loss of waste isolation (EPA 2001).

The study concluded that Class I hazardous injection wells which meet EPA's minimum design and operating requirements pose risks that are well below acceptable levels. According to the study, the probability of containment loss resulting from each of the scenarios examined ranges from one-in-one-million to one-in-ten-quadrillion. The risks for each are ranked as follows (from most probable to least probable): cement microannulus leak, inadvertent extraction from the injection zone, major injection tube failure, major packer failure, breach of the confining zone(s), leak in the packer, and leak in the injection tubing.

EPA attributed this low risk to the use of engineered systems and geologic knowledge to provide multiple barriers to the release of wastewater to USDWs. Although the risk analysis was primarily concerned with Class I hazardous wells, many of the well design and construction requirements also apply to Class I nonhazardous wells and can be extrapolated to the wells planned for the Moore Ranch project.

A third potential pathway would involve drilling through the injection zone. In the unlikely event that a well were drilled through the injection zone, potential exposure is limited by many factors, which are discussed below.

The first factor that would limit potential exposure is that the radius of fluid displacement is limited. For example, for a 10-year operation of the proposed Moore Ranch deep disposal wells the radius of fluid displacement (based on piston-like displacement) is calculated to be 327 feet from each injection well. For the purposes of this discussion it is assumed that this pathway would only exist after the operational life of the Moore Ranch project since EMC would certainly detect drilling activity within the limited radius of fluid displacement during active operations at the site.

In addition, standard drilling practices used in the Power River Basin dictate drilling with mud which provides a hydraulic head in the well greater than the head in the formation drilled. As such, there would be no mechanism for flow from the injection zone into a well that was being drilled with mud. Rather, fluid is continually lost from the well into the formation while drilling proceeds.

Further, concentrations of radionuclides will decrease due to natural dispersion as fluid is displaced from the injection wells. An analogy for the concentration reduction due to dispersion was evaluated for COGEMA (2004; Wellfield Restoration Report, Irigaray Mine). For that project, a MODFLOW/MT3D model was used to assess transport of metals and radionuclides. Model simulations indicated that, on average, the concentration metals and radionuclides were reduced by a factor of seven over a transport distance of 400 feet due solely to dispersion (no retardation or precipitation was assumed).

The mobility of specific radioactive constituents of concern (uranium and radium-226) also is limited by natural retardation. The magnitude of retardation has been researched by Carlos, 2001; Johnson, 1994; U.S. DOE, 1996; and U.S. NRC, 1990. For the same project (COGEMA, 2004), sorption was implemented in some of the solute transport simulations. Sorption refers to the mass transfer between the constituent dissolved in groundwater and the constituent sorbed on the porous medium. Equilibrium conditions are generally assumed to exist between the aqueous phase and the solid phase concentrations and the sorption reactions are fast enough relative to groundwater velocity to be treated as instantaneous. A linear sorption isotherm assumes that the sorbed concentration (Cs) is directly proportional to the dissolved concentration (C):

$$Cs=K_d\,C$$

where: K_d is the distribution coefficient (L/kg).

The equilibrium controlled linear sorption isotherm is incorporated into the MT3DMS code through the use of a retardation factor, defined as:

$$R=1+p_b\,K_d\,/\,\phi$$

where: p_b= bulk density
ϕ= effective porosity

Representative retardation (K_d) values in published literature include:

Constituent	Range of K_d Values (L/Kg)	Source
Uranium	0.4 – 10	Carlos, 2001 Johnson, 1994 U.S. DOE, 1996 U.S. NRC, 1990
Radium-226	5 – 6,700 10	Moody, 1982 U.S. NRC, 1980

MODFLOW simulations using MT3D for transport were run to assess transport of radionuclides at Irigaray. Conservative K_d values on the lower end of the range identified in the literature search were used. Model simulations showed that the concentration of uranium at a distance of 400 feet was only 10% of the initial concentration when a K_d of 0.5 L/Kg was used. At 1,000 years of simulation time, the Ra-226 concentration at a distance of 400 feet was 5 pCi/L (the MCL for Ra-226) using a K_d of 5 L/Kg. This represents an order of magnitude decrease from the initial concentration of 50 pCi/L.

In summary:

- Based on piston-like flow, the radius of fluid displacement for the operational lifetime is small (approximately 327 feet)

- Because of the head induced by drilling mud, it is extremely unlikely that there would be flow from the injection zone into a well that was being drilled with mud. The amount of drilling cuttings generated, and the potential radioactive dose from those cuttings, is expected to be minimal.

- Dispersion alone likely will reduce concentrations of radionuclides by an approximate factor of seven over a 400-foot displacement distance

- Sorption/retardation will further reduce concentrations at 400 feet from the well by approximately one order of magnitude.

Based on the analogies from the COGEMA study, it is reasonable to assume that, if a well was drilled through the injection zone at a distance of 400 feet from the injection well, the concentration of radionuclides would be one to two orders of magnitude less than the original concentration injected into the Class I well. In addition, the use of drilling mud will prevent injected wastes from leaving the injection zone. Hence, potential exposure from a well drilled through the injection zone, even for a well located only 400 feet from the injection well, is minimal.

4.13.2.6 Domestic Liquid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in an approved septic system that meets the requirements of the State of Wyoming. These systems are in common use throughout the United States and the effect of the system on the environment is known to be minimal.

4.13.3 Solid Waste

4.13.3.1 Uncontaminated Solid Waste

Waste which is not contaminated with radioactive material or which can be decontaminated and re-classified as uncontaminated waste includes solid waste, piping, valves, instrumentation, equipment and any other items that are not contaminated or which may be successfully decontaminated. If decontamination of waste material is possible, surveys for residual surface contamination will be made before releasing the material. Decontaminated materials must have activity levels lower than those specified in NRC guidance. Methods for decontamination and release of contaminated equipment are discussed in further detail in Section 5 of the Technical Report.

EMC estimates that the proposed Moore Ranch Project will produce approximately 2,000 cubic yards (yd^3) of uncontaminated solid waste per year. Uncontaminated solid waste will be collected on the site on a regular basis and disposed of in the nearest sanitary landfill.

4.13.3.2 Byproduct Material

All contaminated items that cannot be decontaminated to meet release criteria will be properly packaged, transported, and disposed at a disposal site licensed to accept 11e.(2) byproduct material. Solid wastes generated by this project that may become contaminated with radioactive materials consist of items such as rags, trash, packing material, worn or replaced parts from equipment, piping, filters, protective clothing, and solids removed from process pumps and vessels. Radioactive solid waste that has a contamination level requiring controlled disposal will be isolated in drums or other suitable containers. EMC estimates that the proposed Moore Ranch Project will produce approximately 100 yd^3 of 11e.(2) byproduct material per year. These materials will be stored on site inside the restricted area until such time that a full shipment can be shipped to a licensed waste disposal site or mill tailings facility.

Byproduct material will be collected and stored within the Central Processing Plant (CPP) in appropriate containers (e.g., 55-gallon drums with drum liners). When these containers are full, they will be closed and stored within the CPP or will be moved to the byproduct storage area and stored in a strong tight container as defined by DOT regulations. The strong tight containers will be capable of preventing the spread of contamination and contact with precipitation. EMC plans to use covered roll-off containers with an approximate capacity of 20 cubic yards. Byproduct material will be collected and stored in roll off containers with an approximate capacity of 20 cubic yards. Once full, these containers will be shipped for disposal to a licensed disposal facility. During storage, the containers will be located within a restricted area. Access to the byproduct storage facility will be controlled through the use of security fencing, locked gates, and proper posting as a restricted area.

Larger items such as contaminated equipment that cannot be stored in a roll-off container will be stored in the CPP or covered/sealed in manner that will prevent the spread of contamination in the byproduct storage area.

4.13.3.3 Septic System Solid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in an approved septic system that meets the requirements of the WDEQ for Class V UIC wells.

Disposal of solid materials collected in septic systems must be performed in accordance with WDEQ Solid Waste Management rules and regulations.

4.13.3.4 Hazardous Waste

The potential exists for any industrial facility to generate hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). In the State of Wyoming, hazardous waste is governed by WDEQ Hazardous Waste Rules and Regulations. Based on preliminary waste determinations conducted by EMC in consideration of the processes and materials that will be used on the project, EMC will likely be classified as a Conditionally Exempt Small Quantity Generator (CESQG), defined as a generator that generates less than 100 kg of hazardous waste in a calendar month and that complies with all applicable hazardous waste program requirements. EMC expects that only used waste oil and universal hazardous wastes such as spent batteries will be generated at Moore Ranch.

4.14 CUMULATIVE IMPACTS

4.14.1 Cumulative Impacts of Coal Bed Methane Development Projects

The Powder River Basin has been developed since the mid-1980's for the recovery of coal bed methane (CBM). With advancements in technology, development and production of CBM has been increasing substantially since the mid-1990s. Development has been centered in all or parts of Campbell, Converse, Johnson, and Sheridan counties. The target coal zones are contained in the Fort Union formation.

The following discussion of CBM recovery methods (Section 4.14.1.1) and environmental impacts (Section 4.14.1.2) is based on a Final Environmental Impact Statement (FEIS) prepared by the Bureau of Land Management (BLM) for the Powder River Basin. The proposed Moore Ranch License Area includes existing CBM recovery facilities which are discussed in Section 4.14.1.3. Cumulative environmental impacts of existing CBM development and the Moore Ranch Project are discussed in Section 4.14.1.4.

4.14.1.1 Coal Bed Methane Recovery Method

Recovery of CBM involves installation of facilities including access roads, pipelines for gathering gas and produced water, electrical utilities, facilities for measuring and compressing recovered gas, facilities for treating, discharging, disposing of, containing, or injecting produced water, and pipelines to transport gas to high-pressure transmission pipelines. Several coal beds may occur together. Standard practice in these areas is to drill a separate well to develop each coal bed. Where possible, wells are collocated on the same well pad. Wells and well pads are generally installed on an 80-acre spacing pattern (eight pads per square mile).

Typically, the CBM operators use a truck-mounted water well type of drilling rig to drill CBM wells. A well is drilled to a depth of 350 feet to 1,500 feet or deeper to the top of a coal zone. When the target coal is reached, the well production casing is placed and cemented. Placement of production casing includes insertion of a steel pipe into the drill hole from the bottom of the hole to the surface. Casing is set into the hole one joint at a time and is threaded at one end with a collar located at the other end to connect each joint. The casing is then cemented into place by pumping a slurry of dry cement and water into the casing head, down through the casing string to the bottom, and then up through the annulus between the casing and the well. A plug and water flush is then pumped to the bottom of the well to remove any residual cement from the inside walls of the casing. Sufficient cement is pumped into the annulus to fill the space, where it is allowed to harden. If indications of inadequate primary cementing exist such as lost returns, cement channeling, or mechanical failure of equipment, the operator evaluates the adequacy of the cementing by pressure testing the casing shoe, running a cement bond log, cement evaluation tool log, or a combination.

Cementing the annulus around the casing pipe restores the original isolation of formations by creating a barrier to the vertical migration of fluids and gas between rock formations within the borehole. It also protects the well by preventing pressure in the formation from damaging the casing and retards corrosion by minimizing contact between the casing and corrosive formation waters.

After the coal zone is drilled, the open hole is flushed with clean chlorinated water to remove the coal fines from the hole. Steel tubing is then inserted inside the casing and in the open hole. A submersible electric pump is attached to the bottom end of the tubing to pump water from the coal. The size and capacity of the submersible pump depends on the coal's thickness and the rate of production expected from the well. Most pumps are rated at 10 to 20 gallons per minute. The pump is necessary because water pressure in the coal zone must be reduced before gas (methane) will flow to the open hole. The water is pumped up the tubing to the surface where, generally, it is gathered in a pipeline for disposal. When the gas is released from the coal, it flows up the space between the tubing and the steel casing to the gas-gathering system and compressors at the surface.

After well productivity is established, a small area of about 5 to 6 feet square is leveled and a weatherproof covering or box is placed over the wellhead. Enclosures for wellheads and metering facilities are vented. Usually, a metal fence or rail is installed immediately around the box and electrical panel to protect them from livestock. Meters to measure pressure and rates of water production may be placed in the box. Injection facilities, including some treatment facilities, may be collocated at CBM wells. The power lines for the submersible water pumps are laid in trenches, usually with water pipelines, to minimize surface disturbance and the visual impact of operations.

Three types of pipelines are generally constructed. These pipelines gather gas and produced water and deliver gas at high pressure. The gathering pipelines convey gas from the wells to compressor facilities and the produced water to discharge or disposal points. The high-pressure gas pipelines connect compressor facilities to transmission pipelines. The pipelines to gather gas and produced water are constructed of high density polyethylene (HDPE) pipe with an outside diameter of 2 to 12 inches. The high-pressure pipelines are constructed of steel pipe with an outside diameter of 12 to 16 inches. Rights-of-way for the pipelines vary from 20 to 50 feet for HDPE pipeline and 100 feet for steel pipelines. All pipelines are generally installed along access roads to minimize disturbance.

Produced water is brought to a point of discharge into a natural drainage or into containment for disposal. The average rate of water production per well is about 10 gpm. This rate for an individual well may rise as deeper, thicker coals are produced. Historically, the rate of water production drops to one-half its initial level after the first year of production in a new area where the water pressure is being reduced before gas production begins.

The method of handling produced water varies as the water quality, water volumes, and desires of the surface owner change. Typical water handling methods include direct surface discharge, passive or active treatment of produced water followed by direct surface discharge, infiltration or containment impoundments for produced water, land application using irrigation equipment, and injection of produced water through disposal wells. Presently, the primary method of disposal is to convey the water in an underground pipe to a surface discharge location mutually selected by the operator and the surface owner or lessee. WDEQ permits these surface discharges through the State NPDES program.

Gas-gathering pipelines for an average of 10 wells are tied together in a central measuring facility (CMF). At the CMF, gas is commingled into the gas-gathering system, which transports it to a compressor station. Two types of compressor stations are constructed: central reciprocating and booster stations. Produced natural gas under pressure from the wellhead moves through the low-pressure gas-gathering system to a booster compressor station. Typical pressure in the gathering line is less than 50 psi. At booster stations, low horsepower (350 HP) natural gas or electric-powered boosters or blowers enhance the flow of gas through the pipelines. Gas from the booster compressor stations then flows through medium-pressure pipelines (50 to 125 psi) to a central reciprocating compressor station. High horsepower (1,650 HP) compressors at these stations increase the pressure of natural gas to an estimated 700 to 1,450 psi to facilitate transmission of the natural gas to high-pressure transmission pipelines.

As production areas deplete, surface facilities are removed. Depleted production holes are plugged and abandoned in accordance with Onshore Oil and Gas Order No. 2 and Wyoming Oil and Gas Conservation Commission (WOGCC) rules. Once the well is conditioned as a static column, the well is decommissioned by pouring redundant plugs, a slurry of cement and water at strategic locations in the well bore. These locations are based on each well's configuration to prevent migration of fluids or gas up the well bore or any uncemented paths. A mixture of bentonite and water is placed between the cement plugs. Well pads are recontoured, plowed, and seeded. Wells may also be assigned to the landowner consistent with the terms of the surface use agreement. When the well is assigned, all rights and responsibilities, including reclamation, pass to the landowner, unless otherwise specified. The underground pipelines are cleaned, disconnected, and then abandoned in place to avoid any unnecessary surface disturbance. Underground electric lines are disconnected and are also abandoned in place to avoid any unnecessary surface disturbance. Aboveground lines are disconnected and the power poles are removed from the sites.

The productive life of each well is expected to be about 7 years. Final reclamation of these wells occurs during the 2 to 3 years after production ends, resulting in an overall average life of 10 years.

4.14.1.2 Environmental Impacts of CBM Recovery in the Powder River Basin

In 2003, the BLM issued a Final Environmental Impact Statement (FEIS) and a Record of Decision (ROD) for a proposed expansion of CBM production in the Powder River Basin. The following sections describe the environmental impacts of the alternative approved by the BLM in the ROD. This review is limited to CBM impacts that may contribute to a cumulative impact when considered with the environmental impacts of the Moore Ranch Project as discussed in this Section of the ER. It should be noted that the environmental impacts associated with CBM development discussed in this section were associated with a large project (51,000 total CBM wells) located in a large area within the Powder River Basin (approximately 8 million acres). The cumulative impacts of development in the Moore Ranch Project area will be based on the actual and planned CBM development within that area and are discussed in detail in Section 4.14.1.4.

4.14.1.2.1 Groundwater Impacts

CBM recovery requires the removal of large volumes of groundwater from the coal zone in order to depressurize the zone and release the gas. The BLM estimated that development of CBM in the Powder River Basin through 2018 would remove about 3 million acre-feet, less than 0.3 percent of the total recoverable groundwater (nearly 1.4 billion acre-feet) in the Wasatch and Fort Union Formations within the Powder River Basin. An estimated 15 to 33 percent of the groundwater removed will infiltrate the surface and recharge the shallow aquifers above the coals. Redistribution of pressure within the coals after water production ends would allow the hydraulic pressure head to recover within approximately 50 feet or less of pre-project levels within 25 years after the project end. Complete recovery of water levels likely would take tens to hundreds of years, depending on the location.

BLM models indicated that Wasatch aquifers that overlie the coals also would be affected by development. As the coal is de-pressurized by water removal during mining or development of CBM, water contained in deep Wasatch sands would leak into the coals. Water levels in the deep Wasatch sands would be lowered, but BLM estimated that the drawdown likely would be less than 10 percent of the level that would occur in the coal. Conversely, in some areas BLM estimated that water levels in very shallow Wasatch sands likely would rise initially, up to 50 feet in the immediate vicinity of infiltration impoundments and up to 10 feet at distances of several hundred feet from impoundments or surface drainages that receive CBM discharge. This rise would occur through enhanced recharge from infiltration of CBM produced water.

BLM projected that the infiltration of produced water would not noticeably affect groundwater quality.

Wells completed in developed coals that are located within the areal extent of the 100-foot drawdown contour created by a CBM well could experience drops in water level and possibly methane occurrence. Flowing artesian wells and springs that emanate from coals in these areas would likely experience a decrease in flow rate. BLM estimated that recovery of artesian conditions likely would not occur unless recovery of the last five percent or so of hydraulic head occurs.

4.14.1.2.2 Surface Water Impacts

An estimated 9 to 52 percent of CBM produced water would contribute to surface flows. Perennial flows would be likely to develop in formerly ephemeral channels. The preferred alternative included management of surface water discharges of produced water by sub-watersheds and the emphasized use of infiltration for produced water management. The Moore Ranch Project is located in the BLM Upper Belle Fourche River watershed. Under modeled conditions, the amount of produced water assumed to reach the main stem of the Upper Belle Fourche River sub-watershed during the peak year of CBM water production (2006) was about 61 cfs (44,168 acre-feet/year).

BLM expects noticeable changes in water quality of main stems during periods of low flow. The key water quality parameters of concern due to their impacts on water use for irrigation are sodicity (as measured by the sodium absorption ratio or SAR) and salinity (as measured by conductivity). NPDES permit conditions provide enforceable assurance that water quality standards and designated uses would not be degraded from discharges of CBM produced water. Under modeled conditions, the BLM estimated that the resultant water quality in the Upper Belle Fourche River sub-watershed at Moorcroft, Wyoming, during all months of the year would be adequate to meet the Most Restrictive Proposed Limit (MRPL) for both conductivity and SAR that the WDEQ has adopted in its NPDES permitting process to be protective of downstream irrigation. Under some flow conditions, the modeled SAR values and concentrations of sodium may inhibit the use of irrigation on some tributaries in the Upper Belle Fourche River sub-watershed. However, BLM noted that samples collected since the onset of CBM production in the Upper Belle Fourche River sub-watershed had not detected changes in ambient stream water quality which were predicted by the mass balance model.

BLM projected that concentrations of suspended sediment in surface waters would be likely to rise above baseline levels as a result of increased flows and runoff from disturbed areas. BLM requires site-specific Water Management Plans (WMPs) as an integral part of mitigation planning to control and monitor the potential effects from increased flows in surface drainages.

As a positive impact of CBM development, the discharge of produced water would result in the increased availability of surface water for irrigation and other downstream beneficial uses. Numerous impoundments are constructed to temporarily store CBM produced water for beneficial use. BLM estimated that between 8 to 25 percent of CBM produced water would be held in storage.

4.14.1.2.3 Air Quality Impacts

Fugitive dust and exhaust from construction activities, along with air pollutants emitted during operation (i.e., well operations, injection well and pipeline compressor engines, etc.), are potential causes of decreases in air quality related to CBM development and production. BLM performed air pollutant dispersion modeling to quantify potential PM_{10} and SO_2 impacts during construction based on the individual pollutant's period of maximum potential emissions. Construction emissions would occur during potential road and well pad construction, well drilling, and well completion testing. During well completion testing, natural gas may be flared and exhausted. Maximum air pollutant emissions from each well would be temporary (i.e., occurring during a short construction period) and would occur in isolation. Air quality impacts would occur during production including non-CBM well production equipment and booster and pipeline compression engine exhausts. The amount of air pollutant emissions during construction is controlled by watering disturbed soils, and by air pollutant emission limitations imposed by the WDEQ. Before actual development can occur, the WDEQ must review the specific air pollutant emissions pre-construction permit application that examines the source-specific air quality impacts. As part of these permits (depending on source size), the WDEQ may require additional air quality impacts analyses or mitigation measures.

4.14.1.3 CBM Development at Moore Ranch

Two companies (Barrett Resources Corporation and Devon Energy Corporation) have CBM claims located within the proposed Moore Ranch License Area. EMC has met with representatives of both companies to discuss current and planned CBM operations within he proposed license area and coordination with EMC activities. Currently existing CBM facilities operated by Devon located within the proposed Moore Ranch License Area are shown in Figure 4.14-1. Barrett has plans for future development within the license area. The producing interval is the Anderson/Big George coal at depths of between 1,000 and 1,200 feet below ground surface.

Existing Devon installations were installed approximately seven years ago and will be nearing the end of their operational life at the time EMC expects to begin construction. Reclamation activities for these Devon wells and facilities will likely occur during the operational phase of the Moore Ranch Project.

Barrett plans to install new facilities within the next several years in Sections 2, 3, 4, 33 and the NW ¼ of Section 34. These planned facilities are located outside EMC wellfields.

Based on discussions with both CBM operators and experience with concurrent CBM and uranium recovery development in other locations in the Powder River Basin, EMC believes that these activities can be coordinated to maintain health, safety, and environmental controls.

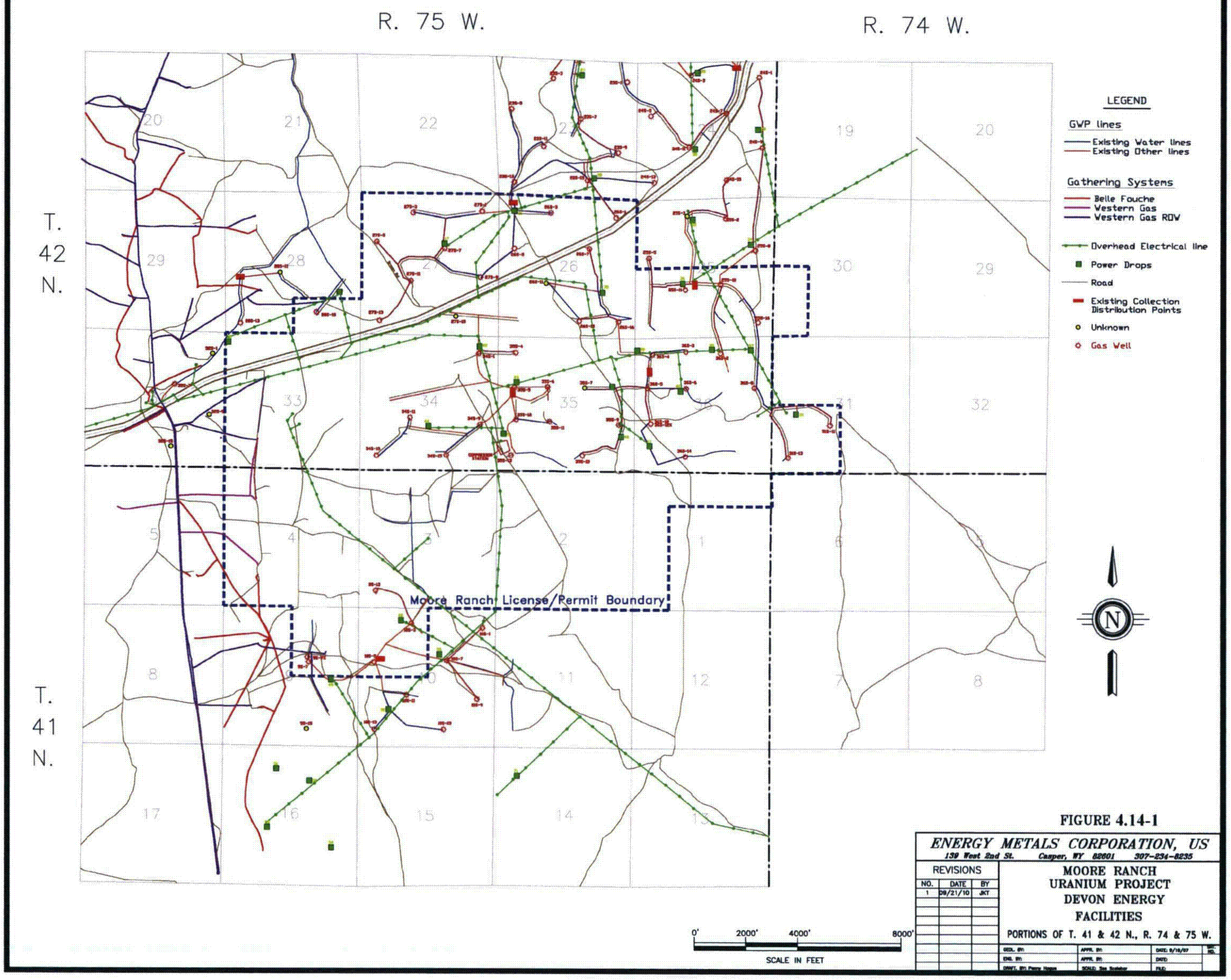


FIGURE 4.14-1

ENERGY METALS CORPORATION, US

139 West 2nd St. Casper, WY 82601 307-234-8235

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MOORE RANCH
URANIUM PROJECT
DEVON ENERGY
FACILITIES

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ENG. BY:	APPR. BY:	DATE:	
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4.14.1.4 Cumulative Environmental Impacts of the Moore Ranch Project and CBM Development

The only potential cumulative environmental impact of CBM and ISR operation would be hydrologic. As previously mentioned, the producing interval for CBM is the Anderson/Big George coal at depths of between 1,000 and 1,200 feet below ground surface. The Anderson/Big George Coal is within the Fort Union Formation and is separated from the uranium-producing 70 Sand in the Wasatch Formation by over 700 feet of interbedded clays, siltstone, and discontinuous sands. As a result, no hydrologic impacts from coal bed methane production are expected on sandstone and clay aquitards relevant to in situ mining at Moore Ranch.

4.14.1.5 Accident Risk Associated with Coal Bed Methane Development

The presence of CBM development on the Moore Ranch Project site presents accident risks that are not commonly associated with ISR mining. These additional accident risks, the control methods that the CBM operators currently have in place, additional control measures proposed by EMC, and the potential effect of accidents on the health and safety of EMC employees and the public and the security of licensed material are discussed in the following sections. The potential accident scenarios that could impact EMC operations are based on those analyzed by the BLM in the 2003 FEIS for the Powder River Basin.

4.14.1.5.1 Methane Migration and Seepage

CBM development includes potentially increased risks of methane seepage, fires, or explosions. Methane is not biologically toxic, but high concentrations in confined spaces can displace oxygen and present a danger of fire or explosion.

Methane gas can reach the surface by naturally occurring seepage along fault lines, fractures, or sandstone layers in areas where coal beds are shallow. Gas migration could also be enhanced during CBM development in areas along a coal outcrop, which are not present on the Moore Ranch site. Non-CBM wells that penetrate the coal seam may provide pathways for migration of methane if the casings or plugs are inadequate or faulty or lack isolation through the coal horizons.

BLM reported in the 2003 FEIS that experience in the Powder River Basin has shown that few cases of methane seeps that involve potentially explosive concentrations of gas have occurred.

Accident Prevention

The potential for migration of methane in CBM wells is minimized or prevented by the use of the current CBM industry standards for cementing and casing wells that isolate or protect all zones from gas or fluid migration. Well construction methods for CBM wells were discussed in detail in this section.

Mitigation

Risks from methane associated with oil and gas wells, including CBM wells, are controlled through the BLM-mandated conditions of approval for the Application for Permit to Drill (APD) that address well conditions, casing, ventilation, and plugging procedures appropriate to site-specific CBM development plans. In addition, CBM operators must have emergency plans and employee training programs that address fire prevention and control measures.

4.14.1.5.2 Pipeline Ruptures

CBM development involves the potential for leaks or ruptures of gas flowlines or pipelines. Most ruptures occur when heavy equipment accidentally strikes the pipeline while operating in close proximity. These ruptures may result in a fire or explosion if a spark or open flame ignites the escaping gas.

The projected development area of the Moore Ranch Project includes approximately 2,100 feet of gas pipeline. Based on a statistical average of one significant safety incident per year per 4,154 miles of total pipeline[1], 0.0001 additional pipeline safety incidents (including ruptures) may occur within the license area per year over the life of the project.

Based on the low incident rate, location of pipelines, and the preventative measures planned for the Moore Ranch Project, there is an insignificant increase in risks to human health and safety and control of licensed material associated with potential pipeline ruptures from CBM-related facilities.

Accident Prevention

Materials used in the pipelines are designed and selected in accordance with applicable standards to minimize the potential for a leak or rupture. Pipeline markers are posted at frequent intervals along the pipelines to warn excavators and to reduce the risk of accidental rupture from excavating equipment. EMC will work with CBM operators located on the proposed license area to ensure that all gas collection and transmission lines within proposed development areas are adequately marked to prevent accidental rupture by EMC activities.

Mitigation

The CBM operators monitor the pipeline flows by either remote sensors or daily inspections of the flow meters. Routine monitoring reduces the probability of effects to health and safety from ruptures by facilitating the prompt detection of leaks. If pressure losses are detected, the wells are shut in until the problem is isolated and addressed.

4.14.2 Cumulative Impacts of Other Uranium Development Projects

The Powder River Basin has been historically developed for the recovery of uranium using ISR and conventional (underground and pit) mining. The only existing licensed uranium projects currently located in the Powder River Basin are the Smith Ranch/Highland Uranium Project (operated by Power Resources, Inc.) and the Irigaray/Christensen Ranch Project (operated by Uranium One USA, Inc). These ISR projects are located approximately 59 km south southeast and 30 km north northwest of the Moore Ranch Project, respectively. Considering the distance between the existing projects and the proposed Moore Ranch Project, cumulative environmental impacts are not expected.

EMC is aware that several companies are actively investigating the potential for ISR mining in areas near the Moore Ranch Project. These projects are in various stages of development. Licensing and permitting applications have not been submitted to the regulatory agencies at the time of this application. As such, it is not possible for EMC to accurately predict the cumulative environmental impacts should these uranium projects seek and ultimately gain regulatory approval and be developed.

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[1] Office of Pipeline Safety, 2007. Pipeline Statistics 2006. [Web Page] located at http://ops.dot.gov/stats/stats.htm#average, Accessed August 24, 2007.