

Geothermal Reserve Pits: Considerations for Installation on BLM-Administered Lands

Jody C. Robins¹, Peter Gower², Hannah Pauling¹, and Clayton McGee²

¹National Renewable Energy Laboratory, USA

²EMPSi, USA

Keywords

Geothermal, BLM, regulation, drilling, reserve pit, sump, groundwater, wildlife, reclamation, pit liner, netting

ABSTRACT

Reserve pits, also known as sumps, are a common aspect of geothermal drilling operations. This paper describes the Bureau of Land Management's regulatory authorities and key environmental considerations associated with geothermal reserve pits. Reserve pit design, the need for environmental compliance measures, and reclamation approaches will vary depending on site-specific conditions. Groundwater and wildlife impacts are the most common environmental considerations related to reserve pits. In some cases, regulations or groundwater or soil conditions necessitate the use of a synthetic liner. However, the chemical composition of most geothermal drilling fluids and muds, completion fluids, and produced fluids that are discharged to reserve pits does not warrant pit liners. The potential for hazardous fluids, high water temperatures, and entrapment are concerns for wildlife. Common wildlife impact avoidance and mitigation measures include fencing, netting, and escape ramps. The need for these measures depends on localized site and environmental conditions. There are requirements to reclaim reserve pits following geothermal drilling operations. Reserve pits often remain in place to accommodate multiple phases of drilling and well testing. They are eventually backfilled and decommissioned.

1. Introduction

Under the authority granted to the Bureau of Land Management (BLM) by the Geothermal Steam Act of 1970, the Mining and Minerals Policy Act of 1970, the regulations under 43 Code of Federal Regulations (CFR) 3260 and 3270, and the Mineral Leasing Act of 1920, the agency has the authority to regulate the placement and use of reserve pits associated with geothermal development. Individual BLM state offices may also issue Instruction Memorandums that clarify policy specific to BLM-administered lands in the state. Through these authorities, the BLM can include stipulations for reserve pits during the leasing phase, identify best management practices,

and specify required design features or conditions of approval as part of the agency’s geothermal drilling permit process for drilling associated with an operations plan for exploration or a utilization plan for development.

Geothermal drilling operators construct reserve pits—excavated basins on the well pad adjacent to drilling rigs—for the containment of drilling fluid, or mud, and geothermal fluids during flow testing.¹ Geothermal reserve pits typically range in size from 0.1 to 0.8 acres, depending on the hole size and depth of the corresponding well (USFWS 2009). The makeup of fluids contained in the reserve pits depends on the type of drilling mud used and the reservoir fluids that the wellbore is drilled through and later produced to surface during flow testing. While reserve pits used for oil and gas operations frequently contain oil or oil-based products, reserve pits used for geothermal operations predominantly contain water-based drilling fluids and low-salinity geothermal brines.

Reserve pits can be unlined, lined with bentonite clay, or lined with a synthetic liner, depending on local geologic features (like groundwater seeps), the characteristics of the drilling fluids to be used, and the nature of the geothermal fluid in the target reservoir. When particularly toxic or corrosive fluids are anticipated, such as in the Imperial Valley in Southern California, the use of steel tanks (or closed loop “pitless” operations) may be recommended. In some cases, reserve pits can be dangerous to birds and wildlife. However, if guidelines established by regulatory agencies (including the BLM) are followed, bird and wildlife mortality can be avoided (USFWS 2009).

For geothermal exploration and development on federal lands, the BLM is the primary agency responsible for authorizing reserve pits. The BLM has the authority to specify design criteria that avoid, minimize, and mitigate potential environmental impacts of reserve pit construction and use. Other federal agencies, such as the U.S. Fish and Wildlife Service (USFWS), may provide input regarding certain design features during the National Environmental Policy Act (NEPA) environmental review process. In addition, state regulatory agencies have limited authority for the permitting of reserve pits on BLM-administered federal lands, primarily to protect wildlife and water resources.

Geothermal operators are ultimately responsible for adhering to agency regulations as part of constructing and operating geothermal exploration and development projects. Industry representatives work closely with the BLM, and other agency staff as appropriate, to ensure that the placement, design, and use of geothermal reserve pits meets agency regulations and permit requirements.

2. Regulatory Framework

The current regulatory framework from the Minerals Leasing Act of 1920, Federal Land Policy and Management Act of 1976, National Environmental Policy Act, and various other federal laws provide the BLM with significant regulatory oversight for reserve pits. These tools can be used during the leasing, drilling, and operation phases of a project. Furthermore, certain states

¹ Flow tests are generally conducted immediately after a well has been drilled to total depth and are used to gauge its potential productivity. During flow tests, geothermal fluids are typically produced directly to the reserve pit.

(such as California and Nevada) can have additional regulatory measures for the management of water and wildlife resources.

2.1 BLM

2.1.1 Leasing

The BLM has the delegated authority through the Minerals Leasing Act of 1920 to issue geothermal leases on federal lands and currently administers approximately 450 geothermal leases over 700,000 acres of land. Section 2 of the Mining and Mineral Policy Act of 1970, as well as Sections 102, (a)(7), (8), and (12) of the Federal Land Policy and Management Act of 1976 (FLPMA) (43 US Code [USC] 1701 et seq.) further define agency policy when issuing geothermal leases.

All potential geothermal development sites are subject to lease stipulations, which vary by site and are an enforceable term of the lease contract that must be followed. The BLM has the authority to apply exceptions, waivers, and modifications to lease stipulations. Lease stipulations must conform to other applicable laws, regulations, and policy, such as the Endangered Species Act, Clean Air Act, National Historic Preservation Act, and the BLM's multiple use mandate under FLPMA. Lease stipulations vary by state and project. The nature and type of stipulations are influenced by applicable BLM resource management plan regulations, state laws, and BLM state-specific Instruction Memorandums.

The BLM, in conjunction with the Forest Service, prepared the Geothermal Leasing Programmatic Environmental Impact Statement (PEIS; BLM 2008) to analyze best management practices and environmental impacts from geothermal leasing in the western United States. The PEIS includes best management practices for geothermal projects, which include construction of reserve pits. The PEIS references requirements for oil and gas operations in "The Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development—The Gold Book" (BLM 2007) for drilling fluids to be captured in a reserve pit or other means. The PEIS describes typical geothermal development as consisting of a plastic-lined pit for small wells or clay-lined pits for larger wells to hold drilling fluids and muds. The PEIS further specifies that reserve pits are to be closed and backfilled within 60 days of the release of the drilling rig, and all reserve pits that remain open longer than 60 days require written approval from an authorized officer. The PEIS includes best management practices for the closure of reserve pits, such as ensuring the proper disposal of pit liners, removing any hazardous substances from the pit before backfilling, and requiring slight mounds on backfilling to promote surface drainage. Individual geothermal leases may include more specific requirements for reserve pits.

2.1.2 Exploration and Development

During the BLM's review and approval of geothermal drilling permits associated with accepted operation plans for exploration or utilization plans for development, the authorized officer can require operators to implement best management practices, such as those in the Geothermal PEIS, and other environmental compliance measures to avoid, minimize, or mitigate the effects of geothermal drilling on natural resources and other land uses. Operators must also adhere to any terms, conditions, and stipulations described in the geothermal lease within which the project is located.

The BLM often references the Gold Book for additional environmental compliance measures beyond those in the Geothermal PEIS and individual geothermal leases. While it is the BLM's standard for implementing oil and gas exploration and development projects on BLM-administered land, the BLM also uses it as a reference for geothermal exploration and development projects. The Gold Book describes the regulatory requirements, protocols, and environmental compliance measures for construction and operation, and reclamation objectives for all aspects of oil and gas development, many of which also apply to geothermal operations. According to the Gold Book, surface operating standards and guidelines for reserve pits specify that they should not be constructed in natural watercourses or near groundwater. It recommends that pits be lined with bentonite clay or synthetic materials to prevent leakage and damage to soil and water resources. Fences should be constructed around reserve pits to keep large terrestrial wildlife out while also protecting smaller terrestrial organisms.

During the NEPA review and permitting processes, the BLM may identify the need for additional design features or environmental compliance measures for reserve pits beyond those described in the lease stipulations or the Gold Book. The purpose of more specific standards would be to avoid impacts on localized natural resources, such as water, soil, or wildlife, and would be at the discretion of the BLM authorized officer.

2.2 State Agencies

State agencies have limited regulatory authority for the permitting of reserve pits on BLM-administered federal lands. These authorities are primarily to protect wildlife and water resources.

2.2.1 Wildlife

State wildlife agencies often engage with the BLM as cooperating agencies during the NEPA review process for geothermal exploration and development projects. As cooperating agencies, state agencies may recommend design features to avoid impacts on wildlife. Specific strategies are discussed in Section 3. Additionally, state law often requires that state wildlife agencies act to protect sensitive species. State wildlife agencies may also have additional limited regulatory authority over reserve pit design and wildlife mitigation requirements. For example, the Nevada Revised Statutes (Chapter 502.390) require an Industrial Artificial Pond Permit if a reserve pit is proposed to contain chemicals that would cause the death of any wildlife. Issuance of the Industrial Artificial Pond Permit is contingent upon the Nevada Department of Wildlife (NDOW) review and approval of wildlife exclusion measures (e.g., bird balls, netting, fencing). In general, Industrial Artificial Pond Permits are not required for geothermal exploration and production projects because the fluids discharged to a geothermal reserve pit typically do not pose a mortality risk to wildlife.

2.2.2 Water and Permitting

State environmental protection agencies, which often include the division or department responsible for regulating water resources, do not typically engage in the NEPA process as cooperating agencies. These agencies may, however, provide comments for the BLM's consideration in developing siting and design requirements for reserve pits.

State agencies also have limited permitting jurisdiction over geothermal development and reserve pits. For instance, through the Safe Drinking Water Act, state environmental protection agencies have discrete authority to issue underground injection control (UIC) permits for the discharge of produced geothermal water to reserve pits. In conjunction with the Nevada Division of Minerals, the Nevada Division of Environmental Protection UIC Permit includes specific design requirements for reserve pits, such as interior embankments, minimum freeboard, and siting locations relative to the 100-year floodplain.

In California, the State Water Resources Control Board regulates the handling of wastes generated during geothermal drilling; this includes the design specifications for reserve pits. Pit liners are required throughout California. In some areas, such as the Imperial Valley, the Water Resources Control Board prohibits the disposal of fluid wastes into surface basins and requires the fluids be contained in metal tanks. In accordance with Title 22 of the California Code of Regulations, the Water Resources Control Board also requires regular testing of stored fluids and solids for hazardous constituents.

2.3 Other Federal Agencies

For geothermal exploration and production projects on BLM-administered lands, other federal agencies may have limited jurisdiction for reserve pit permitting in certain circumstances. For example, per the Clean Water Act, the U.S. Army Corps of Engineers would have regulatory authority for projects located in waters of the United States. Mostly, however, the role of other federal agencies relative to geothermal reserve pits is to provide the BLM with input during the NEPA review process. Federal agencies that may participate as cooperating agencies or provide comments during the NEPA process include the U.S. Fish and Wildlife Service (USFWS), the Department of Defense, U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency (EPA).

3. Considerations and Concerns

The BLM evaluates and permits geothermal exploration and development pursuant to the regulations described in Section 2. While there may be many environmental, cultural, and socioeconomic considerations and concerns related to geothermal activity overall, considerations and concerns specific to reserve pits are mostly related to groundwater, wildlife, and reclamation.

3.1 Groundwater

Standard geothermal industry practice consistent with the regulations in Section 2 has been shown to avoid potential groundwater impacts. Through the use of reserve pits and other strategies, researchers concluded that there are no recorded instances of geothermal operations contaminating groundwater resources in the United States (Robins 2021, Kagel et al. 2007).

For geothermal drilling, the BLM often follows the Gold Book standards for oil and gas, which specify that produced wastewater from drilling be disposed of in lined or unlined pits, by subsurface injection, or another method deemed acceptable to the BLM authorized officer and in accordance with the requirements of Onshore Order No. 7, Disposal of Produced Water, and other federal or state regulations (BLM 2007). While it recommends operators use reserve pits with synthetic liners to prevent contamination, the Gold Book states that reserve pits can be

constructed with or without a liner, depending on the site location. The key considerations related to groundwater are geothermal fluid constituents and soil permeability. Understanding these considerations at a project-by-project level enables the BLM to determine whether pit lining or a closed loop system is appropriate, or whether an unlined pit is adequate.

Geothermal reserve pit fluid and cutting characteristics depend on site soil and groundwater conditions, the type of drilling fluids used, and the geothermal fluid to be produced during flow testing. The Gold Book specifies that operators should use drilling chemicals that are less toxic to the environment and that reserve pits should be constructed away from areas with shallow ground water, lake beds, gullies, draws, steam beds, washes, arroyos, and channels.

Geothermal drilling fluids and muds are used to lubricate the drill bit, stabilize the well cavity, prevent leakage and maintain well pressure, assist in the removal of cuttings, and regulate the chemical and physical characteristics of the mixture being extracted from the well. Additives depend on drilling conditions and differ by site. Drilling fluids and muds typically consist of bentonite and other clays mixed with water. By weight, barite (BaSO_4) is the most abundant constituent in drilling fluids (Noorollahi and Yousefi 2010). In some cases, caustic soda, lime, or cement may be added to the drilling fluid to increase viscosity and drilling performance. The pH of drilling fluid is typically 9.5 to 10.5 (Chemwotei 2011). Recovered drilling fluids are typically treated and reused in the drilling process to the extent the fluids achieve the desired drilling results. After that point, the used drilling fluid is discharged to the reserve pit. Discharged fluids are typically high in total suspended solids, chloride, and the additives used during drilling.

Completion fluids are used once the well is drilled to control down-hole pressure and prevent the intermixing of well formation fluids with desired geothermal fluids. Completion fluids consist of a heavy brine, typically chloride and bromide (EPA 2019). Once the well is ready to receive the geothermal fluid, the completion fluid is discharged to the reserve pit.

Used drilling fluids and cuttings are generally less toxic than oil and gas drilling fluids and cuttings, which often contain hydrocarbons (Ramirez 2009, Ramirez 2010). Only in situations where the geothermal well is being drilled under extreme temperatures and pressures will operators use petroleum additives in drilling fluids. This is needed to prevent evaporation or freezing. Operators may also use oil-based fluids to avoid water absorption when drilling hydratable shale or salt dome soil conditions (EPA 2019).

Following well completion, produced geothermal fluids are often discharged to reserve pits during flow testing. The chemical composition of produced fluids and cuttings is the result of site-specific hydrogeologic conditions. For example, studies have shown that trace constituents such as arsenic can be found at concentrations up to 50 parts per million in geothermal fluids (Ballantyne and Moore 1988). Many states, including Nevada, require sampling and reporting of produced fluids being discharged to reserve pits.

3.1.1 Unlined Pits

For most geothermal exploration and development projects, an unlined reserve pit is the industry-preferred option. Settled bentonite clay from the drilling mud accumulates on the bottom of the reserve pits and acts as a low-permeability clay liner. Especially in arid environments, water-based drilling fluids evaporate faster than percolation could occur through a

clay liner. This avoids the need for any additional measures to prevent drilling fluid from percolating through the bottom of the pit and reaching groundwater.

3.1.2 Lined Pits

If reserve pits are expected to contain high concentrations of hydrocarbons and chlorides, the BLM's Gold Book recommends synthetic, bentonite, or clay liners be used if the area is near shallow ground water or porous soils and fractured aquifers. In areas where there are more porous soils, lined reserve pits can mitigate potential groundwater impacts from infiltrating fluids in the reserve pit. State water quality regulations can also mandate pit liners. In California, liners are currently required in all applications state-wide. If not using a synthetic liner, the porosity of clay liners must be verified by a licensed civil engineer. In Nevada, the Division of Environmental Protection waives the requirement for liners if the UIC permit demonstrates the stored fluids and muds will not be hazardous to groundwater.

Where applicable, synthetic liners should have a minimum thickness of 12 mils and be resistant to UV light, cold and hot weather, tearing, and puncturing (BLM 2007). Best management practices in the Geothermal PEIS recommend that pit liners be textured to facilitate wildlife movement up the pit walls (BLM 2008; see **Section 3.2.3**). In the PEIS, the BLM also suggested that pit liners should be completely removed or removed down to the level of the accumulated solids in the pit. Removal and disposal of a liner introduces an added consideration for reclamation (see **Section 3.3**).

3.2 Wildlife

Geothermal reserve pits pose a potential hazard to wildlife. The most relevant concerns are related to concentrations of hazardous fluids, water temperature, and entrapment of wildlife in the pit. Strategies to avoid or minimize these concerns typically include fencing and/or netting and shallower pit slopes.

3.2.1 Hazardous Fluids

Geothermal reserve pits contain less hazardous materials compared to oil and gas reserve pits, but their elevated temperatures can pose a risk during certain operations. During flow testing, when geothermal drilling fluids are produced to reserve pits, the liquids can exceed 140°F, which may scald (Culver 1998). However, the fluids rapidly cool to ambient temperatures that do not pose a scalding risk. Also, though operators can encounter very high temperatures while drilling through geothermal zones, they typically use mud coolers to reduce the drilling fluid temperature to 125°F before discharging the mud to the reserve pit.

Initially, the concentration of drilling fluid additives in the reserve pit is relatively low as they are diluted by the water that is the primary constituent of the drilling fluid. As the water evaporates, chemical concentrations increase and the remaining fluid can become more hazardous to wildlife. However, as discussed in **Section 3.1**, most drilling fluids are water-based and nontoxic additives are used mainly to control pH and solidify the drilling muds, so impacts on wildlife are unlikely. Though somewhat rare in the United States, discharged fluids can also contain hydrogen sulfide (H₂S) which can be harmful to human and wildlife health (Iowa State University 2021). In the Imperial Valley in California, where produced geothermal fluids can contain H₂S, operators must use a pitless system for flow testing to comply with California State

Water Resources Control Board requirements. The presence of H₂S triggers the need for an H₂S contingency plan, which is outside the scope of this paper.

3.2.2 Entrapment

Poorly designed reserve pits introduce a risk for wildlife entrapment, particularly in desert areas. Standing water in a pit can attract wildlife, which may be unable to escape the pit due to the viscosity of the fluid, steepness of the pit wall, and lack of footing (especially in the case of synthetic pit liners). Birds, bats, insects, amphibians, small mammals, and big game are all at risk of entrapment. The entrapment of prey species can lead to subsequent entrapment of larger predators. For example, when insects become trapped in reserve pits, they have the potential to attract small birds as an easy food target. Similarly, smaller animals trapped in a pit can attract larger birds or terrestrial animals. Although less common in geothermal reserve pits compared with those used in oil and gas or hard mining, birds can become trapped and die from exposure and exhaustion (USFWS 2009).

3.2.3 Avoidance and Mitigation Measures for Wildlife

Common measures to avoid, minimize, or mitigate wildlife impacts from hazardous fluids and entrapment include fencing or netting, escape ramp and wall grade specifications, rapid fluid disbursement, and physical hazing measures.

Fencing and Netting

Fencing prevents reserve pit access by persons or livestock. During active drilling and flow testing, human activity and noise will likely deter most wildlife. The BLM often references fencing standards outlined in the BLM Gold Book and applies those to geothermal projects. According to these standards, the pit must be fenced on three sides during drilling and fencing must be added to the fourth side once drilling has been completed. All fences should be placed tight to the ground, and markings may be required if the fences create a collision hazard for wildlife. The fence should remain in place until pit reclamation begins (BLM 2007, BLM 2012) (see **Section 3.3** for reclamation practices). Fences should be designed according to the wildlife that is present in the area. The Gold Book presents guidelines for the construction of fences in active livestock areas (Figure 1). Minimum fencing requirements are also provided in the BLM Fencing Handbook (BLM 1989). 18 states have fencing requirements for pits, but some states require fencing only for certain types of pits (EPA 2019).

Additional protection measures may be recommended by state wildlife agencies, such as the Nevada Department of Wildlife (NDOW). NDOW has stated that the typical four-strand wire fence may not be adequate to keep terrestrial wildlife out of reserve pits and recommends that fences should be eight feet high in areas with a high density of big game. NDOW also recommends that the bottom four feet of fence be woven or mesh wire to exclude small terrestrial wildlife, with maximum two-inch mesh on the lower two feet and maximum eight-inch mesh on the upper two feet. Additionally, fences that are at least six feet from the edge of lined pits allow wildlife to maneuver around the pit if they accidentally gain access (NDOW 2012). The above measures recommended by NDOW are rarely (if ever) implemented.

Small-diameter netting can prevent pit access by birds and other animals in locations where reserve pit fluids are lethal, contain hydrocarbon residues, or where temperatures exceed 150°F.

If located in a sensitive wildlife area, for example the Stillwater Wildlife Refuge located near the proposed Salt Wells geothermal project near Fallon, Nevada, netting may be required regardless of water quality or temperature. The Gold Book does not include standards for the use of netting; however, state wildlife agencies may have additional recommendations. For example, NDOW recommends the use of 1.5-inch mesh suspended 4–5 feet above the liquid solution surface and secured to the ground or perimeter fencing. Bird balls are another option, provided they sufficiently always cover (>95%) the liquid surface (NDOW 2012). Other measures such as flagging, strobe lights, metal reflectors, and noise makers can be used, but the USFWS has stated that these measures are not effective (BLM 2012; USFWS 2009, 2011).

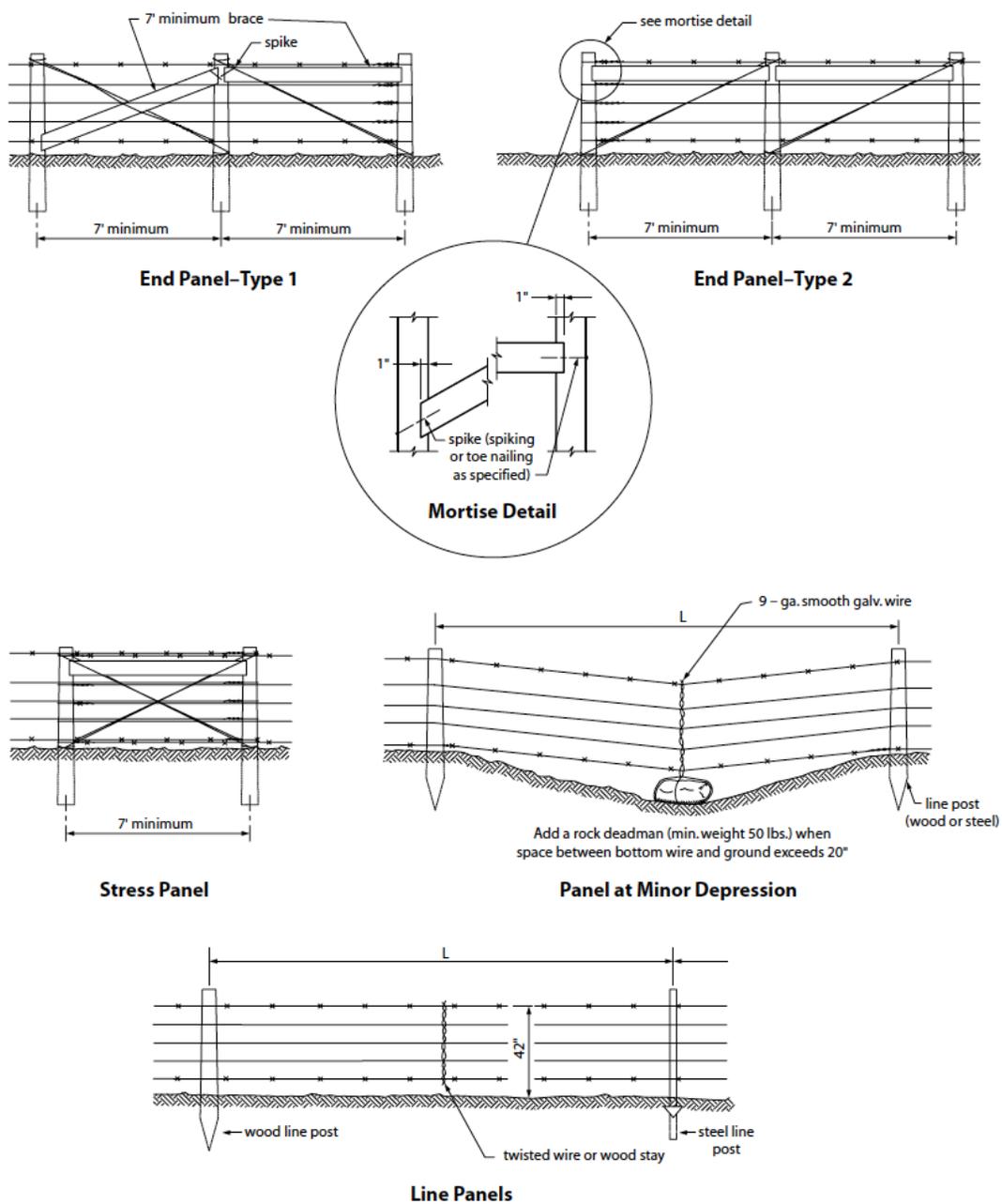


Figure 1. Fencing construction standards recommended by the BLM Gold Book (BLM 2007).

Escape Ramps and Wall Grade Specifications

Escape ramps and gently sloped wall grades are design options to allow wildlife to escape reserve pits. Best management practices in the BLM's Geothermal PEIS specify that at least one side of a reserve pit should have a 3:1 slope to allow wildlife to escape. The PEIS indicates the need for escape ramps where edge slopes are steeper than 3:1 or where pit liners are used. It is common for industry to add wood planks to escape ramps to increase the footing for trapped animals. Other agencies, such as NDOW, recommend at least two sides of every reserve pit be sloped at 4:1 or flatter, and escape ramps be coated with geo-mesh and installed in two corners with a maximum distance between any two ramps not exceeding 200 feet. However, these are not industry standard practices. The BLM does not have any more specific standards or regulations for escape ramps or wall grade specifications beyond those in the PEIS.

3.3 Reclamation

Best management practices in Appendix D of the Geothermal PEIS indicate that immediately upon well completion, all hydrocarbons and solid waste is to be removed from the pit. The BLM allows pits to dry and solidify in place before backfilling. The PEIS specifies that reserve pits will be closed and backfilled within 60 days of release of the drill rig. Subject to approval from the BLM authorized officer, reserve pits can remain open longer. Reserve pits can be used for continuing well operations, such as workovers, or during maintenance.

Lined pits can be backfilled in place and the liner removed down to the level of the accumulated solids. It is generally not feasible to remove the entire pit liner once the drilling fluids and muds are deposited on top.

Depending on the volume of fluids deposited in the pit and local climate conditions, fluid may remain in a pit for several months or more before evaporating. Pumping could be a consideration where fluids are likely to remain in place in areas with slow evaporation rates. Best management practices in the Geothermal PEIS specify that once dry, pits should be backfilled with a minimum of five feet of soil material. Undulations should be left on the surface to disperse surface water away from the backfilled pit (BLM 2008).

4. Conclusion

Reserve pits are a common aspect of geothermal drilling operations. Potential impacts on groundwater and wildlife are the most common environmental considerations and concerns regarding reserve pits. Pit lining and wildlife protection measures, such as netting and escape ramps, may be warranted or required in some situations; however, these measures are often unnecessary. Evidence presented herein demonstrates that implementing geothermal lease stipulations, best management practices from the BLM's Geothermal PEIS, and applying similar standards from the oil and gas industry as described in the Gold Book frequently avoids or mitigates groundwater and wildlife impacts without the need for additional measures. During the NEPA review process for individual geothermal exploration or development proposals, the BLM may identify characteristics of the affected environment that warrant additional design features or environmental compliance measures for reserve pits beyond those described in the lease stipulations or the Gold Book. Requiring these measures would be at the discretion of the BLM authorized officer.

Acknowledgement

This work was supported by the U.S. Department of Interior Bureau of Land Management's Renewable Energy Coordination under contract L20PG00048 with the National Renewable Energy Laboratory (NREL). NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

REFERENCES

- Ballantyne, Judith M., and Joseph N. Moore. 1988. "Arsenic geochemistry in geothermal systems." *Geochimica et Cosmochimica Acta* 52(2), 475–483.
- Bureau of Land Management (BLM). 1989. "Handbook H-1741-1: Fencing."
- Bureau of Land Management (BLM). 2007. "The Gold Book: Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development."
- Bureau of Land Management (BLM). 2008. "Programmatic Environmental Impact Statement for Geothermal Leasing in the Western United States."
- Bureau of Land Management (BLM). 2012. "IM 2013-033: Fluid Minerals Operations Reducing Preventable Causes of Direct Wildlife Mortality."
- Chemwotei, Sichei Chepkech. 2011. "Geothermal Drilling Fluids." United Nations University. Geothermal Training Programme. Reykjavik, Iceland.
- Culver, Gene. 1998. "Drilling and Well Construction." Geo-Heat Center. Klamath Falls, OR.
- Environmental Protection Agency (EPA). 2019. "Management of Exploration, Development and Production Wastes: Factors Informing a Decision on the Need for Regulatory Action."
- Iowa State University. 2021. "Hydrogen Sulfide Toxicity." *Veterinary Diagnostic and Production Animal Medicine*.
- Kagel, Alyssa, Diana Bates, and Karl Gawell. 2007. "A Guide to Geothermal Energy and the Environment." Geothermal Energy Association.
- Nevada Department of Wildlife (NDOW). 2012. "Design Features and Tools to Reduce Wildlife Mortalities Associated with Geothermal Sumps."
- Noorollahi, Younes. and Hossein Yousefi. 2010. "Geothermal Energy Resources and Applications in Iran." *World Geothermal Congress 2010*. Bali, Indonesia.
- Ramirez, Pedro. 2009. "Reserve Pit Management: Risks to Migratory Birds." U.S Fish and Wildlife Service: Environmental Contaminants Program.
- Ramirez, Pedro. 2010. "Bird Mortality in Oil Field Wastewater Disposal Facilities." *Environmental Management* 46:820-826.
- Robins, Jody. 2021. "The Impacts of Geothermal Operations on Groundwater." *GRC Transactions*, Vol. 45, 2021.

- U.S. Fish and Wildlife Service (USFWS). 2009. "Migratory Bird Mortality in Oilfield Wastewater Disposal Facilities." Wyoming Ecological Services Field Office: Environmental Contaminants Program.
- U.S. Fish and Wildlife Service (USFWS). 2011. "The Ineffectiveness of Flagging to Deter Migratory Birds from Oilfield Production Skim Pits and Reserve Pits." Wyoming Ecological Services Field Office.