LIFE EXTENSION 2
CONCEPTUAL DESIGN REPORT
VOLUME V
BRYAN MOUND

U.S. DEPARTMENT OF ENERGY
STRATEGIC PETROLEUM RESERVE
PROJECT MANAGEMENT OFFICE
NEW ORLEANS, LOUISIANA
CONTRACT NO. DE-FE-0023538

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PROJECT LIST

BM-MM-1055

BM-MM-1171

BM-MM-1340

BM-MM-1354

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BM-MM-1358

BM-MM-1365

BM-MM-1371

BM-MM-1462

BM-MM-1524

BM-MM-1528

BM-MM-369

BM-MM-590

BM-MM-774

BM-MM-1055

Convert Crude Oil Tank BMT-4 to External Floating Roof

VCI Project Engineer: Lorna Madison

Recommended Alternative:

Domed Internal Floating Roof

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The Bryan Mound (BM) site will explore the alternative of upgrading Crude Oil Tank BMT-4 to external floating roof configuration and returning the tank to crude oil service. Crude Oil Tank BMT-4 is currently out of service due to a roof failure in May 2015. In its current condition, it cannot be utilized for fill or to stage petroleum for emergency deliveries. In an out-of-service condition, the risk of tank corrosion, internal roof failure, and possible release of hydrocarbons to the atmosphere exist. In addition, any expanded use of the tank for delivery of oil during an emergency drawdown will not be possible.

The Bryan Mound (BM) site is committed to providing a maximum cavern fill rate of 225,000 barrels per day by Level I Performance Criteria.

Functional Requirements

- Crude Oil Tank operation with an external floating roof should accommodate a Level I cavern fill rate of 225,000 barrels per day.
- The system must meet current emission requirements set by the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency (EPA) for an ozone nonattainment area.
- Tank design shall provide a minimum system reliability of 95%.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Anthony Bonadona	VCI, Project Engineer
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Buddy Delaune	FFPO, Principal Mechanical Engineer
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Bob Sevcik	FFPO, Director Environmental Department & Sustainability
Daniel Kosick	FFPO, Manager Project Safety

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. Crude Oil Tank operation with an external floating roof should accommodate a Level I cavern fill rate of 225,000 barrels per day. The system must meet current emission requirements set by the TCEQ and the EPA for an ozone nonattainment area.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely and have the ability to address safety and security concerns during implementation. Project work plans must invoke Strategic Petroleum Reserve (SPR) protocols to establish a safe work environment for all construction related activity.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. Tank design shall provide a minimum system reliability of 95 %.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

The Bryan Mound site is equipped with three tanks for crude oil storage. Crude Oil Tanks BMT-2, BMT-3 and BMT-4 are designated for crude oil storage. Each of these tanks was sized to provide 200,000 barrels of inventory or approximately 21 hours of fill without transfers to cavern storage at a rate of 22,000 barrels per day. Each tank was permitted for 3.35 tons/yr of VOC emissions for storage of crude of 11.0 psia or lower vapor pressure. Operation of two of these three tanks is required to provide sufficient crude storage capacity to meet sweet and sour crude drawdown requirements as set forth in Level I criteria with BMT-4 favored for transferring crude to the Freeport terminal. However, only one crude oil tank is currently available where two are required.

Crude Oil Tank BMT-3 was converted to an external floating roof tank and is currently in service. Crude Oil Tank BMT-2 is of the internal floating roof type and is currently out of service due to hole-through failure of the floating roof. Exploratory work has been initiated under existing project authorization to convert BMT-2 to external floating roof and return the tank to crude oil service. However, significant issues have been uncovered with the floor of the existing tank which will delay its repair. BMT-4 is similarly equipped with an internal floating roof and is out of service due to roof failure as well. The tank roofs of BMT-2 and BMT-4 are so badly damaged that repair was determined to be impossible. Full roof replacement with an internal floating roof or external floating roof is required to return either of these two tanks to service. Assuming one or both of these tanks are fitted with external floating roofs to return one or both of these tanks to crude oil service in compliance with current Federal tank regulations, drawdown capability for sweet and sour crude will be restored.

Conversion of BMT-3 and BMT-2 from internal floating roof to external floating roof were done by permit by rule. The external floating roof configuration is listed by the TCEQ as Best Available Control Technology (BACT) and called out in their tank regulations for permitting tank modifications by rule for aboveground

petroleum storage tanks of greater than 40,000-gallon capacity for crude oil of less than 11.0 psia true vapor pressure at maximum storage temperature. The supporting incremental fugitive emissions calculations filed fall within the existing site permit limits for modifications permit by rule.

Crude oil received by pipeline or by ship is inventoried in the three Crude Oil Tanks. Crude Oil Transfer Pumps and Crude Oil Injection Pumps are used to simultaneously transfer crude oil from these tanks to the caverns. When receiving crude oil, these tanks become critical when the rate of crude oil receipts exceeds the rate at which it can be transferred to the caverns. This can occur when the crude transfer system is out-of-service while receiving crude. However, this system has a reliability in excess of 99% and should not impact the fill operation. The pumps in this system are intended to transfer at a rate which is in excess of the Level I maximum fill rate of 225,000 barrels per day.

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

Maintain the existing system in place.

The Status Quo alternative does not meet mission requirements. The crude oil tank BMT-4 is currently out of service due to an extensive hole-through of the roof. In its current condition, it cannot be utilized for fill or to stage petroleum for emergency deliveries. In an out-of-service condition, the risk of tank corrosion, internal roof failure, and possible release of hydrocarbons to the atmosphere exist. In addition, any expanded use of the tank for delivery of oil during an emergency drawdown will not be possible. This alternative is not feasible.

Viability: No Further Analysis

B. External Floating Roof

Convert the existing damaged internal floating roof of BMT-4 to an external floating roof.

Crude Oil Tank BMT-3 was previously converted from an internal floating roof to an external floating roof tank. The lessons learned from this conversion can be applied to convert BMT-4 to an external floating roof tank. Barring any inspection findings which point to more extensive damage, the new external floating roof can be built in BMT-4 while it is out of service. The external floating roof is considered BACT technology for this service provided the crude oil pressure does not exceed 11.0 psia true vapor pressure at operating conditions. This change can be permitted by rule with the TCEQ to expedite the project.

This option places BMT-4 back in service but limits Bryan Mound flexibility in handling a greater range of crude oils. Should Bryan Mound wish to upgrade the external floating roof for the handling of crude oil with higher true vapor pressure, a lightweight aluminum dome roof can be installed over the tank while in crude oil service to collect fugitive emissions and vent them to a proper emissions control device, i.e., a vapor recovery or vapor destruction unit. The external floating roof does not require modification for this upgrade although many of the operating and maintenance benefits associated with upgrade or replacement of the floating roof would not be captured in the project economics.

Site personnel have five years of experience with the maintenance and operation of BMT-3 as an external floating roof tank. Converting BMT-4 to the same external floating roof configuration as BMT-3 and BMT-2 simplifies tank operation and maintenance.

Viability: Continue Analysis

C. Domed Internal Floating Roof

Convert BMT-4 to a domed tank with internal floating roof.

Conversion of Crude Oil Tank BMT-4 directly to a domed tank with internal floating roof allow Bryan Mound to capture additional project benefits. Installation of a modern, lightweight aluminum domed roof atop the tank provides a weather shield for the tank. This domed roof shields the floating roof from the sun and wind,

thereby reducing evaporative emissions escape through the floating roof rim seals. This weather shielding will also protect the floating roof from precipitation, dirt accumulation, and system corrosion to reduce the potential for hydrocarbon release due to deck drain pluggage, roof sinking, or deck drain piping failure. The shielding of the rim and penetration seals in the floating roof from the sun and weather will increase the performance life of the seals. The installation of the domed roof also reduces the potential for tank fire by lightening spark as a result of the Faraday cage effect created by the domed structure. The domed roof better secures the tank against unauthorized entry and terrorist attack. The domed internal floating roof is considered BACT technology for this service provided the crude oil pressure does not exceed 11.0 psia true vapor pressure at operating conditions. This change can be permitted by rule with the TCEQ to expedite the project.

Covering the tank with a domed roof eliminates the need for floating roof deck drains and permits redesign of the floating roof as a much lighter weight, slim profile floating roof which can be attached by cable to the domed roof. Installed in place of the bulkier external floating roof, installation of this type of internal floating roof from the start of the project simplifies installation and operation, reduces the maintenance required, and allows the floating roof to ride higher in the tank to increase effective working capacity.

Conversion to a domed roof tank sets up the tank for more rapid adaption to vent to control to extend tank service to hotter or higher API crude oils which exhibit true vapor pressures in excess of 11.0 psia. Installation of a blower and a vapor recovery or vapor destruction device completes the upgrade of the domed internal floating roof tank to BACT emissions control to extend BMT-4 to inventory crude oils of higher vapor pressure.

Viability: Continue Analysis

D. New Tank with External Floating Roof

Demolish the existing BMT-4 tank and build a new tank of identical capacity in its place with an external floating roof.

Plans are in development to convert Crude Oil Tank BMT-2 from an internal floating roof to an external floating roof tank in like manner to the successful conversion BMT-3. However, inspection of the existing tank walls and floor has shown that the existing tank is unfit for return to crude oil service without substantial repairs. Project cost and success are improved by pursuing replacement of BMT-2 with a tank of like capacity and design with an external floating roof tank. For lack of available plot space, the project team is considering demolition of the existing tank followed by building of a replacement tank on the same foundation. This same strategy is offered here for replacement of BMT-4 should inspection show that the costs of refurbishing the existing tank for return to service are too high. The change to external floating roof is considered BACT technology for this service provided the crude oil pressure does not exceed 11.0 psia true vapor pressure at operating conditions.

This tank replacement option places BMT-4 back into service but limits Bryan Mound flexibility in handling a greater range of crude oils. Should Bryan Mound wish to upgrade the external floating roof for the handling of crude oil with higher true vapor pressure, a lightweight aluminum dome roof can be installed over the tank while in crude oil service to collect fugitive emissions and vent them to a proper emissions control device, i.e., a vapor recovery or vapor destruction unit. The external floating roof does not require modification for this upgrade although many of the operating and maintenance benefits associated with upgrade or replacement of the floating roof would not be captured in the project economics.

Site personnel have five years of experience with the maintenance and operation of BMT-3 as an external floating roof tank. Converting BMT-4 to the same external floating roof configuration as BMT-3 and BMT-2 simplifies tank operation and maintenance.

This change may well trigger permitting of the replacement tank to complete the project.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternatives, B, C, and D are examined below as alternatives A, B, and C, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative

Assumptions & Constraints

- Bryan Mound is located in a TCEQ/EPA designated severe ozone non-attainment Area.
- Crude Oil Tank BMT-4 cannot be used to stage crude oil deliveries in its current condition.
- Demolition of the damaged roof on BMT-4 must be addressed to either restore the tank to service or to complete taking the tank out of service.
- BMT-4 is assumed to be in good working condition with the exception of the roof such that the tank can be retrofit with an external floating roof and returned to crude oil service in quick order with only minor tank wall and floor repairs.
- Sufficient plot space for installation of a replacement of BMT-4 in a location other than where it is located is not available.
- The BMT-4 tank pad is assumed to be in good working condition to continue operation of BMT-4 or a replacement tank in the current tank location.
- The lessons learned in returning BMT-3 to service as an external floating roof tank for storage of crude oil apply to BMT-4.
- Crude Oil Tank BMT-4 merits refurbishment despite its location in the collapsed zone of Cavern Number 3.
- The system must continue to meet current and revised emission reduction requirements with Best Available Control Technology (BACT) specified by the TCEQ & EPA for a non-attainment area.
- BMT-4 use will be restricted to storage of crude oils of less than 11.0 psia true vapor pressure at maximum tank temperatures such that installation of the equivalent of an internal floating roof is sufficient for fugitive tank emissions control.
- Current on-site practices for vapor pressure management will allow Bryan Mound to abide the 11.0 psia true vapor pressure limit for storage of crude oils in BMT-4.
- Tank modifications and installation of additional tank emissions controls must provide Crude Oil Tank system reliability of 95% or greater.
- Conversion of an external floating roof tank to an internal floating roof tank is most easily accomplished by installing a lightweight aluminum geodesic domed roof on the tank while the tank is in service.
- The modification of an external floating roof to eliminate roof/deck drains and other non-essential roof features reduces floating roof maintenance and may increase working capacity of the existing storage tank following conversion to an internal floating roof tank.
- Removing the secondary rim seals from the external floating roof once the tank is covered with a domed roof will increase the working capacity of the Crude Oil Tank.
- Replacing the external floating roof tank altogether with a new, slim profile, lightweight aluminum internal floating roof under a domed roof will increase the working capacity of the Crude Oil Tank further than modification of the seals would provide.
- Increasing the working of Crude Oil Tank BMT-4 is of no economic value to the Bryan Mound site at present.

- Modifications to BMT-4 will accommodate a design fill rate of 240,000 barrels per day off the pumps to satisfy the Level I cavern fill criterion of 225,000 barrels per day maximum fill rate.
- Tank modification must provide tank system reliability of 95% or greater.
- A Permit By Rule must be obtained from TCEQ prior to the conversion of BMT-4 to an External Floating Roof Tank with primary and secondary seals. Allow two months in the project schedule for FFPO Environmental to prepare the air permit application (after 100% tank design has been finalized) and for TCEQ to issue the Permit By Rule.
- A new permit will be required for the replacement of BMT-4 with a new tank.

A. External Floating Roof

Bryan Mound will convert Crude Oil Tank BMT-4 to an external floating roof tank for crude oil service.

Benefits & Effectiveness

Bryan Mound would be able to restore BMT-4 to crude oil service by permit by rule while restricting service to crude oil of less than 11.0 psia true vapor pressure. Bryan Mound would satisfy the Level I Performance Criterion of 225,000 barrels per day cavern fill.

Risk & Mitigation Factors

There are associated risks with the removal of the existing failed internal roof and installation of an external floating roof. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for External Floating Roof

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Tank requires more extensive repair than expected.	Isolate, clean and clear the tank for inspections at the earliest opportunity. Conduct thorough inspections to confirm the scope of repairs to the tank walls and floor to repair the tank.	Medium - High	Medium Risk Hazard
BMT-4 is located in the collapse zone of Cavern Number 3.	Quantify the risk to future BMT-4 investment and operation prior to finalizing the project scope to make an informed project go/no-go decision.	Medium - Medium	Medium Risk Hazard
External floating roof availability/delivery .	Select and work with tank vendor to design and procure external floating roof upon project funding to avoid delays with delivery.	Low - Low	Low Risk Hazard
Extended schedule outage to retrofit tank.	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - High	Low Risk Hazard
Delays in tank conversion to internal floating roof configuration.	Develop thorough demolition plan with schedule for the removal of the existing failed internal floating roof.	Medium - High	Medium Risk Hazard
SPR reinterprets tank emissions applicability to current and future operations with respect to true vapor pressure of crude.	Validate current interpretation and compliance with TCEQ tank regulations with ongoing operations. Proceed with next tank upgrade to install vent to control BACT with permit modification if required.	High - High	High Risk Hazard
EPA revises tank emissions standards for severe ozone non-attainment areas.	Monitor EPA requirements for compliance with operation in severe ozone nonattainment areas to address new service requirements as they arise. Alternatively, consider internal floating roof design in place of external floating roof design in anticipation of likely changes in EPA requirements to minimize future investment costs.	High - High	High Risk Hazard
Delays and cost over-runs in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays and associated cost over-runs with permitting activities.	Medium - High	Medium Risk Hazard
Safety incidents during demolition of existing tank roof.	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard
Safety incidents during installation of new tank roof	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

B. Domed Internal Floating Roof

Bryan Mound will convert Crude Oil Tank BMT-4 to a domed internal floating roof tank for crude oil service.

Benefits & Effectiveness

Bryan Mound would be able to restore BMT-4 to crude oil service by permit by rule while restricting service to crude oil of less than 11.0 psia true vapor pressure. The weather shielding afforded by the domed roof will improve operational reliability, reduce fugitive emissions, eliminate the potential for accidental hydrocarbon releases, and lay the ground work for future upgrade of BMT-4 to handle higher vapor pressure crude oil. Bryan Mound would satisfy the Level I Performance Criterion of 225,000 barrels per day cavern fill.

Risk & Mitigation Factors

There are associated risks with the removal of the existing failed internal roof and installation of an external floating roof. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for External Floating Roof

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Tank requires more extensive repair than expected.	Isolate, clean and clear the tank for inspections at the earliest opportunity. Conduct thorough inspections to confirm the scope of repairs to the tank walls and floor to repair the tank.	Medium - High	Medium Risk Hazard
BMT-4 is located in the collapse zone of Cavern Number 3.	Quantify the risk to future BMT-4 investment and operation prior to finalizing the project scope to make an informed project go/no-go decision.	Medium - Medium	Medium Risk Hazard
Internal floating roof availability/delivery	Select and work with tank vendor to design and procure external floating roof upon project funding to avoid delays with delivery.	Low - Low	Low Risk Hazard
Plot space limited for onsite construction of domed roof.	Work up the roof construction and lift plans early on in the project to establish and identify the staging area needed to build the domed roof and lift it into place.	High - Medium	Medium Risk Hazard
Extended schedule outage to retrofit tank.	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - High	Low Risk Hazard
Delays in tank conversion to internal floating roof configuration.	Develop thorough demolition plan with schedule for the removal of the existing failed internal floating roof.	Medium - High	Medium Risk Hazard
SPR reinterprets tank emissions applicability to current and future operations with respect to true vapor pressure of crude.	Validate current interpretation and compliance with TCEQ tank regulations with ongoing operations. Proceed with next tank upgrade to install vent to control BACT with permit modification if required.	High - High	High Risk Hazard
EPA revises tank emissions standards for severe ozone non-attainment areas.	Monitor EPA requirements for compliance with operation in severe ozone nonattainment areas to address new service requirements as they arise. Trigger next upgrade to add vent to control capability if/when required.	High - Medium	Medium Risk Hazard
Delays and cost over-runs in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays and associated cost over-runs with permitting activities.	Medium - High	Medium Risk Hazard
Safety incidents during demolition of existing tank roof.	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard
Safety incidents during installation of new tank roof.	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

C. New Tank with External Floating Roof

Bryan Mound will replace Crude Oil Tank BMT-4 with a new tank with external floating roof for crude oil service.

Benefits & Effectiveness

Bryan Mound would be able to demolish and rebuild BMT-4 for crude oil service by permit by rule while restricting service to crude oil of less than 11.0 psia true vapor pressure. Bryan Mound would satisfy the Level I Performance Criterion of 225,000 barrels per day cavern fill.

Risk & Mitigation Factors

There are associated risks with replacement in kind of BMT-4 with upgrade to external floating roof. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for New Tank with External Floating Roof

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Existing BMT-4 tank is amenable to repairs at a reasonable cost.	Isolate, clean and clear the tank for inspections at the earliest opportunity. Conduct thorough inspections to confirm what it takes to repair the existing tank and return it to service if that is possible.	Medium - High	Medium Risk Hazard
Tank pad requires more extensive repair than expected.	Inspect tank pad at the earliest opportunity following demolition of the existing tank. Conduct thorough inspections to confirm the scope of pad repairs and sealing of tank floor remnants to build new tank on same pad.	Medium - High	Medium Risk Hazard
BMT-4 is located in the collapse zone of Cavern Number 3.	Quantify the risk to future BMT-4 investment and operation prior to finalizing the project scope to make an informed project go/no-go decision.	Medium - Medium	Medium Risk Hazard
External floating roof availability/delivery .	Select and work with tank vendor to design and procure external floating roof upon project funding to avoid delays with delivery.	Low - Low	Low Risk Hazard
Extended schedule outage to demolish existing tank and build new tank on existing pad.	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - High	Low Risk Hazard
SPR reinterprets tank emissions applicability to current and future operations with respect to true vapor pressure of crude.	Validate current interpretation and compliance with TCEQ tank regulations with ongoing operations. Proceed with next tank upgrade to install vent to control BACT with permit modification if required.	High - High	High Risk Hazard
EPA revises tank emissions standards for severe ozone non-attainment areas.	Monitor EPA requirements for compliance with operation in severe ozone nonattainment areas to address new service requirements as they arise. Alternatively, consider internal floating roof design in place of external floating roof design in anticipation of likely changes in EPA requirements to minimize future investment costs.	High - High	High Risk Hazard
Delays and cost over-runs in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays and associated cost over-runs with permitting activities.	Medium - High	Medium Risk Hazard
Safety incidents during demolition of existing tank roof.	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard
Safety incidents during installation of new tank roof.	Adhere to project safety guidelines in accord with Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. External Floating Roof

This alternative will convert BMT-4 to a new external floating roof for crude oil service.

B. Domed Internal Floating Roof

This alternative will convert BMT-4 to a domed internal floating roof tank for crude oil service.

C. New Tank with External Floating Roof

This alternative will demolish and replace BMT-4 with an external floating roof tank on the same tank foundation.

Comparison of Alternatives

Core Team Member Ratings

	Safety During Construction	**Ease of Operations**	**Ease of Maintenance**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Less Important*
Alternative A	*Good*	*Good*	*Good*	*Excellent*
	Excellent	*Excellent*	*Adequate*	*Excellent*
	Excellent	*Excellent*	*Good*	*Excellent*
Alternative B	*Good*	*Excellent*	*Good*	*Excellent*
	Excellent	*Good*	*Adequate*	*Excellent*
	Excellent	*Adequate*	*Adequate*	*Excellent*
Alternative C	*Good*	*Excellent*	*Good*	*Excellent*
	Good	*Excellent*	*Good*	*Good*
	Good	*Excellent*	*Good*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$10,983,665**	**$13,013,868**
Alternative B	**$9,422,335**	**$10,143,671**
Alternative C	**$27,342,268**	**$29,355,478**

BM-MM-1171

Replace Microwave Security System at CO Transfer Pumps

VCI Project Engineer: Corb Elsbury

Recommended Alternative:

Microwave Sensor (UltraWave)

Analysis of Alternatives
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US Department of Energy
Strategic Petroleum Reserve

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Recommended Alternative 9

I. PROJECT CONCEPT

Mission Need

The security system for the Bryan Mound crude oil (CO) transfer pumps currently relies on an exterior bistatic microwave sensor system as part of the Intrusion Detection System (IDS) which utilizes microwave sensors that were installed approximately fifteen (15) years ago. The objective is to provide the latest generation technology to incorporate into the assessment and IDS on-site. Therefore, replacing the current microwave sensing system with a system that corresponds with the latest technology and integrates with the on-site security systems is needed.

Functional Requirements

Meet The general requirements of the project are to meet DOE security parameters, ensure functionality of design (used as intrusion deterrent as intended), and provide a more reasonably maintainable system. The following are functional requirements for perimeter security detection on the SPR sites:

- Intrusion detection and assessment systems must function effectively in all environmental conditions and under all types of lighting conditions.
- Intrusion Detection Systems (IDS) alarms used for the protection of the SPR must be capable of immediate investigation by the Protection Force (PF), Central Alarm Station (CAS), and/or personnel via Closed Circuit Television (CCTV).
- Exterior IDS must be designed, where economically feasible, with independent redundant data communication paths for protecting DOE SPR interests. The conductors of the redundant data paths must not be installed in the same conduit, cable tray, or duct bank.
- The IDS system must be compatible with the existing Alarm Display and Annunciation System (ADAS) at the site. Close coordination with the ADAS system integrator is required. It is understood that upgrades to the ADAS system may be required.
- The IDS must be capable of being operated and maintained to ensure that the number of false and nuisance alarms do not reduce the effectiveness of the system, while meeting the nuisance alarm rates described in DOE Order 473.3 A., each exterior intrusion detection sensor should not have a false or nuisance alarm rate of more than one alarm per 24 hours of operation.
- The IDS must be capable of detecting, with a probability of 90 percent and confidence level of 95 percent, an individual crossing the detection zone by walking, crawling, jumping, running, rolling, or climbing at any point in the detection zone.
- The system must deter adversaries from circumventing the detection system.
- The IDS must cover the entire perimeter without any gaps in detection, including the sides and tops of structures.
- The system must be located in such a manner that the length of each detection zone is consistent with the characteristics of the sensors used in that zone and the topography.
- The length of each detection zone must be within the optimal performance range of the sensor system and CCTV system.
- The system must be free of wires, piping, poles, and similar objects that could be used to assist an intruder traversing the isolation zone or that could assist in the undetected ingress or egress of an adversary or matter.
- An isolation zone must be at least 20 feet (6 meters) wide and clear of fabricated or natural objects that would interfere with operation of the detection systems or effective assessment.
- The system must incorporate a stabilized apron of ~3’ on both sides of perimeter fencing to deter rodent burrows and rain erosion underneath the existing fencing.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Corb Elsbury	VCI, Project Engineer
Marc Gross	FFPO, Manager Design Engineering

Team Members

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III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. Ability to address Safety and Security concerns during implementation. Safety is of the greatest importance.

Weight: Most Important

Security during Construction

The selected alternative when implemented will be able to be constructed with minimal to zero impacts to Site Security detection systems. The Site Security Specialist shall coordinate with the site leadership and contractor to accommodate for down time to particular assessment systems during construction.

Weight: Most Important

Constructability during On-going Oil Deliveries

The selected alternative is able to be implemented with little or no impact to on-going oil delivery operations. Close coordination with the Site Security Specialist and site/maintenance operations will allow for minimal impact on oil delivery operations.

Weight: Less Important

Sustainability

The selected alternative when implemented will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. Energy consumption shall be considered in all upgraded equipment criteria.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative

A. Status Quo

Allow the current microwave sensors to remain in place and continue to repair current sensor system as needed. Continuing to use/rely on the outdated microwave sensor system is not a viable option; the manufacturer of the existing system is no longer in business and repair parts are increasingly difficult to procure, causing potential challenges for the PF to plan for compensatory activity during system outages.

Viability: No Further Analysis

B. FlexZone w/Chain Link Fencing

Replace the current microwave sensor system at the CO transfer pumps with the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (FlexZone vendor suggested product replacement for Intelli-Flex) and or an approved equal along with the associated software packages. Install a chain link fence with razor wire on dual outriggers atop fencing around the crude oil transfer pumps pad.

Viability: Continue Analysis

C. Replace with Microwave Sensor System

Replace the existing microwave sensor system with the latest generation of exterior microwave sensor system at the CO transfer pumps using bistatic microwave technology such as Senstar UltraWave or approved equal.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternatives, B and C are examined below as alternatives A and B, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

A. FlexZone w/Chain Link Fence

Replace the microwave sensor system at the CO transfer pumps with the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (FlexZone vendor suggested product replacement for Intelli-Flex) or an approved equal along with the associated software packages. Install a chain link fence (~408') around the crude oil pump pad.

FlexZone is Senstar's latest generation ranging fence-mounted sensor. FlexZone detects and locates any attempt to cut, climb or otherwise break through the fence. It accurately locates intrusions even when there are multiple simultaneous intrusions and in the presence of background environmental noise.

FlexZone can detect and locate perimeter intrusions over a distance of up to 1,968 feet per sensor processor, and within 10 feet of accuracy. One processor can support up to 60 distinct, customizable zones. Both power and data can run over the sensor cables, minimizing infrastructure requirements. Advanced Digital Signal Processing (DSP) enables FlexZone to adapt to a wide variety of fence types to include traditional chain-link fence. Networking capability for remote configurations and alarm reporting is available and the product works reliably in the harsh environments. The FlexZone alternative requires an upgrade of the Alarm Information Management (AIM) installed in the CAS. Current FlexZone warranties provide for a minimum of 2 years from installation and the manufacturer ensures replacement parts are available for a minimum of 10 years from purchase. Training of operators and maintenance personnel on calibration and system maintenance is provided.

Install new, galvanized before weave (GBW) chain-link fencing fabric and posts. Raise fencing in areas affected by consistent flooding and install ~6' (~3' on either side of outer perimeter fence bottom) of aggregate or concrete under fencing system to reduce erosion, deter rodents/animals, control weeds and obscuration, and support the overall Perimeter Security Detection System (PSDS). The installation of concrete or aggregate under the fence will alleviate grass cutters from getting near the fence and prevent weed control chemicals from degrading the sensor tie material, resulting in sagging sensor cables as these ties break. Install razor wire atop the fencing on dual outriggers.

Assumptions & Constraints

Assumptions:

- Replacing the existing system with the same manufacturer used on site (Senstar) ensures similar processes with regard to training, maintenance and repair parts.

Constraints:

- Requires fence and gate installation at the crude oil transfer pump site.
- Adds an additional gate entry procedure.

Benefits & Effectiveness

Replacing the current CO transfer pump microwave sensor system with FlexZone and chain link fencing or an approved equal will allow for improved security measures and will meet the requirements described in DOE 473.3 A. Replacement of the microwave sensor system will allow for expedited response and deterrence of unauthorized entry to the CO transfer pumps. The items below summarize the benefits/effectiveness and mission need items of replacing this portion of the IDS on-site.

- Familiar, new equipment and software will provide for improved maintenance and significantly enhanced performance (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Allows for increased security measures on site, providing optimal security protection at the CO pump pad (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][2]).
- FlexZone allows for precision sensitivity leveling/adjustments.
- Communications path redundancy ensures continued perimeter protection in the event of a cable cut.

- Will allow for optimal protection against ladder/pole assisted climbing intrusion once all razor ribbon on top of perimeter and critical area fencing is installed (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][1]).
- Concrete or aggregate will allow for improved erosion, animal/rodent control, weed control, and protect against potential under wire intrusion (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Replacement of the degrading and now legacy PSDS system, upgrading to a current industry standard system (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- FlexZone is noted for low power consumption.
- Optional Ethernet card with Power over Ethernet (PoE) capability.
- Sensors are calibrated with Windows-based point and click utility (over the network or locally by USB).

Risk & Mitigation Factors

Some potential risks associated with replacing the current microwave sensor system with FlexZone include additional training for employees on a new system, new entrance procedure for the crude oil transfer pumps, and potential safety issues while updating and installing equipment. The table below summarizes the mentioned risks with a correlating mitigation strategy. The table below describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for FlexZone w/Chain Link Fence

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Reduced security posture during construction.	Close coordination between NOLA, site security, and contractor work's scheduling and sequencing.	Medium - Low	Low Risk Hazard
May requires training on the new system.	Minimize the length of training by making the training comprehensive, hands-on, and repetitive. FlexZone is similar to Intelli-Flex, minimum learning curve.	Medium - Low	Low Risk Hazard
Potential safety hazards involved when updating or installing equipment on-site.	The contractors shall prepare a Job Hazard Analysis, and the site shall brief employees near the system update or installation.	Low - Low	Low Risk Hazard
Additional gate entrance procedure for entering the crude oil transfer pumps.	Train all employees on new procedure.	High - Low	Low Risk Hazard

B. Microwave Sensor (UltraWave)

Replace the existing microwave sensor system (4 pr. – Tx/Rx) at the crude oil transfer pumps with the latest-generation of exterior bistatic microwave technology such as UltraWave or approved equal.

Install Senstar UltraWave newest generation of volumetric perimeter intrusion detection system consisting of an all-digital transmitter and receiver that create an invisible detection zone. UltraWave works reliably in extreme environments and provides networking for remote alarm reporting and configuration common to other Senstar sensors (Intelli-Flex and FlexZone). Transmitters and receivers can be located up to 656' apart. They are post-mounted and installed facing each other to form a cylindrical zone of detection where signals create an invisible pattern of microwave energy. A microprocessor and digital signal processor (DSP) algorithms distinguish background environmental effects from the unique signatures of intruders walking, running or crawling. Ten (10) selectable frequency channels enable multiple units to operate in close proximity without mutual interference, including stacking multiple units on a common mounting post. Intruders are reliably detected night or day regardless of weather conditions.

Assumptions & Constraints

- The existing system will be replaced by a similar, but updated microwave sensor system.
- This will also require an upgrade of the Alarm Information Management (AIM) installed in the CAS.
- Requires replacement of current cabling from old sensor system.

Benefits & Effectiveness

Replacing the current CO transfer pump microwave sensing system with UltraWave or an approved equal will allow for improved security measures and will best meet the requirements described in DOE 473.3 A. Replacement of the microwave sensor system will allow for expedited response and deterrence of unauthorized entry to the CO transfer pumps. The items below summarize the benefits/effectiveness and mission need items of replacing this portion of the IDS on-site.

- New equipment and software will provide for improved maintenance and significantly enhanced performance (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Allows for optimal security measures on-site, by providing optimal security protection due to updated technology (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Low nuisance alarms rates (NAR) and high probability of detection (Pd); greater than 99% when properly installed; specific detection ranges include walking target: (16 to 656 ft.), crawling target: (16 to 492 ft.) and Commando roll: (16 to 328 ft.).
- Replacement of the degrading and now obsolete sensor system will bring Bryan Mound to a current industry standard system (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][2]).
- Automatic Gain Control (AGC), automatically adjusts to varying path loss due to Transmit/Receive (Tx-Rx) separation, surrounding conditions and weather.
- Allows for an effective preventive maintenance program due to a reliable source of repair parts (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- System consists of an all-digital transmitter and receiver; sensors lengths from 15' to 600' apart and stackable if needed (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Optional Ethernet card with Power of Ethernet (PoE).
- Designed and manufactured for harsh outdoor environments; provides for its own lightning protection.

Risk & Mitigation Factors

Some potential risks associated with replacing the current microwave sensor system with UltraWave includes additional security measures during construction, training employees on a new system, and

potential safety issues while updating and installing equipment. The table below summarizes the mentioned risks with a correlating mitigation strategy. The table below describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Microwave Sensor (UltraWave)

Risks	Mitigation Strategy	Likelihood - Impact	Impact
Reduced security posture during construction.	Close coordination between NOLA, site security, and contractor work's scheduling and sequencing.	High - Low	Low Risk Hazard
Requires new equipment training.	Minimize the length of training by making the training comprehensive, hands-on, and repetitive.	High - Low	Low Risk Hazard
Potential safety hazards involved when updating or installing equipment on-site.	The contractors shall prepare a Job Hazard Analysis, and the site shall brief employees near the system update or installation.	Low - Low	Low Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. FlexZone w/Chain Link Fencing

Replace the microwave security system at the CO transfer pumps with the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (FlexZone vendor suggested product replacement for Intelli-Flex) or an approved equal along with the associated software packages. Install chain link fencing with razor wire atop fencing on dual outriggers.

B. Microwave Sensor (UltraWave)

Replace the existing microwave sensor system with the latest generation microwave sensor system at the CO transfer pumps with bistatic microwave sensor technology such as Senstar UltraWave or approved equal.

Comparison of Alternatives

Core Team Member Ratings

	Ease of Operations	**Ease of Maintenance**	**Safety During Construction**	**Security During Construction**	**Constructability During Ongoing Oil Deliveries**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Less Important*	*Less Important*
Alternative A	*Good*	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Good	*Excellent*	*Excellent*	*Excellent*	*Good*	*Excellent*
	Good	*Good*	*Excellent*	*Excellent*	*Excellent*	*Good*
Alternative B	*Good*	*Good*	*Excellent*	*Good*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$410,225**	**$433,855**
Alternative B	**$424,970**	**$448,600**

Recommended Alternative

B. Microwave Sensor (UltraWave)

Based on the technical evaluation of the Core Team Members, Alternative B was overall rated higher than Alternative A. The initial cost and life cycle cost of Alternatives A and B were essentially the same by comparison. Therefore, Alternative B is the recommended preferred alternative based on technical evaluation merits with cost factors that essentially provided no differentiation between alternatives.

BM-MM-1340

Replace Perimeter Security Detection Systems

VCI Project Engineer: Corb Elsbury

Recommended Alternative:

FlexZone

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

Perimeter Security is provided at SPR sites to prevent undetected intrusion to the site facilities. This project is intended to provide a more reliable and maintainable intrusion detection system to replace the current aging system. The existing Bryan Mound Perimeter Security Detection System (PSDS) consists of ~16,000 feet Fiber Optic Intelligence Detection System (FOIDS), Infrared Perimeter Intrusion Detection (IPID), taut-wire, and traditional chain-link fencing.

Functional Requirements

The general requirements of the project are to meet DOE security parameters, ensure functionality of design (used as intrusion deterrent as intended), and provide a more reasonably maintainable system. The following are functional requirements for perimeter security detection on the SPR sites:

- Intrusion detection and assessment systems must function effectively in all environmental conditions and under all types of lighting conditions.
- Intrusion Detection Systems (IDS) alarms used for the protection of the SPR must be capable of immediate investigation by the Protection Force (PF), Central Alarm Station (CAS), and/or personnel via Closed Circuit Television (CCTV).
- Exterior IDS must be designed, where economically feasible, with independent redundant data communication paths for protecting DOE SPR interests. The conductors of the redundant data paths must not be installed in the same conduit, cable tray, or duct bank.
- The IDS system must be compatible with the existing Alarm Display and Annunciation System (ADAS) at the site. Close coordination with the ADAS system integrator is required. It is understood that upgrades to the ADAS system may be required.
- The IDS must be capable of being operated and maintained to ensure that the number of false and nuisance alarms do not reduce the effectiveness of the system, while meeting the nuisance alarm rates described in DOE Order 473.3 A.; each exterior intrusion detection sensor should not have a false or nuisance alarm rate of more than one alarm per 24 hours of operation.
- The IDS must be capable of detecting, with a probability of 90 percent and confidence level of 95 percent, an individual crossing the detection zone by walking, crawling, jumping, running, rolling, or climbing at any point in the detection zone.
- The system must deter adversaries from circumventing the detection system.
- The IDS must cover the entire perimeter without any gaps in detection, including the sides and tops of structures.
- The system must be located in such a manner that the length of each detection zone is consistent with the characteristics of the sensors used in that zone and the topography.
- The length of each detection zone must be within the optimal performance range of the sensor system.
- The system must be free of wires, piping, poles, and similar objects that could be used to assist an intruder traversing the isolation zone or that could assist in the undetected ingress or egress of an adversary or matter.
- An isolation zone must be at least 20 feet (6 meters) wide and clear of fabricated or natural objects that would interfere with operation of the detection systems or effective assessment.
- The system must incorporate a stabilized apron of ~3 feet on both sides of perimeter fencing to deter rodent burrows and rain erosion underneath the existing fencing.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Corb Elsbury	VCI, Project Engineer
Marc Gross	FFPO, Manager Design Engineering

Team Members

Patrick Shepherd	DOE, Project Engineer
Jerry Packard	DOE, Security Officer
Bryan Dunlap	DOE, Physical Security Specialist
Jorge Aguinaga	DOE, Lead General Engineer
Chase Carruthers	DOE, General Engineer
Rachel Gray	VCI, Process Engineer
Ron Johnson	FFPO, Sr. Director Security & Emergency Prep
Thomas Guillory	FFPO, Manager Protection & Physical Security
Kenneth Marino	FFPO, Manager Plans & Exercises
Todd Demaris	FFPO, Sr. Protection Physical Security
Randy Bridges	FFPO, Process & Security Systems Control
Michael Sickmiller	FFPO, Director of Site
Damus Vice	FFPO, Site Security Specialist
Mike Cabiran	FFPO, Sr. Site Maintenance Engineer
Dennis Henderson	FFPO, Manager Site Operations
Timothy Kelley	FFPO, Manager Site Construction
Joseph Mravunich	FFPO, Manager Site Maintenance

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Constructability During On-Going Oil Deliveries

The selected alternative is able to be implemented with little or no impact to on-going oil delivery operations. Close coordination with the Site Security Specialist and site/maintenance operations will allow for minimal impact on oil delivery operations.

Weight: Most Important

Ease of Operations

The selected alternative when implemented, will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. Upgrades to existing technology and equipment will allow for optimal operation, as the planned systems shall employ ease of instruction and operation; procurement will include a robust training package.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment, resulting in commonality of similar systems for future maintenance and sparing consideration. Maintenance operations will require less attention as new equipment replaces legacy equipment; all new equipment shall come with a service warranty.

Weight: Most Important

Safety During Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. The ability to address Safety and Security concerns during implementation. Safety is of the greatest importance.

Weight: Most Important

Security During Construction

The selected alternative when implemented will be able to be constructed with minimal to zero impacts to site security detection systems, as the Site Security Specialist shall coordinate to accommodate for down time to particular assessment systems during construction.

Weight: Most Important

Sustainability

The selected alternative when implemented will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. Energy consumption shall be considered in all upgraded equipment criteria.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

Allow the current PSDS system to remain in place and continue to repair as needed. Performance of the FOIDS perimeter detection system is ineffective, experiences high nuisance alarm rates, and is difficult to maintain. FOIDS is secured to the perimeter fencing that is consistently under water or highly prone to flooding in multiple detection zones; consequently, the fencing and supports are rusted and sagging which also contributes to nuisance alarms. The existing Infrared Perimeter Intrusion Detection System (IPID) is experiencing very high nuisance alarm rates, requiring constant attention. Continuing to use/rely on the current PSDS will result in continuation of demanding maintenance efforts and obsolescence; all possibly resulting in undetected intrusion.

Viability: No Further Analysis

B. FlexZone w/Chain Link Fencing

Replace with a single sensor system consisting of the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (Senstar suggested product replacement for Intelli-Flex) and IPIDS or an approved equal with associated software packages. Stabilize the fence to reduce erosion, deter rodents/animals, control weeds in support the PSDS. Replace fencing and posts where degradation has occurred; replace all barbed wire atop fencing with razor wire on dual outriggers.

Viability: Continue Analysis

C. REDSCAN

REDSCAN is an analog system that can be pole or building mounted to provide an infrared laser wall that is installed inside the perimeter fence. The laser watches the fence area and monitors for any movement. REDSCAN does not meet DOE requirements as a standalone system for climbing, cutting, and bridging, as additional perimeter detection systems must be incorporated to meet functional requirements; REDSCAN vertical detection applications are in test stages. The REDSCAN alternative does not accomplish a single system install solution such as Intelli-Flex or its approved equal.

Viability: No Further Analysis

D. AgilFence

AgilFence uses advanced fiber optic, fence mounted sensors. Sensors are embedded in the optical fiber cable to form an array of sensors for perimeter fence intrusion detection. These extremely responsive sensors are used to detect incidents in various scenarios. A slight disturbance to the physical perimeter will trigger a response in the nearest optical fiber sensor that translates to an intrusion alert. This alternative requires replacing the current traditional chain-link fence in its entirety. Comparatively, one of the reasons for the warranted FOIDS replacement is due to fiber cable rodent damage, specifically to fiber cable in cable trays and along fencing. Used in Southeast Asia and Eastern Europe, AgilFence is not used in the U.S. to date.

Viability: No Further Analysis

E. IMPASSE II w/FlexZone

Replace the current components of the PSDS system (FOIDS, IPID and fencing) with a combination of FlexZone and Impasse II. Impasse II is a steel palisade fence with an installed internal raceway for detection sensor systems, video cabling and arresting cables. Stabilize the fencing system to reduce erosion, deter rodents/animals, weed control in support the PSDS.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternatives A, C, and D are eliminated from further consideration. The remaining alternatives, B and E are examined below as alternatives A and B, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comp.

A. FlexZone with Chain Link Fencing

The Bryan Mound perimeter intrusion is experiencing obsolescence and maintenance related issues. Installed ~2002 and ~1997 respectively, the existing fiber optic detection system and infrared perimeter intrusion detection is not meeting the requirements of DOE 437.3 A. High nuisance alarm rates, maintenance difficulties, weather effects and overall performance requires immediate attention. FlexZone provides an alternative to address mentioned shortcomings of the Bryan Mound PSDS, but also introduces a system very much like other systems used across the SPR. FlexZone is the manufacturer suggested replacement of the currently used Intelli-Flex; Intelli-Flex is now a legacy system and soon will be phased completely out from the Senstar inventory (correspondence Dated 23 December 2014).

Replacing the existing perimeter detection system (~19,000') with the latest-generation of a fence-mounted microphonic fence disturbance sensor system such as FlexZone or an approved equal with associated software retains the proven performance of the current Intelli-Flex while introducing a similar system. Replacing the existing IPID (~2) with an ECSI International, Inc. product or approved equal shall address the aging and faulty IPID system. New equipment fielding and training, maintenance, and overall performance is similar and therefore provides a substantial advantage when associated with ease of operation/maintenance.

FlexZone is Senstar's latest generation ranging fence-mounted sensor. FlexZone detects and locates any attempt to cut, climb or otherwise break through the fence. It accurately locates intrusions even when there are multiple simultaneous intrusions and in the presence of background environmental noise.

FlexZone can detect and locate perimeter intrusions over a distance of up to 1,968 feet per sensor processor, and within 10 feet of accuracy. One processor can support up to 60 distinct, customizable zones. Both power and data can run over the sensor cables, minimizing infrastructure requirements. Advanced Digital Signal Processing (DSP) enables FlexZone to adapt to a wide variety of fence types including traditional chain-link fence currently in place on the site. Networking capability for remote configurations and alarm reporting is available and the product works reliably in the harsh environments. Current FlexZone warranties provide for a minimum of 2 years from installation and the manufacturer ensures replacement parts are available for a minimum of 10 years from purchase. Training of operators and maintenance personnel on calibration and system maintenance is provided.

The Architectural IPID system from ESCI International, Inc. provides a dependable security barrier of pulsed infrared technology to create multiple detection zones, each with a range of up to 1000 feet. Solid state electronics are not affected by environmental conditions such as birds, small animals, puddles, leaves, grass or mechanical vibrations. It works in rain and fog instantly pinpointing the intrusion zone via normally opened or closed dry contacts that can be interfaced with any annunciator or data communication system. IPID does not false alarm. The system will only alarm if an object breaks the 3.54" diameter beam more than 98.5%. Easy to use, extremely low nuisance alarm rates and widely used by Government entities, the product is accompanied by a 10-year warranty.

The fencing on the site consists of traditional chain-link fence that has experienced degradation due to sag and rusting from the salt/humid environment over the past 20+ years. Many sections of the fence have been subjected to flooding subsequently contributing to rust damaged fence posts and fabric. As fencing and gates are replaced, particular attention should be paid to the existing (~36) Balanced Magnetic Sensors (BMS) on gates. Replace the BMS as necessary to address HQ DOE findings 2015 of correcting deficiencies regarding to a lack of end of line sensors.

This alternative shall replace all fencing and posts (~19,000') with new, galvanized before weave (GBW) chain-link fencing fabric and posts. It shall also raise fencing in areas affected by consistent flooding and install ~6' (~3' on either side of outer perimeter fence bottom) of aggregate or concrete under fencing system to reduce erosion, deter rodents/animals, control weeds and obscuration, and support the overall Perimeter Security Detection System (PSDS). The installation of concrete or aggregate under the fence will alleviate grass cutters from getting near the fence and prevent weed control chemicals from degrading the sensor tie material, resulting in sagging sensor cables as these ties break. Replace all barbed wire with razor wire mounted on dual outriggers atop all perimeter fencing and critical area fencing (~ 19,400').

In an attempt to reduce sagging over time, remove unused gates (~1) on the outer perimeter and any unused obsolete taut-wire systems on site.

Assumptions & Constraints

Assumptions:

- FlexZone and fencing replacement includes main site, Raw Water Intake Structure and required pump pads.
- Work requires minor adjustments to an already existing DOE approved Task Specification (Intelli-Flex).
- Most, if not all fencing shall be replaced.

Constraints:

- Protection Force (PF) compensatory involvement during construction.
- Chain-link fencing is not considered adequate security to meet today's asymmetric threats.

Benefits & Effectiveness

Replacing the PSDS system will allow for improved security measures on site, which is more cost effective and best meets requirements described in DOE 473.3 A. Repairs to the fencing system and replacements of sensors will allow for expedited response and deterrence of unauthorized entry on site. The items below summarize the benefits/effectiveness and mission need items addressed by replacing the existing PSDS on site with FlexZone.

- Familiar, new equipment and software will provide for improved maintenance and significantly enhanced performance (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Allows for increased security measures on site, providing optimal security protection (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][2]).
- FlexZone allows for precision sensitivity leveling/adjustments.
- Removes unserviceable fencing where degradation has occurred (DOE 473.3 A., Attachment 3, Section A 3-45 [3][b][2]).
- Communications path redundancy ensures continued perimeter protection in the event of a cable cut.
- Provides better fencing in areas affected by consistent flooding (DOE 473.3 A., Attachment 3, Section A 3-45 [3][b][2]).
- Prevent access onto site through removal of un-used gates, further strengthens security measures (DOE 473.3 A., Attachment 3, Section A 3-44 [2][a][1]).
- Will allow for better protection against ladder/pole assisted climbing intrusion once all razor ribbon on top of perimeter and critical area fencing is installed (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][1]).
- Concrete or aggregate will allow for better erosion, animal/rodent control, weed control and protect against potential under wire intrusion (DOE 473.3 A., Attachment 3, Section A 3-44 [2][a][1]).
- Replacement of the degrading and now legacy PSDS system, upgrading to a current industry standard system (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- FlexZone is noted for low power consumption.
- Optional Ethernet card with Power over Ethernet (PoE) capability.
- Sensors are calibrated with Windows-based point and click utility (over the network or locally by USB).

Risk & Mitigation Factors

Some potential risks associated with replacing the current PSDS with FlexZone include potentially reduced security posture during construction, training employees on a new system, and potential safety issues while updating and installing equipment. The table below summarizes mentioned risks with a correlating

mitigation strategy. The table describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for FlexZone with Chain-Link Fencing

Risks	Mitigation Strategy	Likelihood – Impact	Risk Code
Reduced security posture during construction.	Close coordination between NOLA, site security and contractor work scheduling and sequence.	High - High	High Risk Hazard
Will require training on the new system.	Minimize the length of training by making the training comprehensive, hands on and repetitive.	Medium - Low	Low Risk Hazard
Potential safety hazards involved when updating or installing equipment on site.	The contractors shall prepare a Job Hazard Analysis and the site shall brief employees on site near the system update or installation.	Medium - Low	Low Risk Hazard

B. IMPASSE II with FlexZone

The Bryan Mound perimeter intrusion is experiencing obsolescence and maintenance related issues. Installed ~2002, the existing fiber optic detection system is not meeting the requirements of DOE 437.3 A. High nuisance alarm rates, maintenance difficulties, and overall performance requires immediate attention.

This alternative is a high security fence, combined with installing a new perimeter security detection system such as FlexZone or an approved equal; a single perimeter detection system, arrayed in depth by design with new IPID. A recent Fluor physical security system evaluation (dated March 2016) of the Ameristar Impasse II system yielded familiarity and an overall positive evaluation. The Impasse II is widely used for military sites, government facilities, petroleum and chemical facilities, and airports.

A high security fence, IMPASSE II, is a vertical (~8' in height), palisade steel fencing made of pre-galvanized steel, test-based to ASTM B117 standards, with tamper-proof fastenings and an installed internal raceway for detection systems, video cabling and up to 3 arresting cables. The raceway eliminates the need for any trenching, boring, fastening ties, or degradation from fence sag. The Impasse II security fence panels employ a bracketless design using tamper proof fasteners; are installed with heavier posts (I-beam); includes a 15-year warranty. The panels are constructed of heavy duty steel, eliminating fence sag. The Impasse II does not require the use of razor wire atop its fencing panels – a choice of trident, stronghold or gauntlet style options are available.

Replacing the existing perimeter detection system (~19,000') with the latest-generation of a fence-mounted microphonic fence disturbance sensor system such as FlexZone or an approved equal with associated software retains the proven performance and familiarity of the currently installed Intelli-Flex system.

The Architectural IPID system from ESCI International, Inc. provides a dependable security barrier of pulsed infrared technology to create multiple detection zones, each with a range of up to 1000 feet. Solid state electronics are not affected by environmental conditions such as birds, small animals, puddles, leaves, grass or mechanical vibrations. It works in rain and fog instantly pinpointing the intrusion zone via normally opened or closed dry contacts that can be interfaced with any annunciator or data communication system. IPID does not false alarm. The system will only alarm if an object breaks the 3.54" diameter beam more than 98.5%. Easy to use, extremely low nuisance alarm rates and widely used by Government entities, the product is accompanied by a 10-year warranty.

This alternative shall also replace all fencing and posts (~19,500') with the pre-galvanized Ameristar fencing system, Impasse II. It shall also raise areas affected by consistent flooding and install ~6' (~3' on either side of outer perimeter fence bottom) of aggregate or concrete under fencing system to reduce erosion, deter rodents/animals, control weeds and obscuration, and support the overall Perimeter Security Detection System (PSDS). As fencing and gates are replaced, particular attention should be paid to the existing (~36) Balanced Magnetic Sensors (BMS) on gates. Replace the BMS as necessary to address HQ DOE findings 2015 of correcting deficiencies regarding to a lack of end of line sensors.

The installation of concrete or aggregate under the fence will alleviate grass cutters from getting near the fence and prevent weed control chemicals from degrading the sensor tie material, resulting in sagging sensor cables as these ties break. Remove unused gates (~1) on the outer perimeter and any unused obsolete taut-wire systems on site.

Assumptions & Constraints

Assumptions:

- Impasse II and FlexZone installation includes main site, Raw Water Intake Structure and required pump pads.

Constraints:

- Protection Force compensatory activity during installation/construction.

Benefits & Effectiveness

Replacing the fencing and installing FlexZone with IMPASSE II will allow for the optimal security posture on site as described in DOE 473.3 A. This alternative of the PSDS replacement will allow for stricter deterrence of unauthorized entry and improve degrading systems. The items below summarize the benefits and effectiveness of adding the IMPASSE II as the PSDS on site.

- Will replace the degrading fence and allow for replacement of the now legacy PSDS system (DOE 473.3 A. Attachment 3, Section A 3-45 [3][b][2]).
- Allows for higher security measures on site, negates the need for razor wire and enables an improved platform for installation of a selected intrusion system (DOE 473.3 A. Attachment 3, Section A 3-44 [2][a][1]).
- Capable of being an all-inclusive PSDS system in one installation, allowing for shorter duration installation and disruption to site security posture (DOE 473.3 A., Attachment 3, Section A 3-45 [3][b][2]).
- Allows for easier detection probability calculations; versus calculating for multiple systems.
- The Impasse rail system is designed to house all peripherals required to complete a perimeter security system without the expense of trenching and boring typically used in these applications (DOE 473.3 A., Attachment 3, Section A 3-45 [3][b][2]).
- The Impasse rail can accommodate crash barrier components such as arresting cables (DOE 473.3 A., Attachment 3, Section A 3-45 [3][b][2]).
- Impasse II is made from 96% recycled steel.
- Permacoat process gives Impasse II distinct advantage over chain link fencing - a corrosion resistant, polyester top coat (test based on ASTM B117 Standard).

Risk & Mitigation Factors

With any new upgrade at the site come associated risks. Some potential risks associated with IMPASSE II on site are reduced security posture during construction, training employees on a new system, and generating potential safety issues while updating and installing equipment. The table below summarizes the above mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for IMPASSE II with FlexZone

Risks	Mitigation Strategy	Likelihood – Impact	Risk Code
Reduced security posture during construction.	Close coordination between NOLA, site security and contractor work scheduling and sequence.	Medium - High	Medium Risk Hazard
May require extensive training on a new system.	Minimize the length of training by making the training comprehensive, hands on, and repetitive.	Medium - Medium	Medium Risk Hazard
Potential safety hazards involved when updating or installing equipment on-site.	The contractors shall prepare a Job Hazard Analysis (JHA) and the site shall brief employees near the system update or installation.	Medium – Low	Low Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. FlexZone

Replace with the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (Senstar suggested product replacement for Intelli-Flex) and IPID or an approved equal with associated software packages. Stabilize under fencing with aggregate or concrete to reduce erosion, deter rodents/animals, and control weeds to support the Perimeter Security Detection System (PSDS). Replace fencing and posts where degradation has occurred. Replace barbed wire with razor wire mounted on dual outriggers on top of perimeter and critical area fencing. Remove unused gates and any obsolete taut-wire on the site.

B. IMPASSE II with FlexZone

Install the IMPASSE II, is a vertical metal, palisade fencing combined with the latest-generation of fence-mounted microphonic fence disturbance sensor systems such as Senstar FlexZone (Senstar suggested product replacement for Intelli-Flex) and IPID or an approved equal with associated software packages. Stabilize under fencing with aggregate or concrete to reduce erosion, deter rodents/animals, and control weeds to support the Perimeter Security Detection System (PSDS). Remove unused gates and any obsolete taut-wire on the site.

Comparison of Alternatives

Core Team Member Ratings

	Constructability During Ongoing Oil Deliveries	**Ease of Operations**	**Ease of Maintenance**	**Safety During Construction**	**Security During Construction**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Most Important*	*Less Important*
Alternative A	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*	*Good*	*Excellent*
	Good	*Excellent*	*Excellent*	*Excellent*	*Good*	*Good*
Alternative B	*Excellent*	*Good*	*Good*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*	*Good*	*Excellent*
	Good	*Good*	*Excellent*	*Good*	*Good*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$8,467,536**	**$8,592,148**
Alternative B	**$11,802,973**	**$11,945,613**

Recommended Alternative

A. FlexZone

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria. The initial cost and life cycle cost of Alternative A were both lowest of the alternatives. Therefore, Alternative A is the recommended preferred alternative based on both technical and cost factors studied in the alternative analysis.

BM-MM-1354

Replace Crude Oil Injection Pumps

VCI Project Engineer: Lorna Madison

Recommended Alternative:

Two New Pumps and Motors

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

Crude Oil Injection Pumps BMP-1 and BMP-4 produce insufficient head to accomplish cavern injection under all conditions, often requiring cavern to cavern transfers to generate sufficient suction pressure for the pumps to attain adequate injection pressures. The mission is to find an alternative that allows the pumps to attain adequate injection pressures to provide the required Level I fill rate into the caverns.

The Bryan Mound (BM) site is committed to provide a maximum cavern fill rate of 225,000 barrels per day by Level I Performance Criteria.

Functional Requirements

- The crude oil injection pump system must provide sufficient head to inject oil into the caverns at a Level I fill rate of 225,000 barrels per day before and after remediation.
- Pump system modifications should not compromise fill and drawdown operations and should provide installed pump system reliability of greater than or equal to 95%.
- 100% idle spare capacity is to be provided for each new or modified pump service to ensure reliability.
- Pump life should be maximized to minimize equipment and parts replacement requirements over the 25-year life ascribed to the Life Extension 2 (LE 2) projects.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Ed Orloski	VCI, Process Engineer
William Leet	VCI, Process Engineer
Rachel Gray	VCI, Process Engineer
Lisa Eldredge	FFPO, Principal Operations System Engineer
Buddy Delaune	FFPO, Principal Mechanical Engineer
Mike Cabiran	FFPO, BM Site Representative
Janet Roberts	FFPO, Director of Facilities Design & Integrity

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. The crude oil injection pumps must provide sufficient head to inject oil into the caverns at a Level I fill rate of 225,000 barrels per day before and after remediation.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely and have the ability to address safety and security concerns during implementation. Project work plans must invoke the Strategic Petroleum Reserve (SPR) protocols to establish a safe work environment for all construction related activity.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. Pump system modifications should not compromise fill and drawdown operations and should provide installed pump system reliability of greater than or equal to 95%. 100% idle spare capacity is to be provided for each new or modified pump service to ensure reliability.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve the Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

The two existing Crude Oil Injection Pumps at Bryan Mound are facing demand for increased pressure output for fill operations while approaching their end of life.

Crude Oil Injection Pumps BMP-1 and BMP-4 take suction from the discharge of the Crude Oil Transfer Pumps staged in series to take suction on the Crude Oil Storage Tanks as shown in Figure 1. When the Crude Oil Transfer Pumps are staged in series as shown, Crude Oil Injection Pumps BMP-1 or BMP-4 can produce 667 feet of head (257 psi). The maximum discharge pressure expected from this configuration, then, is 661 psig. This will provide a cavern inlet pressure of 650 psig. This pressure would ordinarily be sufficient to fill the caverns to maximum inventory at a design rate of 226,000 barrels per day with oil of a gravity between 27.5^{o} and 30.5^{o} API.

Less dense oil requires a higher cavern fill pressure. It is estimated that a 42o API oil will require a cavern fill pressure of 760 psig. Additional pressure loss in the tubing string following remediation is also anticipated. Some wells will require tubing string liners, which will reduce the inside diameter and increase pressure loss. With these liners in place, the required well head pressures are expected to increase to 884 psig with a 42o API oil. This pressure creates a shortfall in head of 771 feet in the existing pump configuration and capacity. Lower well head pressures during fill reduce the amount of crude that can be inventoried in a cavern. Maximum cavern fill is critical in providing the 254 million barrels of total inventory at Bryan Mound.

Options to replace the two Crude Oil Injection pumps focus on providing sufficient cavern injection pressure along with best sparing philosophy for reliably satisfying new system requirements.

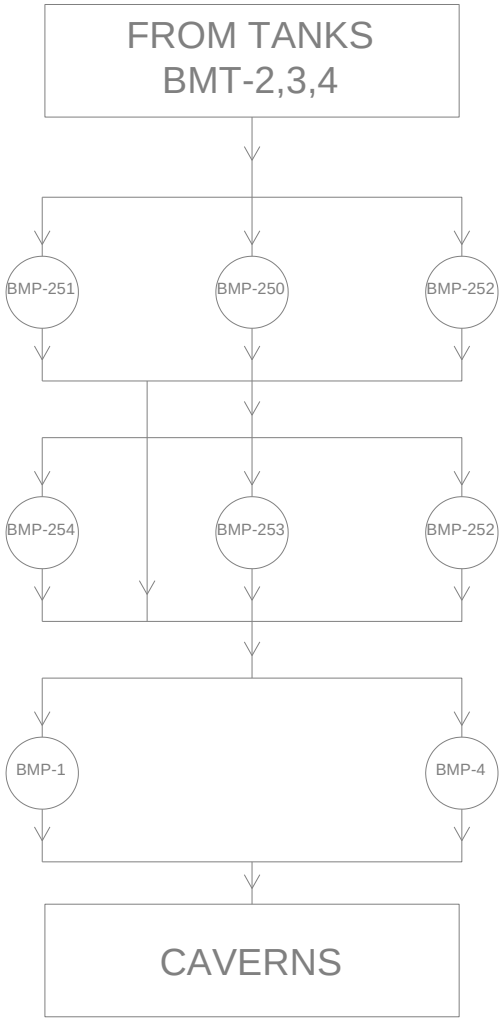

Figure 1 – Existing Pump Configuration at Bryan Mound

A. Status Quo

The status quo is to maintain the existing system in place using the Crude Oil Injection pumps as shown in Figure 1.

The existing pumps do not provide sufficient head to fill individual storage caverns to capacity when storing the lighter crude oils now or in the future. The existing pumps are nearing the end of their useful life.

Viability: No Further Analysis

B. Two New Pumps and Motors

This alternative consists of purchasing two new, higher head 100% capacity replacement pumps for the existing Crude Oil Injection Pumps as shown in Figure 2.

The shortfall in head resulting from a required well head pressure of 884 psig can be obtained by replacing the existing Crude Oil Injection Pumps with new pumps of higher head rated for the pump design flow of 240,000 barrels per day. This would require a minimum head of 1,438 feet as compared to the current head of 667 feet. The additional head substantially increases the motor horsepower requirements which, in turn, will increase the electrical requirements. The current motors are sized at 1500 hp. The new pumps would have motors in excess of 3000 hp. The pumps would be installed in place of the existing BMP-1 and 4. One of the existing pumps would remain operational during the time required to demolish and replace the other.

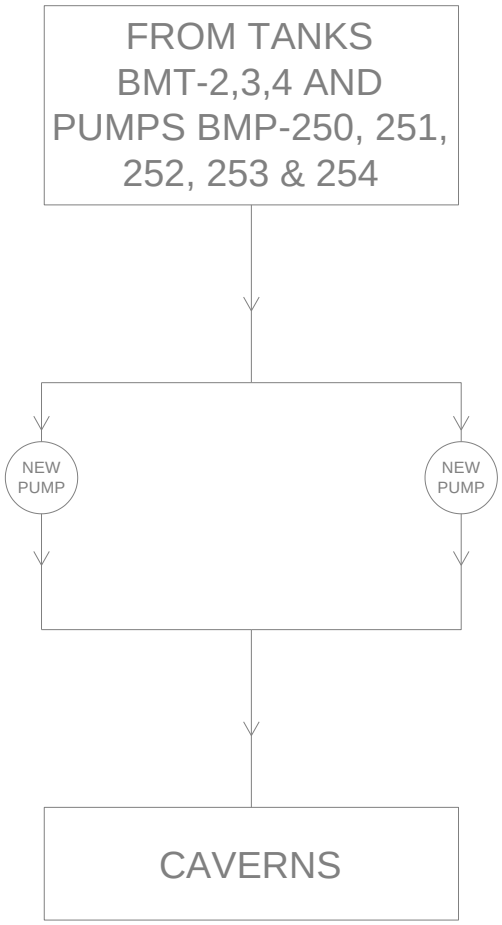

Figure 2 – Two New Pumps and Motors

This option provides a quick and simple solution replacing the existing pumps. Care must be exercised in how these pumps are set and piped up to minimize impact to Bryan Mound fill operations.

Viability: Continue Analysis

C. New Impellers and Motors

This alternative consists of retrofitting the existing two 100% capacity Crude Oil Injection Pumps with new, larger diameter impellers and new motors.

This alternative proposes to install new impellers in the existing pump cases and use existing motors, or if necessary, mount new higher horsepower motors on the pumps to obtain the required minimum head of 1,438 feet at the pump design flow rate of 240,000 barrels per day. Based on pump affinity laws, the impeller diameter would be increased to 19.91 inches to generate the required head. The motor horsepower would increase to 2,750 hp.

The maximum impeller that the existing pump can accommodate is 15.25 inches in diameter. The maximum diameter impeller is unable to supply sufficient head to support a fill rate of 225,000 barrels per day or to completely fill caverns. This alternative is not feasible.

Viability: No Further Analysis

D. Two New Booster Pumps

This alternative consists of installing two new 100% capacity booster pumps in series with the existing Crude Oil Injection Pumps as shown in Figure 3.

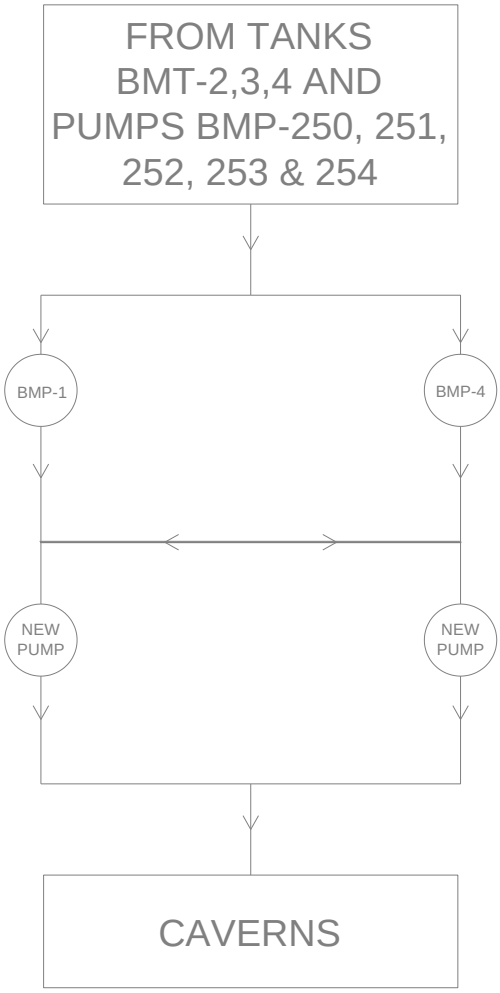

Figure 3 – Two New Booster Pumps

The shortfall in head of 771 feet would be supplied by two additional pumps, which would take suction from the existing Crude Oil Injection Pumps to boost the pressure. One pump would serve as a 100% idle spare. This will provide reliability for this service in excess of 99.7%, given that a typical centrifugal pump has a mean time between failures of approximately 5.5 years. For this service to supply the required head of 1438 feet, two of the Crude Oil Transfer Pumps must operate in series and feed one of the Crude Oil Injection Pumps, which then feed one of the two new Booster Pumps. The total reliability of this line-up will still be greater than 99% with the existing spare pumps and the proposed sparing of the new Booster Pumps.

This option provides the extra pump power to achieve the new pumping requirements at lower cost by buying two new lower head pumps. However, this option does nothing to address the concerns of aging of the existing Crude Oil Injection Pumps. The existing pumps must be maintained and operated to make this alternative work. The addition of two new booster pumps increases the complexity of the pumping system and triggers redesign of the pump system controls

Viability: Continue Analysis

E. One New Pump in Series/Parallel to Existing Pumps

This alternative consists of installing one new higher head 100% capacity pump in parallel to BMP-1 and BMP-4 with the existing pumps as shown in Figure 4.

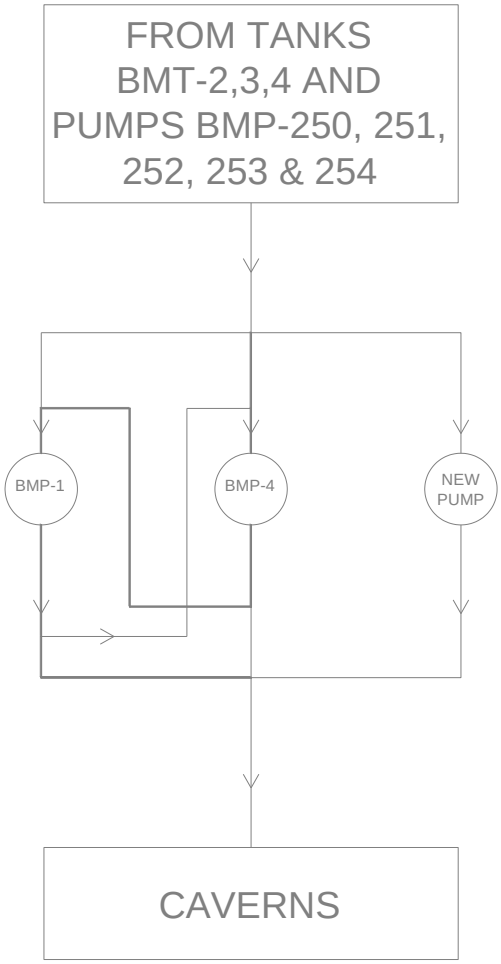

Figure 4 – One New Pump in Series/Parallel to Existing Pumps

This option focuses on reducing purchased pump count and overall project cost while providing the extra piping to network the pumps to satisfy the cavern fill objectives. The new pump would be sized to provide 100% flow at the additional head required when needed to handle less dense crude to top off caverns to maximize cavern storage capacity. The new pump would also provide the necessary head for cavern fill with less dense crude after remediation. This new pump would be piped up to facilitate manual line-up of the new and existing BMP-1 and BMP-4 pumps either in series or parallel combinations as required to fill caverns. Continued operation of the existing Crude Oil Pumps in series/parallel combination with the new pump will provide the pump pressure necessary to fill caverns under all other scenarios. This configuration starts out greater than 99% but declines over time with the degradation of the existing BMP-1 and 4 pumps, which are nearing end of life. System reliability will likely drop below 90% with the further aging of BMP-1 and 4.

This option does not provide a true 100% on-line spare for the new pump as stated previously in the functional requirements. However, 100% sparing is not essential here. The full capacity of the new pump is only required to top off sweet caverns after remediation when storing lower density (higher API) crude oil. Cavern fill with such lower density oil is not conducted as frequently as processing higher density (lower API) sweet and sour crude oils. The increased pump system operating complexity and the increased costs associated with maintaining the reliability of two existing Crude Oil Injection Pumps increase the discomfort

level with implementing this option for 25 years of operation. The existing pump controls would require upgrade to accommodate the increase in operational complexity.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on the initial analysis of the alternatives, alternatives A and C are eliminated from further consideration. The remaining alternatives B, D, and E are examined below as alternatives A, B, and C, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

Assumptions & Constraints

- Insufficient data is available to estimate the remaining life of the existing Crude Oil Injection Pumps to provide comfort operating the existing pumps without replacement over the next 25 years of service.
- Well remediation will proceed in the near future to increase the pump head requirements of the existing system.
- Continued operation of the existing Crude Oil Injection Pumps beyond their useful life is feasible but entails the expectation that repair parts may not be available in the near future.
- Upgrade of the existing pump motors with open motor windings to sealed motors to ascribe to modern best practices for improved safety is recommended where motor replacements are called out.
- Space is available to build at least one new pump foundation to facilitate staging of replacement pumps to minimize impact on fill and drawdown operations.
- Pump replacement must be sequenced one pump at a time to minimize impact on fill and drawdown operations.
- Cost savings may be realized in pursuing a change in pump type from API 610 Pump type BB3 to OH2 in the detailed design of the project.
- Preference should be given to pouring new pump foundations over old after the old foundations are cleaned up.
- New switchgear is required for installation of new pumps.
- The existing power distribution system is adequate to handle new pumps.
- No power system outage may be taken to wire up new pumps if impact is to be minimized on Bryan Mound fill and drawdown operations.
- Replacement of the existing pumps will trigger an upgrade of the existing pump control system in cases where the pump count and pump network configuration change.
- Installation of new higher head pumps and/or addition of more pumps requires installation of newly designed control system to mesh the pump services to advantage.

A. Two New Pumps and Motors

This alternative consists of purchasing two new, higher head 100% capacity replacement pumps for the existing Crude Oil Injection Pumps.

Benefits & Effectiveness

The replacement of the Crude Oil Injection Pumps with two new, higher head 100% capacity pumps allows for multiple benefits and addresses current mission needs.

- This alternative provides the most straight forward approach to increasing Crude Oil Injection Pump head to effectively fill caverns with minimal construction disturbance to Bryan Mound fill operations and with minimal operating control complexity.
- The Bryan Mound site will be able to meet the required fill rate of 225,000 barrels per day with this strategy.

Risk & Mitigation Factors

There are associated risks with replacing BMP-1 and BMP-4 with two new 100% capacity pumps and motors. The table below summarizes risks with a correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Two New Pumps and Motors

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Remaining life of existing Crude Oil Injection Pumps is not determined.	Pursue more aggressive evaluation and routine fitness for service testing on-site at Bryan Mound to project remaining life of existing pumps.	Medium - Medium	Medium Risk Hazard
Pump and motor availability/delivery.	Include adequate escalation to account for delays in fabrication and delivery of long lead items such as pumps. Procure pumps and motors early on in the project schedule to hedge against pricing and delivery issues.	Low - Low	Low Risk Hazard
Pump replacement parts availability.	Confirm replacement parts availability at time of purchase of new pumps. Purchase minimal replacement parts to facilitate timely maintenance.	Low - Low	Low Risk Hazard
Safety incidents during installation of replacement pumps.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during construction.	Medium - Medium	Medium Risk Hazard

B. Two New Booster Pumps

This alternative consists of installing two new 100% capacity booster pumps in series with the existing Crude Oil Injection Pumps.

Benefits & Effectiveness

Modification of the existing Crude Oil Injection Pump system with two new 100% booster pumps in series with the existing pumps allows for multiple benefits and addresses current mission needs.

- This alternative provides a simple approach to increasing Crude Oil Injection Pump head to effectively fill caverns with minimal construction disturbance to Bryan Mound fill operations and with minimal operating control complexity.
- The Bryan Mound site will be able to meet the required fill rate of 225,000 barrels per day with this strategy.

Risk & Mitigation Factors

There are associated risks with supplementing BMP-1 and BMP-4 operation with two new booster pumps. The table below summarizes mentioned risks with a correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Two New Booster Pumps

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Remaining life of existing Crude Oil Injection Pumps is not determined.	Pursue more aggressive evaluation and routine fitness for service testing on-site at Bryan Mound to project remaining life of existing pumps.	Medium - Medium	Medium Risk Hazard
Pump and motor availability/delivery.	Include adequate escalation to account for delays in fabrication and delivery of long lead items such as pumps. Procure pumps and motors early on in the project schedule to hedge against pricing and delivery issues.	Low - Low	Low Risk Hazard
Operation of pumps requires new and more complex control strategy.	Upgrade and extend pump controls to include additional pumps with required system reliability.	High - Low	Low Risk Hazard
Existing Crude Oil Injection Pumps are approaching the end of their useful life.	Assess remaining life and parts availability for existing pumps. Detail maintenance plan to keep pumps running another 25 years. Evaluate impact of maintenance plan on annual budget.	Medium - Medium	Medium Risk Hazard
Safety incidents during installation of replacement pumps.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during construction.	Medium - Medium	Medium Risk Hazard

C. One New Pump in Series/Parallel to Existing Pumps

This alternative consists of installing one new higher head 100% capacity pump in parallel to BMP-1 and BMP-4 with the existing pumps.

Benefits & Effectiveness

Modification of the Crude Oil Injection Pump system with the addition of one new, higher head pump piped in series/parallel to the existing pumps allows for multiple benefits and addresses current mission needs.

- This alternative provides a simple approach to increasing Crude Oil Injection Pump head by manual line-up of the desired pump combination to effectively fill caverns with minimal construction disturbance to Bryan Mound fill operations and with minimal operating control complexity.
- The Bryan Mound site will be able to meet the required fill rate of 225,000 barrels per day with this strategy.

Risk & Mitigation Factors

There are associated risks with the installation of one new pump in series/parallel to the existing pumps. The table below summarizes mentioned risks with a correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for One New Pump in Series/Parallel to Existing Pumps

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Remaining life of existing Crude Oil Injection Pumps is not determined.	Pursue more aggressive evaluation and routine fitness for service testing on-site at Bryan Mound to project remaining life of existing pumps.	Medium - Medium	Medium Risk Hazard
Pump and motor availability/delivery.	Include adequate escalation to account for delays in fabrication and delivery of long lead items such as pumps. Procure pumps and motors early on in the project schedule to hedge against pricing and delivery issues.	Low - Low	Low Risk Hazard
Operation of pumps requires new and more complex control strategy.	Upgrade and extend pump controls to include additional pumps with required system reliability.	High - Low	Low Risk Hazard
Existing Crude Oil Injection Pumps are approaching the end of their useful life.	Assess remaining life and parts availability for existing pumps. Detail maintenance plan to keep pumps running another 25 years. Evaluate impact of maintenance plan on annual budget.	Medium - Medium	Medium Risk Hazard
Safety incidents during installation of replacement pumps.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during construction.	Medium - Medium	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Two New Pumps and Motors

This alternative consists of purchasing two new, higher head 100% capacity replacement pumps for the existing Crude Oil Injection Pumps.

B. Two New Booster Pumps

This alternative consists of installing two new 100% capacity booster pumps in series with the existing Crude Oil Injection Pumps.

C. One New Pump in Series/Parallel to Existing Pumps

This alternative consists of installing one new higher head 100% capacity pump in parallel to BMP-1 and BMP-4 with the existing pumps.

Comparison of Alternatives

Core Team Member Ratings

	Ease of Operations	**Safety During Construction**	**Ease of Maintenance**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Good*	*Excellent*	*Excellent*
Alternative B	*Adequate*	*Excellent*	*Adequate*	*Excellent*
	Adequate	*Excellent*	*Adequate*	*Excellent*
	Good	*Good*	*Adequate*	*Excellent*
Alternative C	*Marginal*	*Excellent*	*Adequate*	*Excellent*
	Marginal	*Excellent*	*Adequate*	*Excellent*
	Adequate	*Good*	*Adequate*	*Excellent*

Cost Comparison

	Total Estimated Cost (TEC)	Life Cycle Cost (LCC)
Alternative A	**$12,487,804**	**$12,649,629**
Alternative B	**$10,066,664**	**$10,420,073**
Alternative C	**$11,236,391**	**$12,638,055**

Recommended Alternative

A. Two New Pumps and Motors

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria, and in fact received the top rating on all but one factor by one Core Team Member. Alternative B has a lower investment cost and life cycle cost. The key deciding factor between alternatives is the benefits from the integrated operation of new pumps and motors in Alternative A. Therefore, Alternative A is the recommended preferred alternative, with the benefits of operational considerations outweighing the higher investment and life cycle cost.

BM-MM-1355

Replace Brine Tank BMT-1 with Purpose Built System

VCI Project Engineer: Lorna Madison

Recommended Alternative:

One New Tank

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The Bryan Mound (BM) site will consider the alternative to add brine storage capacity to reduce reliance on Brine Tank BMT-1. BMT-1 was originally designed and operated in crude oil service before conversion to brine service in 1998. As a brine tank, it is overly large, expensive to maintain, and lacks the flexibility of a multiple tank system where one tank can be taken out of service for such activities as maintenance or crude oil clean-up.

With continued operation off a single large brine tank, Bryan Mound will continue to experience very expensive tank floor repairs and suffer loss of service during repair and maintenance of the tank. When BMT-1 is out of service, cavern fill operations are negatively impacted.

The Bryan Mound site remains committed to providing the required Level I crude oil fill rate of 225,000 barrels per day.

Functional Requirements

- The modified brine tank storage system must maintain the Level I Bryan Mound crude oil fill rate of 225,000 barrels per day by providing a brine disposal rate of 241,000 barrels per day.
- The brine storage tank system must provide sufficient capacity to support site operations (i.e., fill, cavern workovers, cavern pressure maintenance).
- Brine Tank BMT-1 must remain operational to avoid disruptions in fill operations during construction and implementation of a multiple tank solution.
- The modified Brine Tank system must provide minimum reliability of 95%.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Anthony Bonadona	VCI, Project Engineer
Ed Orloski	VCI, Process Engineer
William Leet	VCI, Process Engineer
Rachel Gray	VCI, Process Engineer
Lisa Eldredge	FFPO, Principal Operations System Engineer
Buddy Delaune	FFPO, Principal Mechanical Engineer
David Morrow	FFPO, Sr. Mechanical Engineer
Mike Cabiran	FFPO, Sr. Site Engineer
Daniel Kosick	FFPO, Manager Project Safety
Bob Sevcik	FFPO, Director Environmental Department & Sustainability

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Safety during Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. The site's ability to address safety and security concerns during implementation shall not be impacted. A robust contractor work plan shall be vetted by the Government for all safety concerns that might be of note during construction.

Weight: Most Important

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. The modified brine storage system must maintain the Level I Bryan Mound crude oil fill rate of 225,000 barrels per day with the corresponding brine disposal rate of 241,000 barrels per day. The brine storage tank system must provide sufficient capacity to support site operations (i.e., fill, cavern workovers, cavern pressure maintenance).

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. The modified Brine Tank system must provide minimum reliability of 95%.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve the Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The existing Bryan Mound Brine Tank BMT-1 is a 200,000-barrel crude oil storage tank converted to brine service. Currently, the tank is being used to inventory brine during cavern fill operations, cavern workovers, and cavern depressurization. The tank floor is 222'-7" in diameter and requires frequent repairs. When floor maintenance is required, the tank is removed from service. Required fill, workover, and depressurization operations are impacted until the tank is returned to service. There are no alternatives presently available for providing brine storage when BMT-1 is out of service.

A. Status Quo

The status quo consists of maintaining and operating the existing brine tank. Frequent floor repairs render Brine Tank BMT-1 unserviceable during critical site operations. The reliability of the fill operation is reduced below the required 95% when repairs are ongoing. Continued operation with BMT-1 jeopardizes the mission statement.

Viability: No Further Analysis

B. Two New Tanks

This alternative consists of installing two new brine tanks to replace the existing brine tank. Two new tanks would be located in parallel on suitable plot space to support the fill, workover, and depressurization operations at Bryan Mound. Once commissioned, the existing Brine Tank BMT-1 would be decommissioned. The two tanks would provide the flexibility to take one tank out of service to deal with hydrocarbon contamination or planned tank cleaning, inspection, and repairs, while continuing to operate off the second brine tank. The two tanks would be sized like the West Hackberry brine tanks, which serve a similar purpose. The tanks at West Hackberry support a brine disposal rate of 225,000 barrels per day. The West Hackberry tanks are 50,000 bbl capacity tanks, 110 feet in diameter by 32 feet tall. Each of these tanks provides 10 hours of holdup at a maximum pumping rate of 3500 GPM. The design brine disposal rate at Bryan Mound is 260,000 barrels per day such that the West Hackberry brine tank size should work well at Bryan Mound. The location of the new tanks would be determined by the available plot area at the Bryan Mound site. However, to avoid the relocation of the Brine Tank Pumps, the new tanks should be sited in the area adjacent to the existing pumps. The suction lines would be re-routed from the existing pump location to the new tanks. Tank material selection would be based on providing a 25-year service life. This option requires sufficient plot space for installation of two new brine tanks.

Viability: Continue Analysis

C. One New Tank

This alternative consists of installing one new brine tank in parallel to the existing brine tank. One new tank of 50,000 bbl capacity would be located in the available plot area at the Bryan Mound site. The new tank would supplement the capacity of the existing Brine Tank BMT-1. Operation of the new tank in parallel with the existing Brine Tank BMT-1 would provide the flexibility to take one tank out of service to deal with hydrocarbon contamination or planned tank cleaning, inspection, and repairs, while continuing to operate off the second brine tank. This alternative requires less plot space for the new tank than the two tank alternative. To take advantage of the existing Brine Tank Pumps, the new tank should be located in the area adjacent to the existing pumps. A new suction line would be routed from the new tank to the existing pumps. When the new tank is operational, the existing Brine Storage Tank would be taken out of service and repaired. Both new and existing tanks would be provided with materials to provide for a 25-year service life. This option requires the repair and return to service of the existing Brine Tank BMT-1 together with a future maintenance commitment to keep BMT-1 in service.

Viability: Continue Analysis

D. Two New Brine Ponds

This alternative consists of installing two new brine ponds to replace the existing brine tank. The Strategic Petroleum Reserve (SPR) has considerable experience with brine pond design and operation, including the operation of brine ponds at Bryan Mound during the early days of site operation. Restoring brine pond operations at Bryan Mound would provide the capacity for handling brine as well as for facilitating pigging water collection. Two new brine ponds, each large enough to provide 10 hours of holdup for 260,000 barrels of brine disposal, would be located in an open area in the vicinity of the existing brine tank. The second pond would spare the first to continue to operate while one brine pond is taken out of service for planned or unplanned cleaning, inspection, and repairs. The ponds would feature an internal liner supported by a concrete basin to facilitate clean out. Two new sets of lift pumps would be installed to operate each brine pond with the capability of moving 4000 GPM brine out of each pond. Each set of brine pumps would include an idle spare. Each pond would occupy a plot area of 101,250 sq. ft. with an average depth of 6’-0”. The approximate dimensions of each brine pond would be 225 feet by 450 feet. The brine ponds require considerable plot space for installation as well as new pumps for handling brine. The SPR is pursuing a program to remove brine ponds from service across the SPR sites in favor of using brine tanks out of safety and environmental concerns.

Viability: No Further Analysis

V. ALTERNATIVES ANALYSIS

Based on the initial analysis of the alternatives, alternatives A and D are eliminated from further consideration. The remaining alternatives, B and C, are examined below as alternatives A and B, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

Assumptions & Constraints

- Addition of brine storage capacity is required to preserve brine handling capacity, while taking the Brine Tank BMT-1 out of service for repairs.
- Modification of the existing brine storage and handling system must provide a brine tank system reliability of 95% or greater.
- It is assumed that sufficient plot space is available to install additional brine tanks or brine ponds on site at Bryan Mound.
- The lessons learned in brine handling across SPR sites can be utilized here to design a better and more manageable brine storage and handling system at Bryan Mound.

A. Two New Tanks

This alternative would install two new brine tanks in parallel to replace the existing Brine Tank BMT-1 with materials selected to provide a 25-year life.

Benefits & Effectiveness

Installation of two new brine tanks would provide Bryan Mound the flexibility to isolate one tank for clean-up, maintenance, or repair while utilizing the other for fill. The tanks would each be sized for 50,000 bbl capacity each to support a design brine disposal rate of 260,000 barrels per day. Each of these tanks will provide 10 hours of holdup at a maximum pumping rate of 3500 GPM. Installation of the new tanks would allow the existing Brine Tank BMT-1 to be retired from service to minimize tank maintenance.

The Bryan Mound (BM) site will be able to meet the required Level I crude oil fill rate of 225,000 barrels per day with this strategy.

Risk & Mitigation Factors

There are associated risks with the installation and construction of multiple new tanks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Two New Tanks

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Scheduled outage extended.	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - Low	Low Risk Hazard
Tank wall and floor compatibility with brine.	Verify with tank vendor that the tank wall and floor material (e.g., coatings) are compatible with brine. Ensure material selection can provide a tank life of 25 years.	Low - Low	Low Risk Hazard
Extent of BMT-1 maintenance increases.	Prepare plan to take BMT-1 out of service should maintenance costs prove too expense to continue to service tank.	Low - Low	Low Risk Hazard
Plot space limited on-site.	Develop Bryan Mound site for adequate area for the new tanks. Provide the proper foundation to support the multiple tanks.	Medium - High	Medium Risk Hazard
Delays in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays and associated cost over-runs with permitting activities.	Low - Medium	Low Risk Hazard
Brine system tie-ins error.	Verify the brine system tie-ins are correct and clearly marked prior to pipe installation.	Low - High	Low Risk Hazard
Brine disposal rate limited.	Ensure the new tanks system design will maintain the required fill and disposal rates.	Low - High	Low Risk Hazard
Safety incidents during construction and piping of new tanks.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

B. One New Tank

This alternative would install one new tank in parallel to BMT-1 with materials selected to provide a 25-year life.

Benefits & Effectiveness

A new tank would allow Bryan Mound to do maintenance or repair on the existing Brine Tank BMT-1, while continuing fill operations. The new tank will have a capacity of 50,000 barrels and will be built with material to provide a 25-year service life.

The Bryan Mound (BM) site will be able to meet the required Level I crude oil fill rate of 225,000 barrels per day with this strategy.

Risk & Mitigation Factors

There are associated risks with the installation and construction of multiple new tanks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for One New Tank

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Scheduled outage extended.	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - Low	Low Risk Hazard
Tank wall and floor compatibility with brine.	Verify with tank vendor that the tank wall and floor material (e.g., coatings) are compatible with brine. Ensure material selection can provide a tank life of 25 years.	Low - Low	Low Risk Hazard
Extent of BMT-1 maintenance increases.	Develop detailed plan to address future maintenance of BMT-1 to keep tank in operating condition.	Medium - High	Medium Risk Hazard
Plot space limited on-site.	Develop Bryan Mound site for adequate area for the new tank. Provide the proper foundation to support the multiple tanks.	Medium - High	Medium Risk Hazard
Delays in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays with permitting activities.	Low - Medium	Low Risk Hazard
Brine system tie-ins error.	Verify the brine system tie-ins are correct and clearly marked prior to pipe installation.	Low - High	Low Risk Hazard
Brine disposal rate limited.	Ensure the new tanks system design will maintain the required fill and disposal rates.	Low - High	Low Risk Hazard
Safety incidents during construction and piping of new tanks.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Two New Tanks

This alternative would install two new tanks in parallel to existing brine tank with materials of construction selected for a 25-year life.

B. One New Tank

This alternative would install one new tank in parallel to existing brine tank with materials of construction selected for a 25-year life.

Comparison of Alternatives

Core Team Member Ratings:

	Safety During Construction	**Ease of Operations**	**Ease of Maintenance**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*
	Good	*Excellent*	*Good*	*Good*
Alternative B	*Excellent*	*Good*	*Good*	*Excellent*
	Excellent	*Good*	*Good*	*Excellent*
	Good	*Adequate*	*Adequate*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$25,177,018**	**$25,703,737**
Alternative B	**$13,883,853**	**$14,638,575**

Recommended Alternative

B. One New Tank

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria. Alternative B has significantly lower investment cost and life cycle cost. The key deciding factor between alternatives is the significantly higher costs that are not currently viewed to outweigh the operational benefits. Therefore, Alternative B is the recommended preferred alternative, with the lower estimated costs outweighing the higher technical merits of Alternative A.

BM-MM-1358

Install Vapor Recovery BMT-2, -3, -4

VCI Project Engineer: Lorna Madison

Recommended Alternative:

Vapor Recovery on All Tanks

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The Bryan Mound (BM) site will explore the alternative of upgrading the three Crude Oil Tanks BMT-2, BMT-3, and BMT-4 from external floating roof configuration to vent to control configuration to abide current and future Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency (EPA) above ground tank emissions control regulations for operation in an ozone non-attainment area. It has been proposed to expand the use of the present Crude Oil Tanks for fill and drawdown operations to future operation with higher API gravity crude oil which exhibit higher true vapor pressures. This will increase the fugitive emissions rates off the existing Crude Oil Tanks after they are returned to service with external floating roofs. In order to assure that Bryan Mound retains the flexibility to process crude oil under these circumstances, the tanks will require upgrade to vent to control configuration.

The Bryan Mound (BM) site is committed to providing a maximum cavern fill rate of 225,000 barrels per day by Level I Performance Criteria.

Functional Requirements

- Crude Oil Tanks will be fitted with vent to control capability in support of a Level I fill rate of 225,000 barrels per day for an expanded range of crude oil qualities and storage temperatures.
- The system must meet current or revised emission requirements set by TCEQ and the EPA for a non-attainment area.
- Vent control device efficiency shall exceed 99.9% destruction efficiency.
- Fugitive emissions control system reliability shall provide greater than 95% reliability.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Anthony Bonadona	VCI, Project Engineer
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Daniel Kosick	FFPO, Manager Project Safety
Bob Sevcik	FFPO, Director Environmental Department & Sustainability

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. Crude Oil Tanks will be fitted with vent to control capability in support of a Level I fill rate of 225,000 barrels per day for an expanded range of crude oil qualities and storage temperatures. The system must meet current or revised emission requirements set by TCEQ and the EPA for a non-attainment area. Vent control device efficiency shall exceed 99.9% destruction efficiency.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely and have the ability to address safety and security concerns during implementation. Project work plans must invoke Strategic Petroleum Reserve (SPR) protocols to establish a safe work environment for all construction related activity.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. Fugitive emissions control system reliability shall provide greater than 95% reliability.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve the Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

The Bryan Mound site is equipped with three Crude Oil Tanks BMT-2, BMT-3 and BMT-4, which are designated for crude oil storage. Each of these tanks was sized to provide 200,000 barrels of inventory or approximately 21 hours of fill without transfers to cavern storage at a rate of 225,000 barrels per day. Each tank was permitted for 3.35 tons/yr of VOC emissions for storage of crude of 11.0 psia or lower true vapor pressure at maximum operating temperature. Operation of two of these three tanks is required to provide sufficient crude oil storage capacity to meet sweet and sour crude drawdown requirements as set forth in Level I Performance Criteria. However, wear and tear has taken its toll on these internal floating roof tanks such that all three tanks were removed from service over time as the result of accumulated roof damage.

All three Crude Oil Tanks BMT-2, BMT-3, and BMT-4 are targeted for refurbishment as external floating roof tanks to return them to crude oil service. Crude Oil Tank BMT-3 was previously converted to an external floating roof tank and returned to service under permit by rule. Conversion of Crude Oil Tank BMT-2 is in the early stages of discovery of the extent of repairs required to return the tank to service under a project currently in place. Conversion of Crude Oil Tank BMT-4 to an external floating roof tank and return of BMT-4 to crude oil service is the subject of a current project proposal.

The external floating roof tank configurations do not qualify as acceptable emissions control technology for the storage and handling of crude oils of higher vapor pressure at operating conditions in an ozone

nonattainment zone. The TCEQ website lists the applicable tank regulations for ozone nonattainment areas in Texas and specifies the Best Available Control Technology (BACT) guidelines for controlling fugitive emissions off tanks.

Title 30, Part 1, Chapter 16, Subchapter U, Rule 106.478 Storage Tank and Change of Service states that permit of tank modifications by rule for volatile organic liquids including petroleum is subject to the following constraints:

(2) The true vapor pressure of the compound to be stored must be less than 11.0 psia at the maximum storage temperature.

(3) For those compounds which have a true vapor pressure greater than 0.5 psia and less than 11.0 psia at the maximum storage temperature, any storage vessel greater than 40,000 gallons capacity shall be equipped with an internal floating cover or equivalent control.

TCEQ BACT technology recommendations for internal floating roof equivalency for tanks to be modified by permit by rule include upgrade to internal floating roof with appropriate primary or primary and secondary seals, external floating roof with appropriate primary and secondary seals, and vent to control.

Violation of the constraints listed above for permitting tank modifications by rule requires more extensive modifications of these tanks to reduce fugitive emissions and a more formal permit modification process to approve the changes. TCEQ regulations specify the installation of vent to control with appropriate control device efficiency to manage fugitive emissions when handling large volumes of hotter crude oil or higher API gravity crudes which exhibit vapor pressures in excess of 11.0 psia true vapor pressure at maximum storage temperature. Vapor recovery operating at better than 95% recovery efficiency and vapor destruction operating at better than 98% destruction efficiency are specifically cited as examples of such devices in the TCEQ literature.

Based on these tank regulations, expansion of Bryan Mound operation to hotter crude oil and/or higher API gravity crudes which collectively exhibit greater than 11.0 true vapor pressure, the Crude Oil Tanks must be upgraded to internal floating roof tanks with vapor destruction for emissions control.

List of Alternatives

A. Status Quo

The status quo consists of maintaining the existing system in place.

Bryan Mound Crude Oil Tanks BMT-2, BMT-3, and BMT-4 are located in an EPA non-attainment area. Any expanded use of these tanks to delivery of oil in excess of 11.0 psia true vapor pressure under current or future TCEQ and EPA regulations on fugitive tank emissions in non-attainment areas will invalidate the use of these tanks for storage of higher vapor pressure crude oil as configured today. Hence, this alternative becomes infeasible for supporting more flexible operation of the Bryan Mound Crude Oil Tanks.

Viability: <u>No Further Analysis</u>

B. Vapor Recovery on All Tanks

This alternative consists of converting Crude Oil Tanks BMT-2, BMT-3, and BMT-4 to domed internal floating roof tank with vapor destruction unit (VDU) capacity to destroy the vapors captured under the dome.

In order to implement vapor recovery on the three tanks, containment of the VOCs above the floating roof rim seals is essential. Each tank must first be modified to a domed internal floating roof tank to provide freeboard for the collection of fugitive emissions escaping the floating roof rim seals. This can be done by installing a new, light weight, aluminum geodesic domed roof over the existing external floating roof while the tank is in service to weather shield the floating roof to suppress evaporative emissions. In this way, the tank becomes an internal floating roof tank characterized by reduced evaporative emissions as a result of installing the domed roof as a sun shade and wind screen over the floating roof. Alternatively, the external floating roof can be modified or replaced with an internal floating roof of more modern design to reduce roof maintenance and increase tank working inventory. However, modification or replacement of the floating roof requires taking the tank out of service for an extended period of time to make these changes.

A vapor blower would then be piped up to take suction off the dome to transfer collected vapor from the dome to a new vapor destruction unit (VDU) of the thermal oxidation type to destroy fugitive emissions. VDU destruction efficiency is typically in excess of 98%, exceeding 99.9%. The VOC reduction from the permitted level of the three tanks is on the order of 8.85 tons/yr when all three are equipped with internal floating roofs, geodesic domes, and connection to a VDU system.

Installation of the domed internal floating roof configuration results in more reliable tank operation and maintenance, while reducing tank emissions. The conversion of the tank to a domed internal floating roof tank will shield the internal floating roof from the sun and wind to reduce evaporative emissions further than can be achieved with an external floating roof. This weather shielding will also protect the floating roof from precipitation and dirt accumulation to reduce the potential for hydrocarbon release due to deck drain pluggage, roof sinking, or deck drain piping failure. The installation of the domed roof reduces the potential for tank fire by a lightning spark and increases and tank security against terrorist acts.

The reconfiguration of the tank to domed internal floating roof tank provides the platform for future installation of Best Available Control Technology (BACT) for tank emissions to allow Bryan Mound to store hotter crude oil or higher API gravity crude oil with true vapor pressures greater than 11.0 psia.

These reconfigurations of the tanks fall outside the permit by rule approach to permitting these changes such that formal permit modifications for the tanks will be required. This will adversely impact the project timetable for implementation. Moreover, installation requires substantial plot area to stage geodesic dome installation.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternative, B are examined below as alternatives A.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

A. Vapor Recovery on All Tanks

This alternative consists of converting Crude Oil Tanks BMT-2, BMT-3, and BMT-4 to domed internal floating roof tanks with vapor collection and vapor destruction to minimize fugitive emissions.

Assumptions & Constraints

- Bryan Mound is located in a TCEQ/EPA designated severe ozone non-attainment Area.
- All three Crude Oil Tanks BMT-2, BMT-3, and BMT-4 are returned to service as external floating roof tanks for storage of crude oil prior to upgrade to handle higher vapor pressure crude oil.
- Crude Oil Tank BMT-4 merits refurbishment despite its location in the collapsed zone of Cavern Number 3.
- The system must continue to meet current and revised emission reduction requirements with Best Available Control Technology (BACT) specified by the TCEQ and EPA for a non-attainment area.
- Current tank regulations and Bryan Mound site permits limit crude oil tank operation to the storage of fluids of less than 11.0 psia true vapor pressure in external floating roof crude oil tanks at operating temperatures.
- Additional emissions control devices including crude oil tank conversion to internal floating roof configuration with vapor destruction unit to destroy fugitive emissions are currently required by tank regulations or may be required in the future by tank regulations update for the storage of organic liquids including petroleum of true vapor pressure in excess of 11.0 psia.
- Tank modifications and installation of additional tank emissions controls must provide crude oil tank system reliability of 95% or greater.
- Conversion of an external floating roof tank to an internal floating roof tank is most easily accomplished by installing a lightweight aluminum geodesic domed roof on the tank while the tank is in service.
- The modification of an external floating roof to eliminate roof/deck drains and other non-essential roof features reduces floating roof maintenance and may increase working capacity of the existing storage tank following conversion to an internal floating roof tank.
- The specification of a lighter weight aluminum internal floating roof without pontoons will increase the working capacity of the existing storage tanks.
- The VDU is a thermal oxidation type with destruction efficiency in excess of 99.9%.

The Bryan Mound air permit will need to be modified prior to the installation of vapor recovery on BMT-2, BMT-3, and BMT-4. Allow six months in the project schedule for Fluor Federal Petroleum Operations (FFPO) Environmental to prepare the permit application (after 100% Design Review is finalized) and for TCEQ to issue the modified Bryan Mound air permit.

Benefits & Effectiveness

Conversion of the external floating roof tanks to domed internal floating roof tanks with vapor collection and vapor destruction will reduce VOC emissions by up to 99% or up to 8.85 tons/yr. Installation of these control devices for emissions reduction will allow Bryan Mound to store crude oil with a true vapor pressure of greater than 11.0 psia at working temperatures in the tanks. The domed roof will shield the tank internals, including the floating roof seals from the weather to improve tank operation and maintenance reliability.

Bryan Mound (BM) will be able to meet the required Level I fill rate of 225,000 barrels per day to satisfy the Level I Performance Criteria with this strategy.

Risk & Mitigation Factors

There are associated risks with the installation of an internal floating roof with vapor destruction unit (VDU) on all three tanks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Vapor Recovery on All Tanks			
Risks	**Mitigation Strategy**	**Likelihood - Impact**	**Risk Code**
Must file for significant permit modification.	Filing for significant permit modification will significantly impact the project schedule. Manpower and money resources must be allocated up front to the project to complete this re-permitting in timely fashion.	High - High	High Risk Hazard
BMT-4 is located in the collapse zone of Cavern Number 3.	Quantify the risk to future BMT-4 investment and operation prior to finalizing the project scope.	Medium - Medium	Medium Risk Hazard
Geodesic domes availability/delivery.	Procure geodesic domes in advance to develop schedule to avoid delays with delivery.	Low - Low	Low Risk Hazard
Extended schedule outage to retrofit tank(s).	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low - High	Low Risk Hazard
Shortage of plot space to construct geodesic domes.	Verify adequate plot space is available to construct the geodesic domes.	Medium - High	Medium Risk Hazard
Delays in tank conversion to external floating roof configuration.	Develop thorough project plan with schedule for the conversion of the external floating roof tank to a domed internal floating roof tank followed by construction and commissioning of a VDU to each tank.	Medium - High	Medium Risk Hazard
VDU improperly sized.	Work with VDU vendors to model and size the system to handle a fill rate of 240,000 BPD.	Low - High	Low Risk Hazard
VDU fails to achieve 99.9% thermal destruction efficiency.	Work with VDU vendors to design VDU for 99.9% thermal destruction efficiency with sufficient reliability to address flameout (ignition system) and flash back (flame arrestor).	High - High	High Risk Hazard
Delays and cost over-runs in permitting tank modifications.	Work to expedite permitting process upon approval of project to minimize delays and associated cost over-runs with permitting activities.	Medium - High	Medium Risk Hazard
Safety incidents during demolition of existing tank roof(s).	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard
Safety incidents during installation of new tank roofs and VDU.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Vapor Recovery on All Tanks

This alternative consists of converting Crude Oil Tanks BMT-2, BMT-3, and BMT-4 to internal floating roof tanks with vapor destruction to minimize tank emissions.

Comparison of Alternatives

Core Team Member Ratings

	Safety During Construction	**Ease of Operations**	**Ease of Maintenance**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Good*	*Good*	*Excellent*
	Excellent	*Excellent*	*Good*	*Excellent*
	Good	*Good*	*Good*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$38,824,910**	**$39,440,873**

Recommended Alternative

A. Vapor Recovery on All Tanks

Based on the screening process led by the Core Team Members that reviewed two possible alternatives, Alternative A was the only viable alternative selected to be studied that would meet the mission need and functional requirements. Therefore, Alternative A is the recommended preferred alternative.

BM-MM-1365

Replace Below Grade Fire Water Distribution Piping

VCI Project Engineer: Lorna Madison

Recommended Alternative:

High Density Polyethylene - FM Approved

Analysis of Alternatives

Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The intent of the mission at the Bryan Mound (BM) site in Texas is to replace existing perma-strand fiberglass piping, which has been deteriorating over time and requiring frequent repairs that impair the sites underground fire water distribution system.

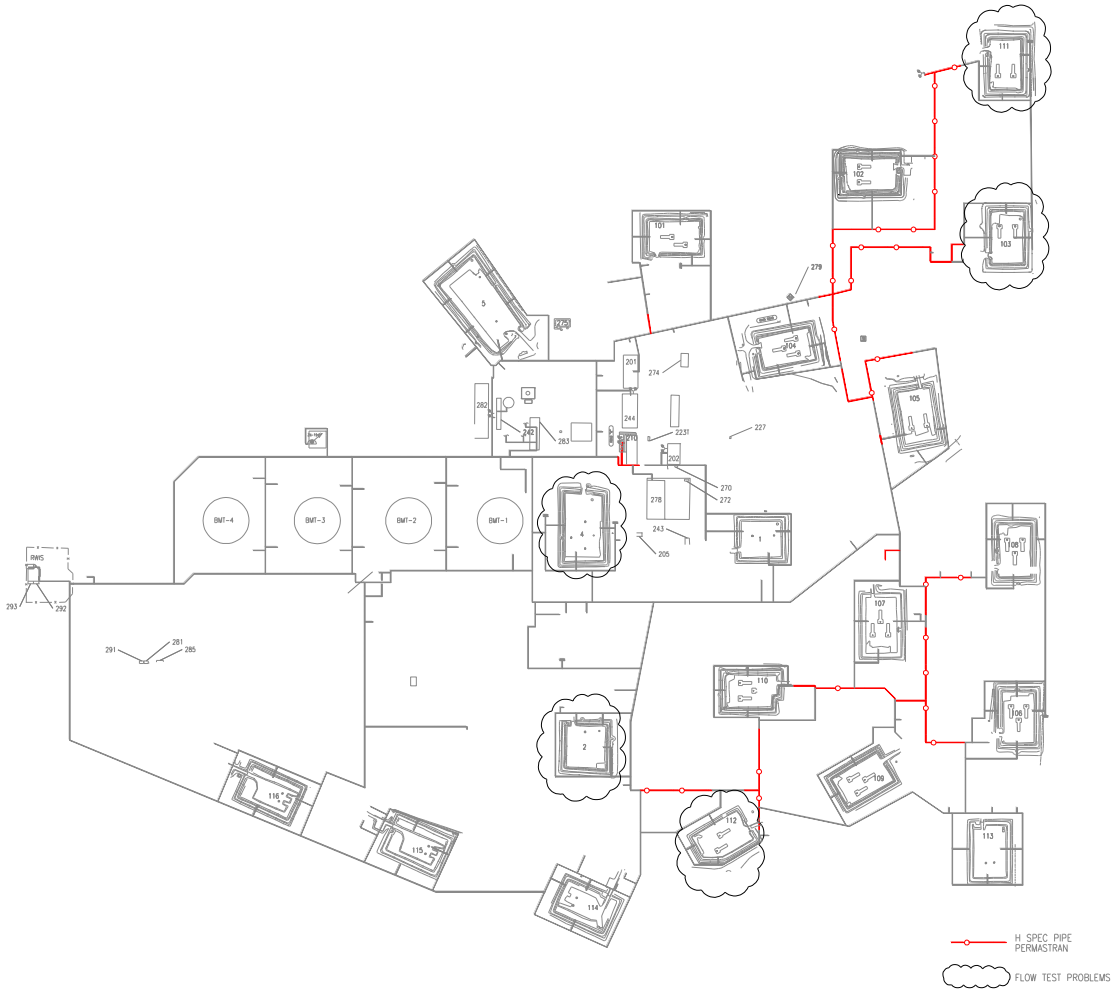

Figure 1 – Existing Perma-Strand Fiberglass Piping

Functional Requirements

The underground fire water distribution system is required to meet fire water demands for fire hazards listed in Design Level III Criteria. The following are functional requirements for fire water demands on the Strategic Petroleum Reserve (SPR) site:

- Wellhead water supplies shall be 2,000 gallons per minute (gpm) at a pressure sufficient to allow the installed monitor streams to reach the wellheads. This shall be a minimum of 100 pounds per square inch gauge (psig) at the monitor.
- Where deluge water spray systems are installed on open pads, they shall be hydraulically calculated to provide a density of at least 0.30 gpm/square foot on all protected equipment plus exposed piping and valves within 25 feet.

- Where foam deluge spray systems are installed on open pads, they shall be hydraulically calculated to provide a density of at least 0.30 gpm/square foot on all protected equipment, adjacent pad, and exposed piping within 5 feet.
- Replacing the perma-strand fiberglass wound pipe with other approved pipe will meet the existing system's current pressure and flow requirements for the hazards found on-site.
- Replacement pipe must be compatible (type connection) or will have to use transition fittings with existing hydrants and monitors.
- Replacing perma-strand pipe (approximately 8,000 feet of 6 inch, 8-inch and 10-inch pipe) can be installed in sections to minimize the impact of the on-site fire water distribution system.
- Replacement pipe shall be Underwriter's Laboratory (UL) listed and Factory Mutual (FM) approved for fire service.
- The size and type of replacement pipe shall meet or exceed current fire water system criteria found in SPR Fire Hazards Analysis dated 12/2/13 and SPR Flow Testing of Fire Protection Water Supplies Rev 1 dated 6/15/12.
- Isolation valves are to allow the capability to maintain 50% firefighting ability upon a pipe failure.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Anthony Bonadona	VCI, Project Engineer
Tim Matey	VCI, Fire Protection
Scott Voelkerding	VCI, Fire Protection
Rachel Gray	VCI, Process Engineer
Lisa Eldredge	FFPO, Principal Operations System Engineer
Buddy Delaune	FFPO, Principal Mechanical Engineer
Steve Carlson	FFPO, Fire Protection
Mike Cabiran	FFPO, Sr. Site Engineer

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Constructability during Ongoing Oil Deliveries

The underground fire water distribution system is provided with sectionalizing valves. The valve locations allow isolation of an underground pipe upon a pipe failure or pipe replacement. Replacement pipe (approximately 8,000 feet of 6-inch, 8-inch and 10-inch pipe) can be installed in sections to minimize the

impact of the on-site fire water distribution system. Isolation valves are to allow the capability to maintain 50% firefighting ability upon a pipe failure.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely. The site's ability to address safety and security concerns during implementation shall not be impacted. A robust contractor work plan shall be vetted by the Government for all safety concerns that might be of note during construction.

Weight: Most Important

Ease of Operations

The selected alternative is similar to existing systems and equipment and when implemented will result in a system that is easily operable without significant additional training.

Weight: Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment, resulting in commonality of similar systems for future maintenance and sparing consideration. Maintenance operations will require less attention. Replacing the perma-strand fiberglass wound pipe with other approved pipe will meet the existing system's current pressure and flow requirements for the hazards found on-site, keeping the site operating at the same capacity.

Weight: Important

Security during Construction

The selected alternative when implemented will be able to be constructed with minimal impacts to site security detection systems. Certain sections of pipe routed below security fences, etc. will require coordination with Site Security.

Weight: Important

Sustainability

Replacement pipe (high density polyethylene, cement lined carbon steel, or ductile iron mortar lined) shall be UL listed and FM approved for fire service. All pipe alternatives have good pipe flow characteristics that do not deteriorate over time, maintaining design flow and minimizing long-term pumping costs.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The project scope of work is set by considering alternatives to replace the Bryan Mound fire water distribution piping currently consisting of perma-strand fiberglass piping. During the development of this AOA, it was determined and verified that significant problems exist with the sectionalizing valves as well as the perma-strand pipe. It is prudent to provide variations of the replacement pipe alternatives to ensure a complete and reliable fire water distribution system.

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

The status quo consists of doing nothing by continuing to maintain the perma-strand fiberglass pipe. The Bryan Mound underground fire water distribution system contains perma-strand fiberglass piping. When a section of perma-strand fiberglass pipe fails, only that section will be replaced with either high density polyethylene (HDPE), cement lined carbon steel (Z Spec), or ductile iron (DI). Depending on what alternative pipe is used for repairs, special configurations are required (perma-strand fiberglass pipe to alternative pipe). Impairments will continue with perma-strand pipe and possibly increase with the continued degradation of the perma-strand pipe, reducing the reliability of the underground fire water system during a fire and/or emergency.

Viability: No Further Analysis

B. High Density Polyethylene - FM Approved

This alternative consists of replacing the perma-strand fiberglass pipe with high density polyethylene. HDPE has been used for underground fire water systems for over 25 years and provides exceptional pipe flow characteristics, which do not deteriorate over time.

HDPE pipe and fittings are FM approved for fire service. The size and type of replacement pipe can meet or exceed fire water demands for fire hazards listed in Design Level III Criteria and current fire water system criteria found in SPR Fire Hazards Analysis dated 12/2/13 and SPR Flow Testing of Fire Protection Water Supplies Rev 1 dated 6/15/12.

B-1. HDPE with Existing Valves and Hydrants

This variation uses HDPE pipe and existing mechanical joint sectionalizing valves. Connecting new HDPE pipe to the existing sectionalizing valves requires an HDPE fitting (flange to mechanical joint) on each side of the sectionalizing valve. In addition, existing hydrants will require transition fitting (flange to mechanical joint) at each hydrant connected to perma-strand pipe. Thrust blocks will need to remain at all hydrants. Replacing +30-year-old perma-strand pipe with new HDPE but using +30-year-old sectionalizing valves will allow the valves to continue to experience impairments and possibly increase with continued degradation, reducing reliability of the underground fire water system with the inability to isolate piping sections.

Viability: No Further Analysis

B-2. HDPE with New Valves

This variation includes replacing perma-strand pipe with HDPE pipe, along with new flanged, sectionalizing valves. The maintenance records at Bryan Mound show that not only does the perma-strand piping need replacing, but also that issues have been experienced with the 30+ year old valves. This variation will explore replacing the perma-strand portion of the fire water system along with all sectionalizing valves to save time during constructability and allow for ease of operation and maintenance on the future system.

Viability: Continue Analysis

C. Cement Lined Carbon Steel Pipe Flanged - UL Listed

This alternative consists of replacing the perma-strand fiberglass pipe with cement lined carbon steel. Cement lined carbon steel pipe is UL listed and FM approved for fire service. Cement lined carbon steel pipe has been used and found to be an excellent pipe for underground fire water systems at the Department of Energy (DOE) SPR sites. The construction at Big Hill incorporated cement lined carbon steel (Z Spec) into the design of the underground fire water system and has experienced good results. The size and type of replacement pipe can meet or exceed fire water demands for fire hazards listed in Design Level III Criteria and current fire water system criteria found in SPR Fire Hazards Analysis dated 12/2/13 and SPR Flow Testing of Fire Protection Water Supplies Rev 1 dated 6/15/12.

C-1. Cement Lined Carbon Steel with Existing Valves and Hydrants

This variation includes using cement lined carbon steel pipe with existing mechanical joint sectionalizing valves. Connecting new cement lined carbon steel pipe to the existing sectionalizing valves requires a

transition fitting (flange to mechanical joint) on each side of the sectionalizing valve. In addition, existing hydrants will require transition fitting (flange to mechanical joint) at each hydrant that is connected to perma-strand pipe. Thrust blocks will need to remain at all hydrants. Replacing +30-year-old perma-strand pipe with new cement lined carbon steel but using +30-year-old sectionalizing valves will allow the valves to continue to experience impairments and possibly increase with continued degradation, reducing the reliability of the underground fire water system with the inability to isolate piping sections.

Viability: No Further Analysis

C-2. Cement Lined Carbon Steel with New Valves

This variation includes replacing perma-strand pipe with cement lined carbon steel pipe, along with new flanged sectionalizing valves. The maintenance records at Bryan Mound show that not only does the perma-strand piping need replacing, but also that issues have been experienced with the 30+ year old valves. This variation will explore replacing the perma-strand portion of the fire water system along with replacing all sectionalizing valves in order to save time during constructability and allow for ease of operation and maintenance on the future system.

Viability: Continue Analysis

D. Ductile Iron Pipe Mechanical Joint - UL Listed

This alternative consists of replacing the perma-strand fiberglass pipe with ductile iron. Ductile iron (DI) enamel or mortar-lined pipe is UL listed and FM approved for fire service. For years, DI has been used and found to be an excellent pipe for underground fire water systems. DI assures extended physical and hydrostatic strength of the pipe and fittings. The pipe requires mechanical joints (restrained or unrestrained) at all connections. The size and type of replacement pipe can meet or exceed fire water demands for fire hazards listed in Design Level III Criteria and current fire water system criteria found in SPR Fire Hazards Analysis dated 12/2/13 and SPR Flow Testing of Fire Protection Water Supplies Rev 1 dated 6/15/12.

D-1. Ductile Iron with Existing Valves and Hydrants

This variation includes using DI pipe with existing mechanical joint sectionalizing valves. DI pipe is connected by mechanical joint; therefore, the use of a transition fitting is not required at the existing sectionalizing valves or fire hydrants. Thrust blocks will need to remain or be replaced at all hydrants, tees, and elbows. Replacing +30-year-old perma-strand pipe with new ductile iron pipe but using +30-year-old sectionalizing valves will allow the valves to continue to experience impairments and possibly increase with continued degradation, reducing the reliability of the underground fire water system with the inability to isolate piping sections.

Viability: No Further Analysis

D-2. Ductile Iron with New Valves

This variation includes replacing perma-strand pipe with DI pipe along with new mechanical joint sectionalizing valves. Thrust blocks are still required because the use of a mechanical joint connection is not a fully restrained joint. The maintenance records at Bryan Mound show that not only does the perma-strand piping need replacing, but also that issues have been experienced with the 30+ year old valves. This variation will explore replacing the perma-strand portion of the fire water system along with replacing all sectionalizing valves in order to save time during constructability and allow for ease of operation and maintenance on the future system.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternatives A, B-1, C-1, and D-1 are eliminated from further consideration. The remaining alternatives B-2, C-2, and D-2 are examined below as alternatives A, B, and C, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

Assumptions & Constraints

Assumptions:

- Fire water pumps at water intake structure are available as an emergency back up to the main pumps.
- Existing underground fire water system includes:
  - Approximately 8000 feet of 6-inch, 8-inch and 10-inch perma-strand pipe
  - Approximately 24 sectionalizing (8-inch, 10-inch) valves are installed on perma-strand pipe, an additional 60 sectionalizing valves (8-inch, 10-inch, 12-inch) are located on other type of fire water piping.

Constraints:

- Existing fire hydrants and sectionalizing valves may be inoperable or have damaged connections (mechanical joint, flanged) requiring repair or replacement of the hydrant or valve during construction.
- May not be able to isolate small sections of pipe for replacement due to existing sectionalizing valves being unable to stop water flow.

A. High Density Polyethylene – FM Approved

This alternative replaces the below grade fire water distribution with high density polyethylene. HDPE pipe and fittings are FM approved for fire service.

HDPE is non-conductive; therefore, cathodic protection is not required and is immune to stray ground currents for minimum long-term maintenance. HDPE pipe flow characteristics do not deteriorate over time.

Pipe and fitting systems offer superior toughness and ductility to other plastics. HDPE pipe and fittings have exceptional resistance to rapid crack propagation and excellent environmental stress crack resistance (ESCR) for both pipe and fittings. FM testing assures extended physical and hydrostatic strength of the pipe and fittings. HDPE pipe provides superb abrasion resistance and superior fatigue resistance, which means fewer problems with water hammer. HDPE is flexible and lightweight, with superior tensile strength and flexibility. These characteristics of HDPE make the butt fusion welds as strong as the pipe. This benefits directional drilling and pipe bursting.

HDPE allows cold bending flexibility to follow "lay of the land" contours and reduce the need for directional fittings. HDPE does not rust, rot, corrode, or tuberculate. The HDPE piping is a fully restrained system without external tie rods or restraints. Butt fusion, flanged, and mechanical adapter joints are fully restrained to eliminate the need for thrust blocks and external joint restraints. The Average Daily Traffic (ADT) and large equipment loading over the pipe is a consideration when using HDPE. Engineered backfill and inspection, along with sufficient depth and manufacturer's recommended bedding and cover is required for the anticipated loads. HDPE pipe arrives on-site as a non-structure at about 10 percent of the installed system's required strength and requires proper contractor installation and fill materials to reach its manufacturer-specified service strength. HDPE does not have a long history of performance, yet the plastic pipe industry has made a claim that extrapolates a service life of nearly 100 years for some applications.

The installation and inspection of HDPE must be performed according to the manufacturer's specification and be in compliance with relevant standards. Because HDPE pipe transfers loading to the surrounding support soil, the type of backfill used, the width of the installation trench, and the resulting soil strength must be carefully determined, approved, and inspected during installation. Soil found to be extremely contaminated with hydrocarbons can result in pipe degradation.

Benefits & Effectiveness

The replacement of the below grade fire water distribution piping with HDPE allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of using HDPE on-site.

- HDPE is non-conductive. Therefore, cathodic protection is not required and is immune to stray ground currents for minimum long-term maintenance.
- HDPE is a fully restrained system without external tie rods or restraints. Butt fusion, flanged, and mechanical adapter joints are fully restrained to eliminate the need for thrust blocks and external joint restraints.
- HDPE allows cold bending flexibility to follow the "lay of the land" contours and reduce the need for directional fittings.
- HDPE pipe flow characteristics do not deteriorate over time. Therefore, design flows are maintained, and long-term pumping costs are minimized.
- HDPE is a fusion bonded pipe, allowing for fast installation.
- Operating sectionalizing valves not required; therefore, current fire water capability is not impaired.
- Condition of existing underground sectionalizing valves is not an issue.
- Replacing the entire fire water system will save time during constructability and allow for ease of operation and maintenance on the future system.

Risk & Mitigation Factors

Replacing the below grade fire water distribution piping with HDPE will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for HDPE with New Valves

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while removing and installing new pipe.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
ADT and large equipment loading over the pipe.	Specific criteria when using HDPE. Engineered backfill and inspection along with sufficient depth. A manufacturer recommended bedding and cover is required for the anticipated loads.	Medium - Medium	Medium Risk Hazard
Undetected pipe.	Provide detectable metal tape.	Medium - Medium	Medium Risk Hazard
Impact by equipment (backhoe).	Inspection prior to digging.	Medium - Medium	Medium Risk Hazard
Water hammer.	Fully restrained pipe network (flange).	Medium - Medium	Medium Risk Hazard

B. Cement Lined Carbon Steel Pipe Flanged – UL Listed

This alternative replaces the below grade fire water distribution with cement lined carbon steel. Cement lined carbon steel pipe assures extended physical and hydrostatic strength of the pipe and fittings. The pipe requires that all connections are welded. The protection provided by the cement lining can increase the effective life of the pipe, depending on its condition and environment.

Cement lining does not deteriorate over time like unlined piping. Z Spec pipe does require special coatings and cathodic protection to reduce corrosion to the outside of the pipe. Z Spec pipe is 100% welded and, therefore, is a fully restrained system without external tie rods or restraints. This eliminates the need for thrust blocks and external joint restraints. Z Spec pipe is UL listed and FM approved for fire service and is currently used at the site in areas of the meter skid and seven (7) caverns. Z Spec pipe has been used and found to be an excellent pipe for underground fire water systems at the DOE SPR sites. The construction of Big Hill incorporated Z Spec pipe into the design of the underground fire water system and has had good results. Replacing perma-strand with Z Spec pipe may require transition (mechanical joint to flange) at non-perma-strand pipe connections.

Benefits & Effectiveness

The replacement of the below grade fire water distribution piping with cement lined carbon steel allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of using Z Spec on-site.

- The construction of Big Hill incorporated Z Spec pipe into the design of the underground fire water system and has experienced good results.
- Z Spec piping assures the extended physical and hydrostatic strength of the pipe and fittings. The protection provided by the cement lining can increase the effective life of the pipe, depending on its condition and environment.
- Cement lining does not deteriorate over time. Therefore, the design flows are maintained.
- Z Spec piping is 100% welded and, therefore, a fully restrained system without external tie rods or restraints. This eliminates the need for thrust blocks and external joint restraints.
- The transition (flange to flange) from existing Z Spec pipe to new Z Spec pipe is not an issue.
- The ADT and large equipment loading over the pipe is not an issue.
- Operating sectionalizing valves are not required; therefore, current fire water capability is not impaired.
- The condition of the existing underground sectionalizing valves connections is not an issue.

Risk & Mitigation Factors

Replacing the below grade fire water distribution piping with cement lined carbon steel will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Cement Lined Carbon Steel with New Valves

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while removing and installing new pipe.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
Corrosion of pipe.	Wrap pipe and provide cathodic protection.	Medium - Medium	Medium Risk Hazard
Water hammer.	Fully restrained pipe network (flange) and welded connections.	Medium - Medium	Medium Risk Hazard

C. Ductile Iron Pipe Mechanical Joint – UL Listed

This alternative replaces the below grade fire water distribution with DI. DI is UL listed and FM approved for fire service. DI requires special coatings to reduce corrosion to the outside of the pipe.

DI piping assures extended physical and hydrostatic strength of the pipe and fittings. The protection provided by the cement mortar lining can increase the effective life of the pipe, depending on its condition and environment. The lining does not deteriorate over time.

DI pipe is a mechanical joint; therefore, it is not a fully restrained system unless special joint restraints are provided. DI will require thrust blocks due to it not being a fully restrained system. However, DI will not require transitions, making transitioning (mechanical joint to mechanical joint) from new DI pipe to existing hydrants connected to perma-strand a non-issue.

Benefits & Effectiveness

The replacement of the below grade fire water distribution piping with DI allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of using DI on-site.

- DI pipe assures extended physical and hydrostatic strength of the pipe and fittings.
- The protection provided by the enamel lining can increase the effective life of the pipe, depending on its condition and environment.
- The lining does not deteriorate over time. Therefore, design flows are maintained, and long-term pumping costs are minimized.
- ADT and large equipment loading over the pipe is not an issue.
- Operating sectionalizing valves are not required; therefore, current fire water capability is not impaired.
- The condition of the existing underground sectionalizing valve connections is not an issue.

Risk & Mitigation Factors

Replacing the below grade fire water distribution piping with DI will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Ductile Iron with New Valves

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while removing and installing new pipe.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
Corrosion of pipe.	Wrap pipe and provide cathodic protection.	Medium - Medium	Medium Risk Hazard
Water hammer.	Provide additional fully restrained pipe connections and/or add thrust blocks.	Medium - Medium	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. High Density Polyethylene - FM Approved

This alternative consists of replacing perma-strand pipe with HDPE pipe, along with new flanged, sectionalizing valves.

B. Cement Lined Carbon Steel Pipe Flanged - UL Listed

This alternative consists of replacing perma-strand pipe with cement lined carbon steel pipe, along with new flanged sectionalizing valves.

C. Ductile Iron Pipe Mechanical Joint - UL Listed

This alternative consists of replacing perma-strand pipe with DI pipe along with new mechanical joint sectionalizing valves.

Comparison of Alternatives

Core Team Member Ratings

	Safety During Construction	**Constructability During Ongoing Oil Deliveries**	**Ease of Operations**	**Ease of Maintenance**	**Security During Construction**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Good*	*Excellent*	*Good*	*Excellent*	*Excellent*
	Excellent	*Good*	*Good*	*Good*	*Excellent*	*Excellent*
	Good	*Good*	*Excellent*	*Good*	*Good*	*Good*
Alternative B	*Good*	*Adequate*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Good*	*Good*	*Good*	*Excellent*	*Excellent*
	Good	*Good*	*Excellent*	*Adequate*	*Good*	*Adequate*
Alternative C	*Good*	*Adequate*	*Excellent*	*Good*	*Excellent*	*Excellent*
	Excellent	*Adequate*	*Good*	*Good*	*Excellent*	*Excellent*
	Good	*Good*	*Excellent*	*Adequate*	*Good*	*Adequate*

Cost Comparison

	Total Estimated Cost (TEC)	Life Cycle Cost (LCC)
Alternative A	**$5,781,299**	**$5,781,299**
Alternative B	**$12,127,301**	**$12,172,574**
Alternative C	**$9,911,415**	**$9,956,688**

Recommended Alternative

A. High Density Polyethylene - FM Approved

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria. The initial cost and life cycle cost of Alternative A were both lowest of the alternatives. Therefore, Alternative A is the recommended preferred alternative based on both technical and cost factors studied in the alternative analysis.

BM-MM-1371

Heat Exchanger Bundle Spares

VCI Project Engineer: Lorna Madison

Recommended Alternative:

New Isolation Valves and Spare Tube Bundles (SeaCure)

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The heat exchangers at each Strategic Petroleum Reserve (SPR) site are mission critical. Without the heat exchangers the SPR drawdown capability is severely limited. The existing heat exchanger internal components (tube bundles) have been in service for over a decade and are subject to corrosion due to the properties of the available water sources. While the anticipated service life of the existing tube bundles is unknown and projections based on the analysis of corrosion coupons show an extended life, tube bundles in general suffer degradation over time such that individual bundles may need to be taken out of service for tube maintenance or repair. Irrespective of the service life predicted or achieved, an effective repair and replacement strategy must be developed. If the heat exchangers cannot be guaranteed reliable, taken out of service for repair, or replaced with readily available spare bundles, the SPR drawdown rate cannot be met, and the mission would be compromised.

Functional Requirements

- Heat exchanger tube bundle sparing when combined with material selection of spares and operating philosophy must provide design cooling capacity with 100% reliability during drawdown over the life of the Life Extension 2 (LE 2).
- Tube bundle material selection combined with bundle sparing should provide a 25-year service life.
- Spare tube bundles must fit into the existing exchanger shells and provide the same heat transfer, same flow capacity, and same or lower pressure drop as the original tube bundles.
- Positive shutoff isolation valves must be provided to isolate the exchangers to plug tubes in place and/or to replace tube bundles as required in support of the sparing philosophy.

FIGURE 1 – Heat Exchanger Tube Bundle Transport

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

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William Leet	VCI, Process Engineer
Lisa Eldredge	FFPO, Principal Operations System Engineer
Buddy Delaune	FFPO, Principal Mechanical Engineer
David Morrow	FFPO, Sr. Mechanical Engineer
Mike Cabiran	FFPO, Sr. Site Maintenance Engineer

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. Cooling capacity is critical to meeting mission needs. Current design cooling capacity must be met or exceeded. Tube bundle sparing must allow development of operating procedures designed to produce 100% cooling capacity on every drawdown over the 25-year life of LE 2 without the expectation of tube failures during a drawdown.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely. The site's ability to address safety and security concerns during implementation shall not be impacted. Project work plans must invoke SPR protocols to establish a safe work environment for all construction related activity.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. Spare tube bundles must fit existing exchanger shells with metallurgy compatible with service requirements to meet or exceed the 25-year life of LE 2.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve the Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. Exchanger bundle sparing should be minimized to reduce materials and energy consumption in support of sustainability goals.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

The Bryan Mound (BM) site is equipped with a network of twenty Crude Oil Coolers (Figures 2.1 & 2.2), which must cool 1,500,000 barrels per day of crude oil on drawdown using a raw water pumping rate of 1,545,000 barrels per day. The ability to satisfy the Level I design criterion for crude oil drawdown is jeopardized when one or more exchangers suffer simultaneous tube failures and are taken out of service.

The twenty Crude Oil Exchangers are arranged in a network which consists of five parallel trains of four exchangers with the latter arranged as two stacks of two exchangers in series and in parallel with each other. In this configuration, the exchangers are not equipped with means to isolate exchanger trains, pairs of stacked exchangers, or individual exchangers to plug leaking tubes such that the failure of a single tube at Bryan Mound will force suspension of a drawdown to address the leak. All 5 trains are equipped with single isolation gate valves on the crude oil and raw water inlet and outlets. None of these valves provide the positive shutoff required to safely isolate the exchangers during a drawdown to repair leaking tubes.

Currently the exchanger tube bundles are constructed of SeaCure tube material. This material is a high performance ferritic stainless steel. It was specifically developed as a lower cost alternative to titanium, which is resistant to chloride crevice corrosion and chloride pitting. Preliminary testing indicated that this metallurgy was a good choice for upgrading the original carbon steel (CS) tube bundles installed in the Crude Oil Coolers at Bryan Mound to address ongoing corrosion issues with under deposit pitting observed with stagnate brackish water and biological growth in the exchanger bundles. The original CS tube bundles were replaced with SeaCure tube bundles to overcome the rapid tube bundle corrosion failures experienced with the original CS tube bundles. The SeaCure tube bundles have been in service for more than 10 years with no loss of performance. Monitoring has shown no significant increase in pressure drop across the exchanger shell and tubes. No leaks have been observed in the field. However, this constitutes limited history with respect to service life from which to project remaining tube bundle life. Given the progressive nature of corrosion and the lack of data to project remaining tube life, the reliability of the Crude Oil Coolers is subject to question. This introduces some risk in continuing to reliably operate the Bryan Mound site to the Level I drawdown rate of 1,500,000 barrels per day over the next 25 years.

The Crude Oil Coolers at Bryan Mound are identical in size and design to those installed at the West Hackberry and Bayou Choctaw SPR sites. In developing a sparing philosophy for the Bryan Mound exchanger tube bundles, consideration should be given to sparing bundles on-site and among these three SPR sites to provide effective, timely response to manage the potential impact of tube bundle failures on drawdown schedules.

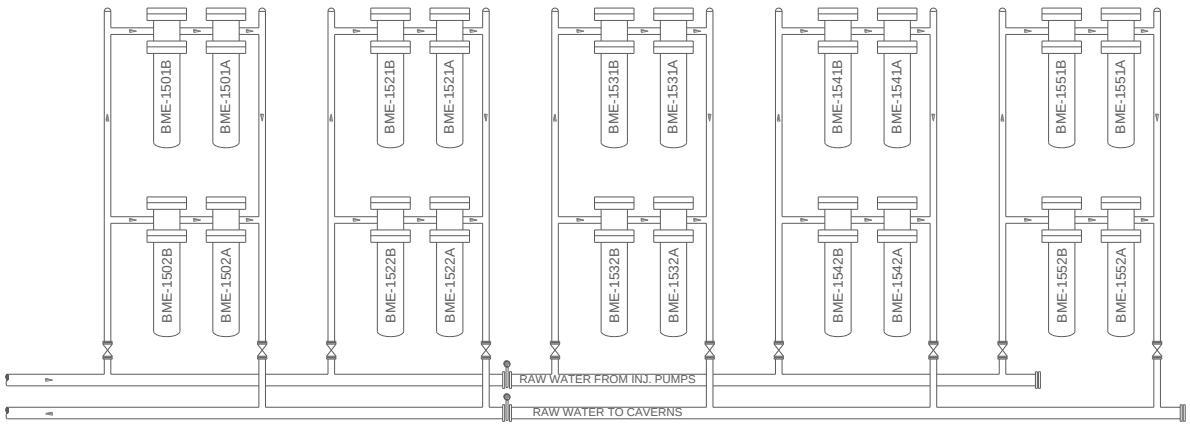

FIGURE 2.1 – Raw Water Heat Exchanger Tube Bundles

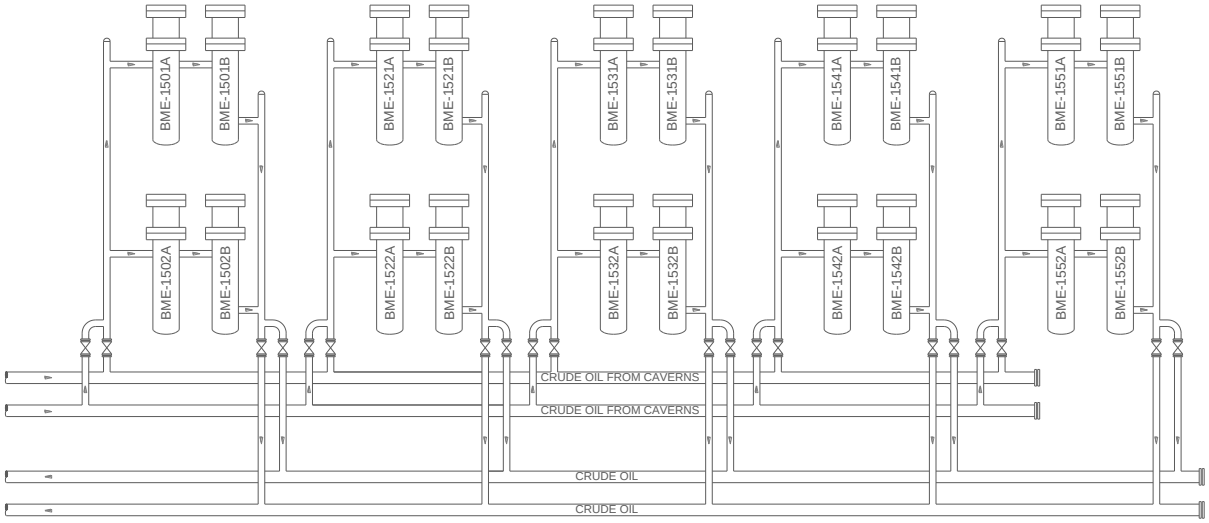

FIGURE 2.2 – Crude Oil Heat Exchanger Tube Bundles

1. Alternatives for Sparing Heat Exchanger Tube Bundles

The project scope of work is set by considering alternatives for how the existing Crude Oil Coolers are best spared.

A. Status Quo

The status quo is to maintain the existing system in place without providing spare tube bundles.

The existing SeaCure tube bundles have performed well over the last 10-16 years of service with little evidence of deterioration in performance. This alloy was specifically chosen for applications where localized corrosion in chloride-containing waters is an issue. However, insufficient data has been collected to project the remaining useful life of these exchangers to determine whether the SeaCure tube bundles will last another 25 years.

The existing heat exchangers are not equipped with isolation valves, which can provide positive shutoff on the crude oil and raw water (cooling water) sides to facilitate isolation of exchanger trains, stacked

exchanger pairs, or individual exchangers to identify and repair tube leaks. A tube leak will compromise drawdown operation by reducing effective cooling capacity and allowing the higher pressure raw water to leak into the exported crude oil, pushing the crude oil off spec on high basic sediment and water (BS&W). To address a tube leak, the drawdown must be suspended to take the entire heat exchanger network out of service to locate and repair the tube leak. The time it takes to effect repairs in this way will delay drawdown to the detriment of the drawdown schedule. Given the nature of corrosion, the risk increases of jeopardizing the mission by failing to plan a tube bundle sparing philosophy to address corrosion and preserve drawdown capability over the next 25 years.

Viability: No Further Analysis

B. New Isolation Valves Without Spare Tube Bundles

This alternative consists of maintaining the heat exchanger network in place without providing spare tube bundles. Instead, isolation valves will be provided in the appropriate numbers and placement for each stacked exchanger pair on both the crude oil and raw water inlets and outlets to permit isolation of any one of the 10 pairs of exchangers which suffers a tube failure.

Installation of isolation valves facilitates isolation of stacked exchanger pairs before drawdown or on the run during a drawdown operation. Isolation from service allows for opening of the isolated exchanger pairs to effect repairs and plug tubes should they fail a fitness for service test to more quickly repair and return an exchanger to service before drawdown. These isolation valves also provide the capability to identify and isolate a leak in any one stacked exchanger pair during drawdown to eliminate the leak and proceed with drawdown at a lower rate. Single isolation valves are already provided on all the crude oil and raw water inlet and outlet lines. However, the single valves do not provide the positive shutoff required for safely working with the exchangers. Based on first look, 40 new isolation valves would have to be added to upgrade all 20 exchangers for safe, positive isolation of stacked exchanger pairs. The preferred configuration leads to installation of true double block and bleed isolation capability upstream and downstream of each exchanger on both the crude oil and water sides.

Given the nature of corrosion and the increasing frequency of tube bundle failures over time, the risk increases of jeopardizing the mission by failing to actually stage spare bundles to replace tube bundles. This accumulates too many tube plugging repairs such that the available heat transfer area is no longer adequate to preserve cooling capacity for drawdown.

Viability: No Further Analysis

C. New Isolation Valves and Spare Tube Bundles

This alternative consists of maintaining the existing system in place and providing appropriate numbers and placement of valves for isolation of each stacked exchanger pair. Also, a number of spare tube bundles will need to be provided so exchangers can be quickly repaired by plugging failed tubes or replacing tube bundles with spares on hand following the discovery of failures during fitness for service testing prior to drawdown.

The effectiveness of plugging individual tubes is limited in the face of progressive tube failures due to corrosion, leading to continued loss of effective heat transfer area in the exchanger and exchanger capacity. Having spare tube bundles available provides for full tube bundle replacement to restore full heat transfer surface area to avoid reducing drawdown rates below the Level I criterion. Purchase of 2 spare bundles for Bryan Mound is recommended for insurance against tube bundle leaks. This amounts to 50% sparing of one single exchanger train or 10% of the total exchanger tube bundle count. The purchase of 2 spare bundles provides insurance against leakage of a new bundle on initial installation. It also provides contingency against storage and handling damage to the new spare bundles.

As part of the bundle sparing philosophy across SPR sites, the 2 spare bundles purchased for the West Hackberry site can be imported in an emergency along with the 2 bundles purchased for Bryan Mound to bring the initial spare count to 4 bundles. This amounts to initially sparing 100% of one single exchanger train or 20% of the total exchanger tube bundle count. Sparing with 4 bundles in this fashion should provide sufficient time to fabricate and deliver additional tube bundles to address any unforeseen increase in corrosion rate or bundle deterioration towards the end of LE 2.

Viability: Continue Analysis

D. Spare Tube Bundles Without New Isolation Valves

This alternative consists of maintaining the existing system in place and providing a number of spare tube bundles, so the tube bundles in an entire train of exchangers can be replaced with new bundles should failures be experienced preceding drawdown. The purchase of 2 spare tube bundles for Bryan Mound is recommended as noted in alternative C above.

The ease and effectiveness with which individual heat exchanger tube leaks can be isolated and repaired prior to drawdown or during drawdown is compromised by failure to install the proper crude oil inlet and outlet isolation valves cited in alternative C above.

Viability: No Further Analysis

2. Alternatives for Tube Bundle Materials Selection

The project scope of work is set by considering alternatives for materials of construction for the spare tube bundles.

A. Status Quo - SeaCure

Ferritic Stainless Steel (SeaCure) is a high performance stainless steel that can be used as an alternative to copper-nickel and titanium tubing. SeaCure is a high strength/low work material with good ductility. This alloy is specifically fabricated for applications where localized corrosion in chloride-containing waters is an issue. While performance data is not widely available for SeaCure in similar applications, the installed SeaCure tube bundles have performed admirably in service at Bryan Mound relative to their failure prone carbon steel predecessors with little evidence of significant deterioration to date.

Viability: Continue Analysis

B. Austenitic Stainless AL-6XN

Austenitic Stainless AL-6XN is a low carbon, high purity austenitic stainless alloy, which is designed to be a seawater resistant material. High nickel and molybdenum contents make AL-6XN an answer to chloride ion stress corrosion cracking. Whereas, the nitrogen content allows AL-6XN to have a greater tensile strength, while retaining high ductility and impact strength. AL-6XN is a relatively new offering for this service with limited performance data with respect to the corrosion mechanisms witnessed at Bryan Mound.

Viability: No Further Analysis

C. Super Duplex Stainless 2507

Super Duplex Stainless 2507 is a chromium, molybdenum, and nickel based alloy, which has exceptional strength and corrosion resistance. Duplex 2507 exhibits excellent resistance to chloride stress corrosion cracking and pitting, making this material good for seawater application. Super Duplex Stainless 2507 is a relatively new offering for this service with limited performance data with respect to the corrosion mechanisms witnessed at Bryan Mound.

Viability: No Further Analysis

D. Titanium

Titanium (Grade 2) is a high titanium alloy that possesses good weldability, strength, ductility, and formability. Titanium (Grade 2) is typically used in applications where corrosion resistance is required for various aggressive materials. This material is resistant to high chloride content and service life may extend beyond the LE 2 25-year life requirement. Titanium may be more susceptible to flow induced vibration and failure for the wide variation in flow experienced at Bryan Mound without careful exchanger design. Nonetheless, titanium has a track record of successful application in high chloride service such as seawater dating back over 40 years.

The substitution of titanium for SeaCure requires repeating the Heat Transfer Research, Inc. (HTRI) software calculation to determine heat exchange rate, placement of baffles, tube wall thickness and minimum bend radius for tubes. A material change would also require redesign of the tubesheet and the tube to tubesheet welding, currently designed for welding ferritic stainless tubes to the tubesheet. All would be required because the strength, elongation, minimum bend radius and welding of Titanium is different from that of Ferritic Stainless steel.

Viability: Continue Analysis

E. Inconel

Inconel (Alloy 22) is a fully austenitic nickel based alloy, which exhibits excellent resistance to corrosive attacks by seawater, stress corrosion cracking, pitting, general corrosion, and crevice corrosion. Inconel is engineered to offer a combination of heat resistance, high temperature corrosion resistance, toughness, and strength. However, Inconel has limited performance data with respect to the corrosion mechanisms witnessed at Bryan Mound.

Viability: No Further Analysis

V. ALTERNATIVES ANALYSIS

Initial screening reduces the viable alternatives to providing new isolation valves and spare tube bundles with the bundles fabricated from SeaCure or titanium for further analysis. These alternatives are examined below as Alternatives A and B.

Assumptions & Constraints

- Even though the manufacturer reports that it has never experienced a failure in designed service of the SeaCure material which has been around since 1978, there currently is insufficient data available to estimate the remaining life of the tube bundles currently in place to provide assurance of 100% reliability during drawdowns without bundle replacements over the next 25 years of service.
- SeaCure tube metallurgy is field proven in the current service to a life of 10-16 years, based on SPR experience with SeaCure tube bundles across sites.
- No data has been collected to date which justifies a change in tube bundle metallurgy from SeaCure.
- Even though Titanium metallurgy is field proven in the current service by 40+ years of industrial experience apart from the SPR, a level of unreliability is introduced for SPR service by having to repeat the HTRI calculation to determine heat exchange rate, placement of baffles, tube wall thickness and minimum bend radius for tubes and by the redesign of the tubesheet and the tube to tubesheet welding.
- Lead times on fabrication of spare tube bundles are excessive such that replacement bundles must be inventoried to quickly address tube failures when discovered to initiate drawdown.
- Tube bundle and tube plug procurement and inventory must be managed effectively to provide the repair and replacement parts in time to initiate drawdowns.
- The purchase of 2 spare tube bundles provides sufficient insurance to spare the 20 exchangers on-site at Bryan Mound, following installation of isolation valves for each of the 10 stacked pairs of exchangers.
- Sparing of exchangers among sites is possible given that the existing tube bundles at Bryan Mound are interchangeable with those at the West Hackberry and Bayou Choctaw sites.
- Detailed design will request to have all HTRI calculations redone by the vendor in order to determine if any issues exist like vibration problems with the tubing. It is also recommended that a third party verify the accuracy of the calculations/findings.

Sparing Philosophy

The basic philosophy for sparing Crude Oil Cooler tube bundles against leaks follows the following logical progression of steps:

- Conduct periodic inspection and fitness for service testing to assess exchanger readiness for drawdown service and provide early indication and repair of potential tube failures.
- Monitor exchanger pressure drops in the field for an indication of increased pressure drop or tube failure to provide early indication and repair of potential tube failures.
- Isolate and test individual exchangers for leaks when leaks occur. Pull heads and plug up to 8-10% of tubes as leaks are discovered to repair leaks and return exchangers to service.
- Replace leaking tube bundles with spare bundles purchased for site if more than 8-10% of tubes require plugging in any one exchanger to address leaks. Recondition pulled bundles as spares, following replacement.
- Replace leaking tube bundles with spare bundles from other SPR sites if more than 2 spare bundles are required to address leaks. Recondition pulled bundles as spares, following replacement.
- Purchase additional replacement bundles for fabrication when inventory of spare bundles is depleted.

A. New Isolation Valves and Spare Tube Bundles (SeaCure)

This alternative would add isolation valves to provide proper isolation capability on the crude oil side and cooling water side isolation of individual exchangers to facilitate on-site repair and bundle replacement of tube bundles, which fail fitness for service testing prior to drawdown in timely fashion. This alternative would also provide a number of spare SeaCure tube bundles to replace leaking tube bundles should failures precede drawdown or during drawdown.

Benefits & Effectiveness

This alternative will allow for the effective management of Crude Oil Cooler tube bundle life in the face of progressive corrosion of indeterminate rate over the next 25 years of operation based on the performance of SeaCure tube metallurgy observed on-site over the last 10 years of operation.

Installing crude oil side and water side isolation capability on each individual heat exchanger allows for quick isolation, opening, and repair of tube bundles when they fail the pressure step fitness for service testing conducted prior to each drawdown or for isolation of leaking bundles. The installation of the isolation block valves also provides the capability to isolate a leaking tube bundle when the leak is detected during drawdown to proceed with drawdown at a reduced rate.

As discussed previously, purchasing and staging of 2 spare bundles for Bryan Mound provides sufficient insurance to quickly replace 2 of 20 tube bundles (the equivalent of 20% one train or 10% of the total exchanger count) upon discovery of tube failure or one too many repairs by plugging tubes to preserve cooling capacity to the Level I drawdown criterion. Sharing spares with the West Hackberry and Bayou Choctaw sites increases the options available to Bryan Mound to address tube bundle leak issues

Specification of SeaCure metallurgy for the tubes in the bundle provides a service life greater than 10-16 years based upon SeaCure tube bundle performance witnessed to date across the SPR sites. This is expected to provide sufficient life to see Bryan Mound through the next 25 years with selective replacement of any failed tube bundles. In specifying the same metallurgy in use at Bryan Mound today, procurement, inventory, and maintenance procedures are simplified to working with familiar metallurgy.

The Bryan Mound site will be able to meet the required Level I drawdown rate of 1,500,000 barrels per day.

Risk & Mitigation Factors

There are associated risks with the installation of new isolation valves and spare SeaCure tube bundles option. The table below summarizes risks with the correlation mitigation strategy. The table also describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for New Isolation Valves and Spare Tube Bundles (SeaCure)

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Existing SeaCure tube bundle remaining life is indeterminate.	Pursue more aggressive corrosion monitoring and fitness for service testing on-site at Bryan Mound to project remaining life of existing tube bundles.	High - High	High Risk Hazard
Existing SeaCure tube bundle life is shorter than expected.	Restrict life forecast to what has been observed in the field to date and proceed with collection of data to properly estimate remaining life as noted above.	Medium - High	Medium Risk Hazard
Existing or spare tube bundle life is shortened by mishandling of individual tube bundles.	Revisit special handling procedures to cope with size and weight of bundles during handling and with the effects of the thin tube wall design to avoid damaging a bundle, which may trigger additional bundle purchase.	High - High	High Risk Hazard
Spare tube bundle life is shortened by improper bundle storage.	Work with fabricator to specify proper bundle storage and handling practices in advance of purchase of spare bundles. Implement best practices.	High - High	High Risk Hazard

Risk and Mitigation Strategies for New Isolation Valves and Spare Tube Bundles (SeaCure) (Continued)			
Risks	**Mitigation Strategy**	**Likelihood - Impact**	**Risk Code**
Tube bundle sparing count is low.	Rework the exchanger bundle repair and sparing plan in greater detail as remaining life calculations are completed to assess spare bundle count. Work to expand sparing philosophy across SPR sites.	Medium - High	Medium Risk Hazard
Lead time on tube bundle fabrication is long.	Assume lead time is long and pursue procurement and proper layup of new bundles in storage within short order of approval of funds for project.	High - Low	Low Risk Hazard
Metals price for parts fabricated from SeaCure is highly variable over time.	Include allowance in cost estimate for future price increases. Request pricing for both SeaCure and titanium in requests for proposal for fabrication of spare exchanger tube bundles to ensure competitive pricing.	High - High	High Risk Hazard
Mix-up on tube bundle replacement parts in storage.	Risk mitigated by specifying and stocking only SeaCure plugs for exchanger tube bundle repairs.	Low - Low	Low Risk Hazard
Valves called out in SPR piping specs are no longer commercially available.	Verify commercial availability of valves called out in SPR piping standards before specifying valves for purchase.	High - High	High Risk Hazard
Lead time on isolation block valve delivery is long.	Procure isolation block valves within short order of approval of funds for project.	High - High	High Risk Hazard
Safety Incidents during installation of isolation block valves.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during construction.	Medium - High	Medium Risk Hazard
Safety incidents during heat exchanger bundle repairs or bundle replacements.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

B. New Isolation Valves and Spare Tube Bundles (Titanium)

This alternative would add isolation valves to provide proper isolation capability on the crude oil side and cooling water side isolation of individual exchangers to facilitate on-site repair and bundle replacement of tube bundles, which fail fitness for service testing prior to drawdown in timely fashion. This alternative would also provide a number of spare titanium tube bundles to replace leaking tube bundles should failures precede drawdown or during drawdown.

Benefits & Effectiveness

This alternative will allow for the effective management of Crude Oil Cooler tube bundle life in the face of progressive corrosion of indeterminate rate over the next 25 years of operation based on industrial performance of titanium tube metallurgy observed 40+ years of operation.

Installing crude oil side and water side isolation capability on each individual heat exchanger allows for quick isolation, opening, and repair of tube bundles when they fail the pressure step fitness for service testing conducted prior to each drawdown or for isolation of leaking bundles. The installation of the isolation block valves also provides the capability to isolate a leaking tube bundle when the leak is detected during drawdown to proceed with drawdown at a reduced rate.

As discussed previously, purchasing and staging of 2 spare bundles for Bryan Mound provides sufficient insurance to quickly replace 2 of 20 tube bundles (the equivalent of 20% one train or 10% of the total exchanger count) upon discovery of tube failure or one too many repairs by plugging tubes to preserve cooling capacity to the Level I drawdown criterion. Sharing spares with the Bayou Choctaw and West Hackberry sites increases the options available to Bryan Mound to address tube bundle leak issues.

Specification of titanium metallurgy for the tubes in the bundle provides a service life of 15-20 years based upon similar industrial experience. This is believed to provide sufficient life to see Bryan Mound through the next 25 years with selective replacement of any failed tube bundles. However, selecting titanium complicates the storage and handling of replacement exchanger parts as this metallurgy is not familiar to Bryan Mound.

The Bryan Mound site will be able to meet the required Level I drawdown rate of 1,500,000 barrels per day.

Risk & Mitigation Factors

There are associated risks with the installation of new isolation valves and spare titanium tube bundles option. The table below summarizes risks with the correlation mitigation strategy. The table also describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for New Isolation Valves and Spare Tube Bundles (Titanium)

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Existing SeaCure tube bundle remaining life is indeterminate.	Pursue more aggressive corrosion monitoring and fitness for service testing on-site at Bryan Mound to project remaining life of existing tube bundles.	High - High	High Risk Hazard
Existing SeaCure tube bundle life is shorter than expected.	Restrict life forecast to what has been observed in the field to date and proceed with collection of data to properly estimate remaining life as noted above.	Medium - High	Medium Risk Hazard
Tube bundle life is shortened by mishandling of individual tube bundles.	Revisit special handling procedures to cope with size and weight of bundles during handling and with the effects of the thin tube wall design to avoid damaging a bundle, which may trigger additional bundle purchase.	High - High	High Risk Hazard
Spare tube bundle life is shortened by improper bundle storage.	Work with fabricator to specify proper bundle storage and handling practices in advance of purchase of spare bundles. Implement best practices.	High - High	High Risk Hazard

Risk and Mitigation Strategies for New Isolation Valves and Spare Tube Bundles (Titanium) (continued)			
Risks	**Mitigation Strategy**	**Likelihood - Impact**	**Risk Code**
Tube bundle sparing count is low.	Rework the exchanger bundle repair and sparing plan in greater detail as remaining life calculations are completed to assess spare bundle count. Work to expand sparing philosophy across SPR sites.	Medium - High	Medium Risk Hazard
Lead time on tube bundle fabrication is long.	Assume lead time is long and pursue procurement and proper layup of new bundles in storage within short order of approval of funds for project.	High - Low	Low Risk Hazard
Metals price for parts fabricated from titanium is highly variable over time.	Include allowance in cost estimate for future price increases. Request pricing for both SeaCure and titanium in requests for proposal for fabrication of spare exchanger tube bundles to ensure competitive pricing.	High - High	High Risk Hazard
Mix-up on tube bundle replacement parts in storage.	Provide for segregation of SeaCure and titanium plugs for exchanger tube bundle repairs.	Low - Low	Low Risk Hazard
Valves called out in SPR piping specs are no longer commercially available.	Verify commercial availability of valves called out in SPR piping standards before specifying valves for purchase.	High - High	High Risk Hazard
Lead time on isolation block valve delivery is long.	Procure isolation block valves within short order of approval of funds for project.	High - High	High Risk Hazard
Safety Incidents during installation of isolation block valves.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during construction.	Medium - High	Medium Risk Hazard
Safety incidents during heat exchanger bundle repairs or bundle replacements.	Adhere to project safety guidelines in accord with the Federal & Industry Safety Standards during maintenance operations.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. New Isolation Valves and Spare Tube Bundles (SeaCure)

This alternative would add isolation valves to provide proper isolation capability on the crude oil side and cooling water side isolation of individual exchangers to facilitate on-site repair and bundle replacement of tube bundles, which fail fitness for service testing prior to drawdown in timely fashion. This alternative would also provide a number of spare SeaCure tube bundles to replace leaking tube bundles should failures precede drawdown or during drawdown.

B. New Isolation Valves and Spare Tube Bundles (Titanium)

This alternative would add isolation valves to provide proper isolation capability on the crude oil side and cooling water side isolation of individual exchangers to facilitate on-site repair and bundle replacement of tube bundles, which fail fitness for service testing prior to drawdown in timely fashion. This alternative would also provide a number of spare titanium tube bundles to replace leaking tube bundles should failures precede drawdown or during drawdown.

Comparison of Alternatives

Core Team Member Ratings

	Safety During Construction	**Ease of Operations**	**Ease of Maintenance**	**Sustainability**
	Most Important	*Most Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*
Alternative B	*Excellent*	*Excellent*	*Good*	*Excellent*
	Excellent	*Excellent*	*Good*	*Excellent*
	Excellent	*Excellent*	*Adequate*	*Excellent*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$4,965,437**	**$12,558,523**
Alternative B	**$4,749,669**	**$12,342,755**

Recommended Alternative

A. New Isolation Valves and Spare Tube Bundles (SeaCure)

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria, and in fact received the highest rating on every factor by all Core Team Members. Alternative B has a slightly lower investment cost and life cycle cost. The key deciding factor between alternatives consistency in materials with currently proven technology that is shown in the higher ratings on ease of maintenance. Therefore, Alternative A is the recommended preferred alternative, with the benefits of material and maintenance considerations outweighing the slightly higher investment and life cycle cost.

BM-MM-1462

Replace Oil-in-Water Monitors

VCI Project Engineer: Lorna Madison

Recommended Alternative:

New UV Fluorescence Monitors

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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Core Team Member Ratings: 10
Cost Comparison: 11

Recommended Alternative 11

I. PROJECT CONCEPT

Mission Need

The Oil-in-Water Monitor Instrumentation installed in the Brine Return Line at Bryan Mound (BM) must be replaced in order to detect and eliminate oil breakthrough into the Brine Pond and subsequent oil carryover into the remainder of the brine handling system in order to address environmental and safety standards.

Functional Requirements

The following are the functional requirements for the replacement of the Oil-in-Water Monitor at Bryan Mound:

- Monitors must be installed farther upstream than the current monitor in cavern header piping for individual wellheads to provide early warning and timely response to oil breakthrough due to wellhead string failure in order to minimize site environmental impact.
- Monitor selection shall provide the sensitivity required to detect initial oil breakthrough from any one cavern wellhead.
- Monitor selection shall provide for robust, reliable operation with minimum inspection, calibration, and repair activity over the estimated 25-year life of the Life Extension 2 (LE 2).
- Monitor installation plans shall consider providing alternative means of cavern depressurization/fill in a safe manner during installation.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Lorna Madison	VCI, Project Engineer
Stephen Brothers	FFPO, Principal Operations System Engineer

Team Members

Anthony Bonadona	VCI, Project Engineer
Ed Orloski	VCI, Process Engineer
William Leet	VCI, Process Engineer
Rachel Gray	VCI, Process Engineer
Lisa Eldredge	FFPO, Principal Operations System Engineer
Buddy Delaune	FFPO, Principal Mechanical Engineer
Randy Bridges	FFPO, Process and Security Systems Control
Bob Sevcik	FFPO, Director - Environmental Department
Mike Cabiran	FFPO, Sr. Site Maintenance Engineer

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as necessary to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate alternatives and select a recommendation.

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment. Monitors must be installed farther upstream than the current monitor in cavern header piping at the individual wellheads to provide early warning and timely response to oil breakthrough to minimize environmental impact. Monitor selection shall provide the sensitivity required to detect initial oil breakthrough from any one cavern wellhead.

Weight: Most Important

Ease of Maintenance

The selected alternative features technology which exhibits the necessary detector sensitivity and compatibility with existing controls' hardware and which can be readily serviced and maintained on-site alongside existing equipment. Monitor selection shall provide for robust, reliable operation with minimum inspection, calibration, and repair activity over the estimated 25-year life of LE 2.

Weight: Most Important

Safety during Construction

The selected alternative when implemented will be able to be constructed and operated safely and have the ability to address Safety and Security concerns during implementation. A robust contractor work plan shall be vetted by the Government for all safety concerns that might be of note during construction.

Weight: Most Important

Constructability during Ongoing Oil Deliveries

The selected alternative is able to be implemented with little or no impact to ongoing oil delivery operations. Close coordination with the Site Security Specialist and site/maintenance operations will allow for minimal impact on oil delivery operations. Monitor installation plans shall consider providing alternative means of cavern depressurization/fill in a safe manner during installation.

Weight: Important

Sustainability

The selected alternative when implemented will be able to achieve the Department of Energy (DOE) sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. Water monitors/interface instrumentation installed in the brine return line at the Bryan Mound site shall be replaced in order to ensure that the required oil/hydrocarbon content criteria in the brine pond are met.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

The status quo consists of continuing to use the existing Oil-in-Water monitor at Bryan Mound.

Current practice for detecting oil breakthrough to the brine side on cavern wellhead string failure in time to prevent significant oil contamination of the brine system is not effective. Operators are trained to successfully to check for pressure equalization across the wellhead to detect a string break in a blocked-in, no-flow scenario. However, the currently installed instrumentation for detection of oil breakthrough under flowing conditions is not effective. The currently installed system has failed to detect entrained oil content in the header system multiple times due to issues with monitor type, monitor installation, monitor

maintenance, and installed location of the monitor. Based on experience to date, the single monitor is currently installed too close to the end of the line into the brine pond to protect the brine piping from accumulating significant quantities of oil with breakthrough of that oil into the brine pond where it registers as an environmental excursion. Continuing to operate the existing Oil-in-Water Monitor does nothing to reduce the incidence of environmental excursion with oil breakthrough into the brine pond and downstream brine systems.

Viability: No Further Analysis

B. Flowmeters

This alternative consists of conducting a pilot study using the existing flowmeters on site to see if they can detect oil in water. This pilot study would be conducted before any other alternative being pursued to monitor oil in water. The flowmeters are already installed on-site. The pilot study is pending.

Should the pilot study determine that the flowmeters are not capable of detecting oil in water, then an alternative technology would be selected from the list below to pursue reliable detection of oil in water. Alternate technology selection necessitates a second pilot test to prove the capabilities of the alternate technology in the field.

Viability: Continue Analysis

C. New UV Fluorescence Monitors

This alternative consists of installing new ultraviolet (UV) fluorescence based monitors at individual wellheads to provide for early detection and response to oil breakthrough into the brine header at each wellhead. Brine quality, line velocity, temperature, suspended solids, and organic matter do not affect measurement by UV fluorescence based monitors. These monitors are highly accurate, providing instantaneous and continuous measurement. They have the required sensitivity with range of detection from 0–10 parts per million (ppm) to 0–150 ppm oil-in-water. They are self-cleaning and require low maintenance. They are available for an in-line and a loop/side stream type installation.

Viability: Continue Analysis

D. New UV Absorption Monitors

This alternative consists of installing new UV absorption based monitors at individual wellheads to provide for early detection and response to oil breakthrough into the brine header at each wellhead. The presence of organic materials including bacteria, yeast, and algae will interfere with the performance of these meters. Compensation, filtering, or frequent zeroing is required to successfully operate these monitors. This monitor type cannot be recommended as a reliable Oil-in-Water Monitor for Bryan Mound brine operations on account of these potential interferences and the extra care required to maintain performance of this instrument in service.

Viability: No Further Analysis

E. New Calorimetry Monitors

This alternative consists of replacing the existing monitor/system with calorimetry based monitors at individual wellheads to provide for early detection and response to oil breakthrough into the brine header at each wellhead. The presence of solids will interfere with the performance of these meters. Compensation, filtering, or frequent zeroing is required to successfully operate these meters. Catalyst addition is required for color transformation/recognition, and a database of standards of colors must be collected and defined for each different hydrocarbon and application. Moreover, this does not provide the user with the ppm oil detection sensitivity required.

Viability: No Further Analysis

F. New Light Scatter Monitors

This alternative consists of replacing the existing monitor/system with nephelometry (light scatter) based monitors at individual wellheads to provide for early detection and response to oil breakthrough into the brine header at each wellhead. The presence of solids, trace chemicals, and color bodies will interfere with the performance of these meters in the absence of sample stabilization to give a false high hydrocarbon reading. Compensation and filtering techniques are required to offset potential interferences. This monitor type cannot be recommended as a reliable Oil-in-Water Monitor for Bryan Mound brine operations.

Viability: No Further Analysis

G. New Microscopy Monitors

This alternative consists of replacing the existing monitor/system with microscopy (imaging) based monitors at individual wellheads to provide for early detection and response to oil breakthrough into the brine header at each wellhead. Brine quality, line velocity, temperature, suspended solids, and organic matter do not affect measurement of these monitors. These monitors are highly accurate, providing instantaneous and continuous measurement. They have the required sensitivity with range of detection of up to 1000 ppm oil-in-water and the ability to detect particle and droplet size information e.g. Dv10, Dv50, and Dv90 data. The above features can be combined with other analyses like florescence and spectral analyses for the best available reliability in measurement techniques.

Viability: Continue Analysis

H. New Radar, Acoustic, Capacitance, or Energy Absorption Monitors

This alternative focuses on alternative technology selection from a list of options which are typically characteristic of interface level control and not oil-in-water measurement. This includes options such as radar, microwave, acoustic, and capacitance, energy absorption, etc. The monitor of choice among these would be installed at each individual wellhead to provide for early detection and response to oil breakthrough into the brine header at each wellhead. The presence of solids and organics will interfere with the performance of these meters. Compensation, filtering, recalibration, or frequent zeroing is required to successfully operate these meters. These meters lack the required sensitivity for gaging oil breakthrough. They typically measure oil concentrations on the percent level rather than the ppm level desired for detecting oil breakthrough. These meters are better suited to gaging oil water interface levels than for detecting oil entrainment into system flows. These monitor types cannot be recommended for reliable oil-in-water monitoring service for Bryan Mound brine operations.

Viability: No Further Analysis

I. New Technology

This alternative consists of replacing the existing monitor/system with new technology that is still in its testing phase such as laser-based monitors. Although newer technology may be available, insufficient field testing has been performed and communicated to establish such technology as commercially reliable and robust options for application here. Therefore, new technology lacking full proving in the field is not considered a viable alternative here.

Viability: No Further Analysis

V. ALTERNATIVES ANALYSIS

Based on the initial analysis of the alternatives, alternatives A, D, E, F, H and I are eliminated from further consideration. The remaining alternatives, B, C, and G, are examined below as alternatives A, B, and C, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

Common Assumptions & Constraints

- Monitor selection will provide for robust, reliable operation with minimum inspection, calibration, and repair activity over the estimated 25-year life of the Life Extension 2 (LE 2).
- Monitors will be installed farther upstream than the current monitor in cavern header piping at the individual wellheads to provide early warning and timely response to oil breakthrough due to wellhead string failure to minimize site environmental impact.
- Monitor selection will provide the sensitivity required to detect initial oil breakthrough from any one cavern wellhead.
- Monitor installation plans will consider providing alternative means of cavern depressurization/fill in a safe manner during installation.
- Monitors will meet the required environmental and safety standards.

A. Flowmeters

This alternative will evaluate the existing installed flowmeters to detect oil in water under flowing conditions.

Assumptions & Constraints

- The flowmeters are installed and fully operational.
- The flowmeters will be performance tested in the field to confirm whether they can reliably detect oil breakthrough into water.
- The flowmeter pilot study will be conducted first before any alternative technology is considered.
- If the flowmeter fails to detect oil in water, the next best alternative from the list of alternatives below will be selected, and a pilot test will be performed to determine its viability.

Benefits & Effectiveness

The use of the current flowmeters installed at the site allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of conducting a pilot test and using the current flowmeters.

- The pilot test will allow the site to test whether current equipment installed on-site is able to detect oil in water.
- If the pilot test shows that the flowmeters are adequate, no new equipment will need to be purchased.

Risk & Mitigation Factors

Conducting a pilot test on the currently installed flowmeters will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Using the Flowmeters/Conducting a Pilot Test

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while conducting the pilot test.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
Flowmeters do not reliably detect oil in water.	Conduct performance test in the field to establish whether they work. If they don't provide the desired results, proceed with selection and testing of alternative technology.	Medium - Medium	Medium Risk Hazard

B. New UV Fluorescence Monitors

This alternative will replace the existing monitors/system with UV fluorescence based monitors/system.

Assumptions & Constraints

Assumptions:

- New ultraviolet UV fluorescence monitors are installed at each individual wellhead.
- The monitors can detect from 0–10 parts per million (ppm) to 0–150 ppm oil-in-water.
- UV florescence monitors are self-cleaning and low maintenance.

Constraints:

- Meter recalibration may be required from time to time for changes in ratios of Aliphatic/Aromatic vs. Total Hydrocarbon (HC).
- Performance testing of a single monitor installed in the field is required to confirm this technology selection before committing to purchase of additional monitors.
- Monitor life requires periodic field servicing and periodic replacement over the estimated 25-year life of the Life Extension 2 (LE 2).

Benefits & Effectiveness

The replacement of the existing monitors/system with UV fluorescence based monitors/system allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of installing new monitors/system on-site.

- The UV fluorescence based monitors/system will eliminate the risk of getting oil into the brine pond.
- Process Parameters, Total Suspended Solids (TSS), and Organic Matter cannot influence or affect the measurement of UV fluorescence based monitors.
- The monitors/system are highly accurate, providing instantaneous and continuous measurement.
- The monitor/system have a good range of detection from 0–10 parts per million (ppm) to 0–150 ppm oil-in-water.

Risk & Mitigation Factors

Replacing the existing monitors/system with UV fluorescence based monitors/system will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing the Existing Monitors/System with UV Fluorescence Monitors

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while removing and installing the new monitors/system.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
UV florescence monitors not compatible with oil.	Supply analyzer vendors adequate information on the chemical/physical properties of the oil and brine.	Medium - High	Medium Risk Hazard
UV florescence monitors incorrectly calibrated.	Ensure the monitors are calibrated for the correct ratios of Aliphatic/ Aromatic vs. Total Hydrocarbon.	Medium - High	Medium Risk Hazard
UV florescence monitors installed too far from wellheads.	Ensure location of the monitors will provide adequate oil detection and response time from site personnel.	Medium - High	Medium Risk Hazard

C. New Microscopy Monitors

This alternative will replace the existing monitors/system with microscopy based monitors/system.

Assumptions & Constraints

Assumptions:

- New Microscopy monitors are installed at each individual wellhead.
- Microscopy monitors are the best technology available.
- The detection is up to 1000 ppm oil-in-water and particle and droplet size information e.g. Dv10, Dv50, and Dv90 data

Constraints:

- Microscopy monitors are more suitable for water injection type work.
- Microscopy monitors analyses side stream only.
- Performance testing of a single monitor installed in the field is required to confirm this technology selection before committing to purchase of additional monitors.
- Monitor life requires periodic field servicing and periodic replacement over the estimated 25-year life of the Life Extension 2 (LE 2).

Benefits & Effectiveness

The replacement of the existing monitors/system with microscopy based monitors/system allows for multiple benefits and addresses current mission needs. The items below summarize the benefits and effectiveness of installing new monitors/system on-site.

- The microscopy based monitors/system will eliminate the risk of getting oil into the brine pond.
- Process Parameters, Total Suspended Solids, and Organic Matter cannot influence or affect the measurement of UV fluorescence based monitors.
- The monitors/system are highly accurate, providing instantaneous and continuous measurement.
- The monitors/system have a good range of detection of up to 1000 ppm oil-in-water, and the ability to detect particle and droplet size information e.g. Dv10, Dv50, and Dv90 data.
- The microscopy based monitors/system can be combined with other analyses like florescence and spectral analyses for the best available reliability in measurement techniques.

Risk & Mitigation Factors

Replacing the existing monitors/system with microscopy based monitors/system will come with associated risks. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing the Existing Monitors/System with Microscopy Monitors

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Safety while removing and installing the new monitors/system.	Ensure a job hazard analysis is prepared by contractors and for anyone on-site in the area of replacement.	Medium - Medium	Medium Risk Hazard
Microscopy monitors not compatible with oil.	Supply analyzer vendors adequate information on the chemical/physical properties of the oil and brine.	Medium - High	Medium Risk Hazard

Risk and Mitigation Strategies for Replacing the Existing Monitors/System with Microscopy Monitors (continued)			
Risks	**Mitigation Strategy**	**Likelihood - Impact**	**Risk Code**
Microscopy monitors incorrectly calibrated.	Ensure the monitors are calibrated for the correct concentration (ppm) and particle/droplet size.	Medium - High	Medium Risk Hazard
Microscopy monitors installed too far from wellheads.	Ensure location of the monitors will provide adequate oil detection and response time from site personnel.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Flowmeters

This alternative will utilize the existing flowmeters currently installed to monitor oil in water.

B. New UV Fluorescence Monitors

This alternative will replace the existing monitors/system with ultraviolet fluorescence based monitors/system.

C. New Microscopy Monitors

This alternative will replace the existing monitors/system with microscopy based monitors/system.

Comparison of Alternatives

Core Team Member Ratings

	Safety During Construction	**Ease of Operations**	**Ease of Maintenance**	**Constructability During Ongoing Oil Deliveries**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Important*	*Less Important*
Alternative A	*Excellent*	*Good*	*Adequate*	*Excellent*	*Good*
	Excellent	*Good*	*Good*	*Excellent*	*Good*
	Excellent	*Good*	*Excellent*	*Excellent*	*Excellent*
Alternative B	*Good*	*Excellent*	*Excellent*	*Good*	*Excellent*
	Excellent	*Good*	*Excellent*	*Good*	*Excellent*
	Good	*Excellent*	*Excellent*	*Good*	*Excellent*
Alternative C	*Good*	*Adequate*	*Good*	*Good*	*Excellent*
	Excellent	*Good*	*Adequate*	*Good*	*Excellent*
	Good	*Adequate*	*Good*	*Good*	*Excellent*

Cost Comparison:

	Total Estimated Cost (TEC)	Life Cycle Cost (LCC)
Alternative A	**$301,015**	**$000,000**
Alternative B	**$8,549,528**	**$10,092,740**
Alternative C	**$8,508,800**	**$10,085,810**

Recommended Alternative

B. New UV Fluorescence Monitors

Based on the technical evaluation of the Core Team Members, Alternative B was rated overall higher on the evaluation criteria. Alternative A has a significantly lower investment cost and life cycle cost followed by Alternative C and Alternative B. Alternative A has a significant risk of technically not meeting the mission need and functional requirements and therefore is not recommended. Alternative B was rated significantly higher overall than Alternative C on the evaluation criteria. Therefore, Alternative B is the recommended preferred alternative, with the significant benefits of operational considerations outweighing the higher investment and life cycle cost.

BM-MM-1524

RWIS Infrastructure Upgrades at BM

VCI Project Engineer: Jason McCrossen

Recommended Alternative:

Perform Overhaul of RWIS

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

The level 1 criteria for the Bryan Mound SPR Site is to be capable of drawing down 1.5 million barrels per day of oil. To accomplish this, 1.8 million barrels of raw water must be taken in at the Raw Water Intake Structure (RWIS) and injected into the caverns to displace the oil.

The RWIS consists of 4 intake pumps, motors and valves, 4 traveling screens, one flush water pump, one screen wash pump, firewater pumps, motors, valves and electrical equipment, a sump sparging system, bar racks, hand rails, cathodic protection system, and the associated concrete, steel, and timber support structures.

It is mission critical for the Bryan Mound Site (BM) to have an operating, 24-hour ready, easy to use Raw Water Intake Structure (RWIS) for drawdown purposes.

Functional Requirements

A dependable, reliable, fully operating RWIS is mission critical. The RWIS will provide raw water to displace cavern oil during drawdown activities. The SPR system shall provide the capability to draw down and deliver crude oil from SPR storage sites to designated distribution terminals with further access to commercial pipeline distribution networks and marine docks. Each SPR site shall be capable of drawing down and delivering crude oil to the designated distribution terminals and pipelines for custody transfer at rates prescribed by the level 1 requirement.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Jason McCrossen	VCI, Project Engineer
Marc Gross	FFPO, Manager Crude Oil Program and Logistics

Team Members

Jorge Aguinaga	DOE, Site Lead General Engineer
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Timothy Kelley	FFPO, Manager Site Construction
Mike Cabiran	FFPO, Sr. Site Maintenance Engineer
Ken Swanson	FFPO, Manager Site Operations

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Constructability During On-Going Oil Deliveries

The selected alternative is able to be implemented with little or no impact to on-going oil delivery operations.

Weight: Most Important

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration.

Weight: Most Important

Safety During Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. Ability to address Safety and Security concerns during implementation.

Weight: Most Important

Security During Construction

The selected alternative when implemented will be able to be constructed with minimal to zero impacts to Site Security detection systems.

Weight: Most Important

Sustainability

The selected alternative when implemented will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. SOW is mainly civil/structural repairs. It could potentially become important if there are required mechanical upgrade.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

Continue to operate as normal and perform normal maintenance as needed.

The RWIS currently meets the mission need but continued wear on equipment could hinder drawdown readiness going forward. Therefore, this alternative does not meet the life extension goal of providing a 25-year life expectancy for the RWIS.

Viability: No Further Analysis

B. Perform Overhaul of RWIS

Repair concrete, steel, and timber structures; upgrade sump sparging system to alleviate continuous silting in of intake; refurbish traveling screens; rewind intake pumps motors; upgrade flush water/firewater supply pumps and motors; rework/replace valves; refurbish electrical systems; refurbish cathodic protection system. This will save the DOE SPR money in the long run vs continuing to repair as needed.

Viability: Continue Analysis

C. Eliminate RWIS and Use Portable Pumps When Drawdown Is Needed

Portable pumps can be used on as-need basis since drawdown is not a regular occurrence.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternatives, B and C are examined below as alternatives A and B, respectively

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

A. Perform Overhaul of RWIS

Repair concrete, steel, and timber structures; upgrade sump sparging system to alleviate continuous silting in of intake; refurbish traveling screens; rewind intake pumps motors; upgrade flush water/firewater supply pumps and motors; rework/replace valves; refurbish electrical systems; refurbish cathodic protection system.

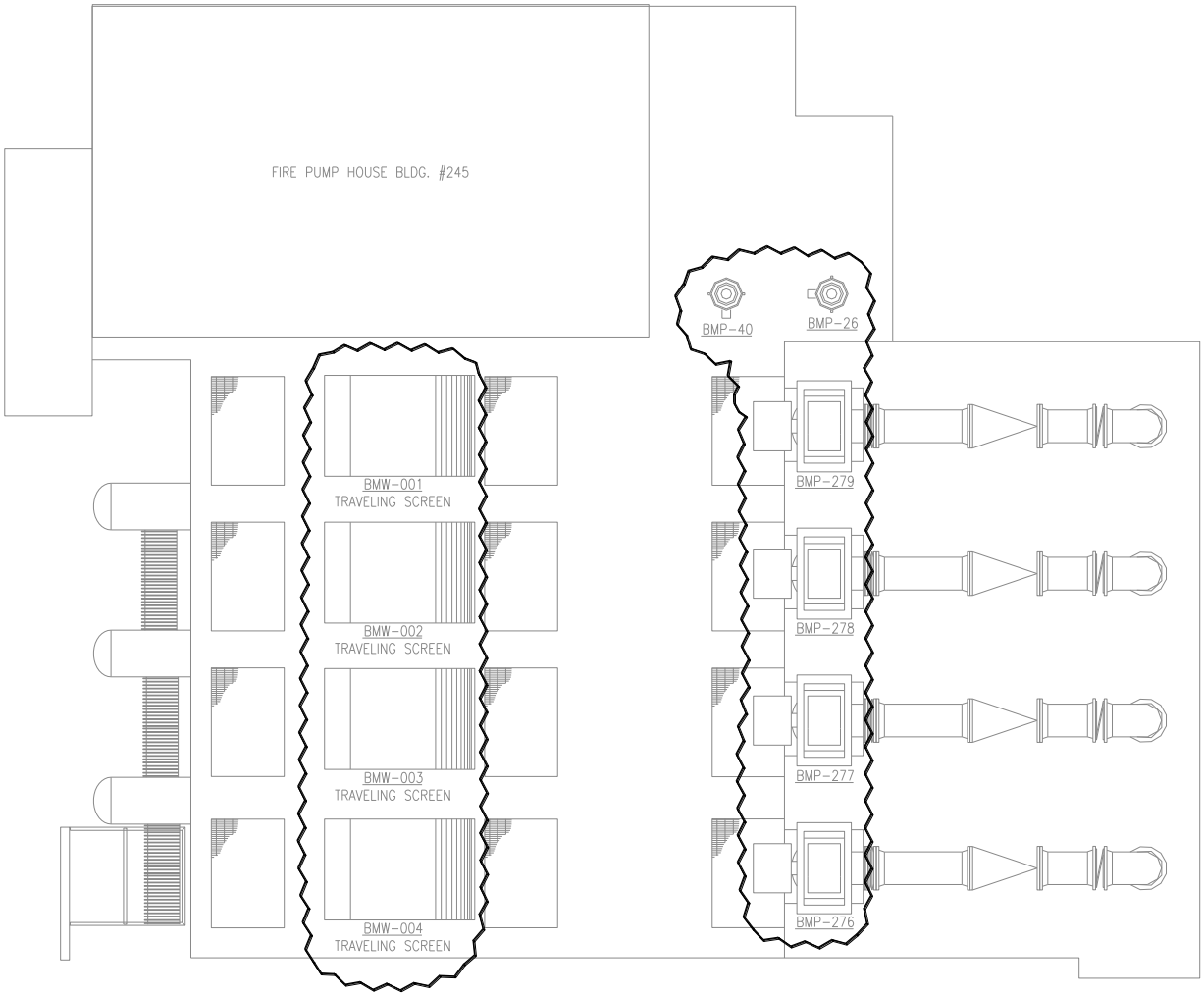

Figure 1 – Raw Water Intake Structure

Assumptions & Constraints

Site must maintain a level 1 drawdown rate. To accomplish this, only a limited portion of the structure can be down for maintenance at a time. In addition, the structure provides raw water for more than the Raw Water Injection Wells. String flush and pig runs for pipelines all require raw water from the structure.

Benefits & Effectiveness

A complete overhaul would support the mission by improving the functionality of a critical drawdown process for a 25-year period. Refurbishing the existing structure and equipment would reduce maintenance time and expense. Reworking the existing pumps, motors, and valves would result in improved performance and decreased energy costs needed for operation. There would be no additional training necessary for operation and no additional security measures due to the structure being located within the existing security perimeter.

Risk & Mitigation Factors

There are associated risks with this alternative which are summarized in the table below. The table describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Overhaul of RWIS			
Risks	**Mitigation Strategy**	**Likelihood – Impact**	**Risk Code**
Large upfront expense.	Upfront expense offset by decreased maintenance costs over the life of the RWIS.	High – Low	Low Risk Hazard
Partial operating structure may not meet Level 1 Requirements.	Leave enough pumps in service to maintain Level 1 readiness.	Low – High	Low Risk Hazard
Safety concern for work over water.	Wear appropriate PPE to include an U.S. Coast Guard-approved Personal Floatation Device (PFD).	Low – High	Low Risk Hazard

B. Eliminate RWIS and Use Portable Pumps When Drawdown is Needed

Portable pumps can be used on as-need basis since drawdown is not a regular occurrence.

Assumptions & Constraints

Using portable pumps for drawdown would be functional but increase logistical challenges associated with performing the SPR's function in a timely manner. Pumps are used for more than just raw water to the Raw Water Injection pumps. The structure is used during quarterly exercises and pig runs besides during drawdown. Construction of a portable pump system should not pose a significant construction obstacle to ongoing operations or cause a construction safety concern.

Benefits & Effectiveness

It would be a beneficial to have an overall reduction in maintenance costs by eliminating the RWIS but the portable pumps would require regular maintenance and exercise to ensure preparedness for drawdown. The new system of portable pumps would require significant operational training. Security concerns would not change significantly as pumps would be operated within existing security perimeter. Use of diesel powered portable pumps would be much less sustainable than the existing RWIS pumps.

Risk & Mitigation Factors

There are associated risks with this alternative which are summarized in the table below. The table describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Eliminate RWIS and Use Portable Pumps When Drawdown is Needed

Risks	Mitigation Strategy	Likelihood – Impact	Risk Code
Drawdown delay due to portable pump procurement.	Store and maintain portable pumps for drawdown on site.	High – High	High Risk Hazard
Drawdown delay due to portable pump installation.	Develop installation procedures and regular testing of portable pumps on the system.	High – High	High Risk Hazard
Deterioration of Raw Water line to site if not in regular service.	Perform regular flushes of line.	High – High	High Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Perform Overhaul of RWIS

Repair concrete, steel, and timber structures; upgrade sump sparging system to alleviate continuous silting in of intake; refurbish traveling screens; rewind intake pumps motors; upgrade flush water/firewater supply pumps and motors; rework/replace valves; refurbish electrical systems; refurbish cathodic protection system.

B. Eliminate RWIS and Use Portable Pumps When Drawdown is Needed

Portable pumps can be used on as-need basis since drawdown is not a regular occurrence.

Comparison of Alternatives

Core Team Member Ratings

	Constructability During Ongoing Oil Deliveries	**Ease of Operations**	**Ease of Maintenance**	**Safety During Construction**	**Security During Construction**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Most Important*	*Less Important*
Alternative A	*Adequate*	*Excellent*	*Excellent*	*Good*	*Good*	*Excellent*
	Adequate	*Excellent*	*Excellent*	*Good*	*Good*	*Excellent*
	Good	*Excellent*	*Good*	*Good*	*Excellent*	*Adequate*
Alternative B	*Marginal*	*Adequate*	*Adequate*	*Good*	*Adequate*	*Adequate*
	Marginal	*Adequate*	*Adequate*	*Good*	*Adequate*	*Adequate*
	Excellent	*Adequate*	*Adequate*	*Good*	*Good*	*Adequate*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$5,359,482**	**$5,735,836**
Alternative B	**$15,676,771**	**$20,417,748**

Recommended Alternative

A. Perform Overhaul of RWIS

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria. The initial cost and life cycle cost of Alternative A were both lowest of the alternatives. Therefore, Alternative A is the recommended preferred alternative based on both technical and cost factors studied in the alternative analysis.

BM-MM-1528

Replace Physical Security CCTV Assessment System

VCI Project Engineer: Corb Elsbury

Recommended Alternative:

Replace CCTV System (Digital)

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

Replace the existing physical security Closed Circuit Television (CCTV) assessment systems with latest technology at Bryan Mound on the main site, Raw Water Intake Structure (RWIS), Electrical Sub-Station (ESS), and Raw Water Injection Pump Pad (RWIPP) consisting of perimeter and critical area fixed nose-to-tail cameras, Pan Tilt Zoom (PTZ) cameras for use as part of the surveillance and intrusion detection alarm assessment system.

Functional Requirements

The SPR assessment system must meet DOE Order 473.3 A. requirements and USNRC Intrusion Detection Systems and Subsystems Technical Information, March 2011, Office of Nuclear Security and Incident Response.

- Cameras and lighting must be effective in all weather conditions and all lighting conditions; lighting must compliment and not interfere with effectiveness of the assessment system.
- Central Alarm Station (CAS) monitors/screens shall be of sufficient size, picture quality and refresh rates to provide an accurate display of persons or animals without undue eye strain or inability to determine images.
- The CCTV assessment system shall be configured as an element of the total Intrusion Detection System (IDS) along with the required complimentary lighting.
- Lighting shall allow for the fast and reliable assessment of alarms from either the CCTV system or Protection Force (PF) personnel as defined in the Site Security Plan (SSP).
- The system must have the capability to automatically switch to the camera associated with the alarm event and clearly display the event for operator assessment.
- Video assessment coverage must be complete (e.g., no gaps between zones or areas that cannot be assessed due to shadows or objects blocking the camera's field of view).
- CCTV systems shall use real time signal or near real time transmission of camera views.
- Alarms shall be enabled to assess immediately by either the PF or by a central alarm monitoring station personnel using the CCTV management system; ergonomics shall be considered in design.
- CCTV assessment cameras used as primary assessment for alarms shall be fixed (i.e., not pan or tilt) with fixed focal length lenses or zoom capability.
- All cameras must be compatible with the existing Alarm Display and Annunciation System (ADAS) at the site. Close coordination with the ADAS system integrator is required as part of this study. It is understood that technical upgrades to the ADAS system may be required.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
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Marc Gross	FFPO, Manager Design Engineering

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Mike Cabiran	FFPO, Sr. Site Maintenance Engineer
Dennis Henderson	FFPO, Manager Site Operations
Timothy Kelley	FFPO, Manager Site Construction
Joseph Mravunich	FFPO, Manager Site Maintenance

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Constructability During On-Going Oil Deliveries

The selected alternative is able to be implemented with little or no impact to ongoing oil delivery operations. Close coordination with the Site Security Specialist and site/maintenance operations will allow for minimal impact on oil delivery operations.

Weight: Most Important

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration.

Weight: Most Important

Safety During Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. Ability to address Safety and Security concerns during implementation. Safety is of greatest importance.

Weight: Most Important

Security During Construction

The selected alternative when implemented will be able to be constructed with minimal to zero impacts to Site Security detection systems.

Weight: Most Important

Sustainability

The selected alternative when implemented will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

Continue to maintain existing analog cameras at Bryan Mound. Maintaining the current system, requires additional maintenance repairs and of greater importance, the security assessment system will continue to degrade. The current analog technology residing on the site is antiquated and does not function at optimal capacity in its current configuration.

It is the opinion of the Government security team that increasingly scarce repair parts will become nonexistent within the next two (2) years. Assessment capabilities will eventually be degraded to the point that the site fails to meet DOE Order 473.3 A. and USNRC Intrusion Detection System requirements if the CCTV system remains analog.

Viability: No Further Analysis

B. Replace CCTV System (Analog)

Replace all existing fixed and Pan-Tilt-Zoom (PTZ) physical security Closed Circuit Television (CCTV) assessment system cameras (~105) (hardware, software and monitors included) on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed. Install latest generation analog cameras on the perimeter and critical structures; replacement of video transmission lines, video servers and monitors may be required. Digital IP encoders are required to allow viewing remotely by NOLA DOE and M&O staff during emergencies. Intelligent video capabilities at the camera or at the server are recommended upgrades

Viability: Continue Analysis

C. Replace CCTV System (Digital)

Replace all existing fixed and Pan-Tilt-Zoom (PTZ) physical security Closed Circuit Television (CCTV) assessment system cameras (~105) (hardware, software and monitors included) on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed. Install latest generation digital IP cameras on the perimeter and critical structures; replacement of video transmission lines, video servers and monitors will be required. Digital IP encoders are required to allow viewing remotely by NOLA DOE and M&O staff during emergencies. Intelligent video capabilities and analytics at the camera or at the server are recommended upgrades.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternatives, B and C are examined below as alternatives A and B, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

A. Replace CCTV System (Analog)

Replace all fixed (~105) analog cameras with the latest generation of analog camera technology. Replacing older model analog cameras and components at Bryan Mound will reduce the amount of maintenance difficulties, sparing/stocking challenges, and repair parts issues. The existing fixed day/night cameras require long fields of view which possess no zoom capability, therefore reducing intrusion detection efforts. Poor quality images captured by the analog camera systems are inadequate for retrieving detail or attempting a positive identification.

The site continues to experience repair and replacement difficulties. Maintenance and Operations (M&O) personnel are challenged with antiquated components and in some cases, repair is beyond Instrumentation & Electrical (I&E) personnel capabilities and training.

Replace the existing fixed analog CCTV system (cameras, monitors, cabling, and digital video recorders - DVR) with the latest generation technology of Pelco cameras or approved equal at Bryan Mound. Replace all fixed (~89 Pelco ExSite Series camera or approved equal), Pan-Tilt-Zoom (PTZ) (~16) Pelco ExSite Series camera or approved equal), physical security Closed Circuit Television (CCTV) assessment system cameras on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed at Bryan Mound. Intelligent video analytics capabilities at the cameras or at the servers are recommended upgrades. Fixed cameras shall be equipped with image stabilization, auto iris, and zoom capabilities required in accordance with DOE Protection Order 473.3 A. and USNRC Intrusion Detection Systems and Subsystems Technical Information.

The Pelco ExSite Series analog cameras are integrated camera systems that meet stringent explosion proof and dust-ignition proof requirements. The ExSite Pan/Tilt Series combines a receiver, pan/tilt, and enclosure in a single, easy-to-install system, but also includes an Integrated Optics Package (IOP). The ExSite Fixed Series can be installed in a standard or inverted position and features manually adjustable 200 degrees of pan and 180 degrees of tilt positioning. The Integrated Optics Package contains an autofocus camera and lens module with configurable features. These explosion proof camera systems (fixed and pan/tilt camera systems) shall include an optional programmable window wiper and washer/wipe sequence under a single command. Any cameras currently mounted on wooden utility poles (~5) shall be mounted on square tapered 7-gauge, steel hinged poles, 30’ in length. Each newly installed camera poles shall be properly grounded and have a lightning air terminal on top of the pole.

Lighting is critical for optimal performance and shall be addressed in the ongoing lighting upgrade efforts; white light is one of the critical essentials (illumination-white light, camera and lens) needed at the front end of every CCTV system.

Assumptions & Constraints

Assumptions:

- Camera types and lighting replacements shall be compatible (done during detailed design).
- A site modeling determination shall be conducted prior to camera installation to establish detailed requirements and potentially gained efficiencies.

Constraints:

- Construction dates of lighting projects (~2020 project); lighting and camera specifications must be compatible for optimal performance (CCTV replacement is tentatively scheduled for ~2023).
- The primary limitation is not only the analog technology, but the fact that analog cameras have to comply with analog TV standards, producing decoding errors as the camera attempts to resolve images; the result is blurring and inaccurate rendering of colors.
- Wireless analog is very unreliable and poor quality, and any underground cables are extremely prone to lightning.
- Analog is a 50-year-old technology, very sensitive to interference and analog cameras generally do not accommodate big distances, getting them to work over broad ranges is difficult.

- The major disadvantage of analog cameras comes down to image quality; problematic with applications that demand high security and the need to re-encode the signal to IP for transmission to remote offsite monitoring and alarming stations.

Benefits & Effectiveness

Replacing all cameras with new analog cameras will allow for better security and safety measures while eliminating difficulty of maintenance and operability. Maintenance procedures will streamline as characteristics of systems are updated to a new camera system, allowing effective diagnosis and triage. The information below summarizes the benefits and effectiveness of replacing all analog cameras on site with current technology as well as addressing the mission needs of the site.

- Maintenance procedures are reduced with all new components. All new equipment shall be installed and accompanied with manufacturer warranties and product training.
- The CCTV assessment system will function at acceptable capacity, providing the PF response enough time to assess areas and intruder incursions.
- The potential for the re-use of existing cabling that is still serviceable allows for cost reduction during installation.
- Meets the DOE Protection Order 473.3 A. requirements.

Risk & Mitigation Factors

With any new upgrade at the site come associated risks. Some potential risks associated with replacing all of the analog cameras on site include reduced security posture during construction, rapidly advancing technology and the lack of training of employees. The table below summarizes the above mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replace CCTV System (Analog)

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Rapidly advancing CCTV technology, analog becomes outdated.	Implement a rigid 5-year life cycle replacement interval.	High - High	High Risk Hazard
May require training on the new system, which can take time to learn.	Minimize the length of training by making the training comprehensive, easy to follow and hands on.	High - Low	Low Risk Hazard
Site Security posture is degraded during installation.	Work closely with NOLA and site security to alleviate gaps in security, potentially compensatory PF options.	High - High	High Risk Hazard
Existing cabling infrastructure is not serviceable and needs to be replaced.	Must survey all existing camera locations and the existing cable for suitability for re-use.	Medium - High	Medium Risk Hazard

B. Replace CCTV System (Digital)

The existing analog CCTV systems are experiencing issues related to obsolescence and maintenance. Digital IP CCTV systems have been installed for the cameras at Big Hill and West Hackberry sites and are experiencing higher performance and improved maintenance rates. The existing assessment system consists of an assortment of analog cameras of varying makes and models. Some cameras have issues communicating with current servers and finding compatible cameras is becoming increasingly difficult. Infra-red (IR) cameras are ineffective because of on-site and off-site lighting. Currently, the fixed day/night cameras have long fields of view with no zoom capability, potentially causing threat identification challenges. Current antiquated camera technology increases down time and increases repair/replacement costs, and sparing issues for Fluor Maintenance and Operations (M&O) is difficult. Assessment capabilities will degrade to the point of failure to meet DOE Order 473.3 A. requirements if the CCTV system shortcomings are not addressed. Extensive damage could result from undetected intrusion. The CCTV system includes technology that utilizes Infrared (IR) and Thermal (TH) cameras as well as cameras using conventional illumination.

A digital IP camera digitizes the video signal using a specialized encoder that contains an onboard IP encoder and web management interface. This allows the IP camera to act as an IP network device, thus allowing captured video images to be viewed not only through an existing network, but also through a web browser that can be accessed through the Internet; thus allowing NOLA and authorized users to view the specific site video images as needed. Digital IP encoders are not required to allow viewing remotely by NOLA DOE and M&O staff during emergencies as the video feed from the camera is already IP encoded. Intelligent video capabilities at the camera or at the server are recommended upgrades to allow for video analytics. Video analytic capabilities allow for the CCTV system to set parameters for alarm conditions. Replacement of video transmission lines, video servers and monitors will likely be required to support an IP over Ethernet network connection to the CCTV system.

This alternative proposes to replace the existing CCTV system (cameras, monitors, cabling, and digital video recorders - DVR) cameras (~105) with the latest generation technology of Pelco cameras or approved equal at Bryan Mound. Digital cameras require a Network Video Recorder – NVR versus a DVR (input from the network versus direct connection). Replace all fixed cameras with (~89) the Pelco ExSite IP EHXME Series camera or approved equal. Replace all pan/tilt/zoom (PTZ) cameras (~16) with the Pelco ExSite IP IPSXME Series camera or approved equal. Install these cameras on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed on Bryan Mound.

The Pelco ExSite IP Series cameras are fixed and pan/tilt/zoom, explosion proof IP cameras designed to meet the rigorous requirements for hazardous locations with integrated camera/lens/receiver for safe and efficient installation. These cameras feature low-light technology, multiple compression formats, and both upright and inverted operation for optimal image quality, performance, and reliability. The Pelco Exsite IP is capable of recording, managing, configuring, and viewing multiple live streams. This explosion proof camera system (fixed and pan and tilt camera systems) shall include an optional programmable window wiper and washer/wipe sequence under a single command.

Dome cameras were not suggested replacements for two (2) important reasons. Fitting on camera illumination to a dome camera is more difficult (requiring significant additional lighting efforts) than fitting illumination to a fixed or PTZ system; lighting cannot be fitted to follow the movement of the camera. Therefore, it is assumed dome cameras lack optimal night-time performance requirements needed unless each dome camera is retrofitted with its own lighting assembly. Secondly, dome cameras are extremely sensitive; typically, they are outfitted with smoked domes, integral zoom lenses, and higher F-stop ratings (aperture speed) which reduce light transmission needed for optimal performance.

Any cameras currently mounted on wooden utility poles (~5) shall be mounted on square tapered 7-gauge, steel hinged poles, 30’ in length. Each newly installed camera pole shall be properly grounded and have a lightning air terminal on top of the pole.

Lighting is critical for optimal performance and shall be addressed in ongoing lighting upgrade efforts; white light is one of the critical essentials (illumination-white light, camera and lens) needed at the front end of every CCTV system.

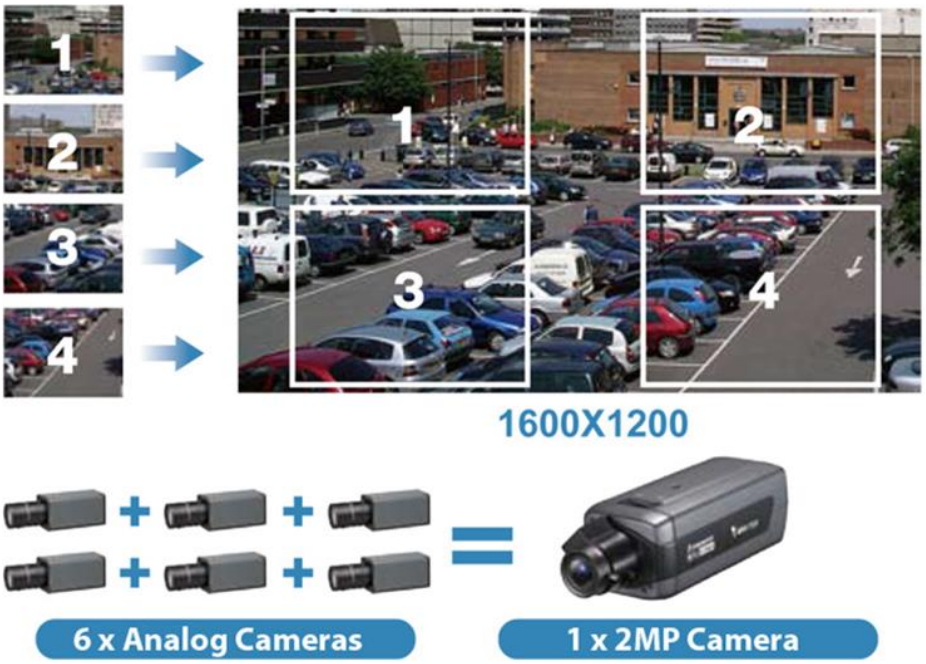

Figure 1 – One (1) Digital Camera Can Cover the Same Area as Six (6) Analog Cameras

Assumptions & Constraints

Assumptions:

- Camera types and lighting replacements shall be compatible (done during detailed design).
- Eventually IP CCTV will be the standard for CCTV systems, providing a longer term solution than analog.
- New digital high definition camera technology will allow for a reduced number of cameras (fixed) to cover a given field of view.
- A site modeling determination shall be held to establish detailed requirements and potentially gained efficiencies.
- The existing network backbone can handle the increase in bandwidth needed for a digital camera replacement alternative.
- All new equipment shall be installed and accompanied with manufacturer warranties and product training.

Constraints:

- Construction dates of lighting projects (~2020 project); lighting and camera specifications must be compatible for optimal performance (CCTV replacement is tentatively scheduled for ~2023).

Benefits & Effectiveness

Replacing all cameras with digital IP technology will allow for optimal security and safety measures while eliminating difficulty for maintenance and operability. Maintenance procedures will streamline as characteristics of new systems are installed, allowing effective triage and diagnosis.

The information below summarizes the benefits and effectiveness of replacing all cameras on site with digital IP technology as well as addressing the mission needs of the site.

- Replaces antiqued technology and camera equipment; detection, classification, and identification are achieved in the most expeditious and accurate manner.

- A new high definition digital IP camera can cover a much wider area than a standard definition analog or IP camera. (See Figure 1)
- One Cat5e cable can be used to send multiple cameras back to the NVR, saving time and money spent on running multiple cables for analog; IP system installs require significantly less wiring than an analog system.
- High definition Digital IP cameras can provide up to 25% more resolution than analog and are especially better at capturing objects that are moving and running, even at high speed.
- Difficult maintenance procedures are all but eliminated with all components having “like” characteristics and troubleshooting techniques.
- The CCTV assessment system will function at optimal capacity, providing the PF response speeds fast enough to assess areas and intruder incursions without latency; the biggest advantage with a megapixel IP CCTV system is extremely high resolution pictures.
- Optimal viewing capacity and zoom capabilities, potentially reducing the total number of cameras and ancillary equipment needed to accomplish the DOE protection mission (~6 analog cameras are required to get the same resolution as one 2 megapixel digital IP camera).
- A digital IP camera can be wired to the nearest network switch where it uses the existing network infrastructure.
- Eliminating the need to re-encode an analog camera feed to IP for remote viewing reduces the amount of encoders, servers and matrix switches that analog signal cameras require.
- The use of an IP encoded CCTV signal allows for greater flexibility for integration with IDS, access control and video analytics.
- Consistently meet the DOE Protection Order 473.3 A. requirements, negating DOE Headquarters security assessment inspection shortcomings/findings.

Risk & Mitigation Factors

With any new upgrade at the site come associated risks. Some potential risks associated with replacing all of the cameras on site include reduced security posture during construction, rapidly advancing technology and the lack of new equipment training for employees. The table below summarizes the above mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing All Cameras (Digital)

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Rapidly advancing CCTV technology.	Implement a rigid 5-year life cycle replacement interval.	Low - Low	Low Risk Hazard
Digital IP cameras will require equipment modifications to current ADAS system at the site.	Upgrade BC ADAS (require NVR and additional encoders vs existing DVR) in conjunction with upcoming ADAS upgrade projects at WH and BM.	Medium - Medium	Medium Risk Hazard
May require training on the new system.	Minimize the length of training by making the training comprehensive, easy to follow and hands on.	High - Low	Low Risk Hazard
Site Security posture is degraded during installation.	Work closely with NOLA and site security to alleviate gaps in security, potentially compensatory PF options.	High - Low	Low Risk Hazard
Existing cabling infrastructure is not serviceable and needs to be replaced.	Must survey all existing camera locations and the existing cable for suitability for re-use.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Replace CCTV System (Analog)

Replace all existing fixed, Pan-Tilt-Zoom (PTZ) physical security Closed Circuit Television (CCTV) assessment system cameras with latest analog technology (hardware, software and monitors included) on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed.

B. Replace CCTV System (Digital)

Replace all existing fixed, Pan-Tilt-Zoom (PTZ) physical security Closed Circuit Television (CCTV) assessment system cameras with the latest generation digital technology (hardware, software and monitors included) on the main site, employee parking lots, Electrical Sub-Stations (ESS), Raw Water Injection Pump Pads (RWIPP), and any additional identified areas of security coverage needed.

Comparison of Alternatives

Core Team Member Ratings

	Constructability During Ongoing Oil Deliveries	**Ease of Operations**	**Ease of Maintenance**	**Safety During Construction**	**Security During Construction**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Most Important*	*Important*
Alternative A	*Excellent*	*Adequate*	*Adequate*	*Excellent*	*Adequate*	*Excellent*
	Excellent	*Adequate*	*Good*	*Good*	*Good*	*Good*
	Excellent	*Good*	*Good*	*Excellent*	*Good*	*Adequate*
Alternative B	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Adequate*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Good*	*Good*	*Excellent*
	Excellent	*Excellent*	*Good*	*Excellent*	*Good*	*Adequate*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$6,802,098**	**$13,361,039**
Alternative B	**$7,217,151**	**$14,175,350**

Recommended Alternative

B. Replace CCTV System (Digital)

Based on the technical evaluation of the Core Team Members, Alternative B was clearly rated equal or superior on all evaluation criteria. The key factors in the higher technical rating were the better day-to-day operability and capability of the digital cameras, with a corresponding better ability to maintain. The initial cost and life cycle cost of Alternative A was slightly lower than Alternative B. Alternative B is the recommended preferred alternative, with the better performance characteristics of digital over analog being worth significantly more than the slightly higher initial investment and life cycle costs.

BM-MM-369

Upgrade Outdoor Lighting

VCI Project Engineer: Corb Elsbury

Recommended Alternative:

Replace Designated Utility Poles, All Lights and Associated Cabling (LED)

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

Lighting at SPR sites is integral to providing increased security and safety of site personnel and facilities. The project intent is to provide more sustainable, reliable, and lower maintenance lighting servicing the cavern and building areas as well as frequently used roadways. Specifically, this project looks at adding new lighting in areas that are under-lighted, replacing existing lights with energy efficient types, removing lights in areas that no longer need them, installing low-maintenance poles, and installing new wiring in duct banks.

Functional Requirements

Lighting levels to meet Design Level III Criteria and DOE Order 473.3 A. requirements.

- Perform a lighting survey to identify areas where lighting is inadequate or no longer needed; use light modeling programs using methods recommended by the Illuminating Engineering Society (IES).
- Adequately light each work area, walkway and parking area whenever an employee is present (OSHA 1915.82(a) (2).
- Compliment the lighting systems with the electro optical/closed circuit television (CCTV) assessment system.
- Allow for the rapid and reliable assessment of alarms from either the CCTV system or Protective Force (PF) personnel.
- Install maintenance free utility poles with protected cabling.
- Consider energy efficient lighting.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Corb Elsbury	VCI, Project Engineer
Marc Gross	FFPO, Manager Design Engineering

Team Members

Patrick Shepherd	DOE, Project Engineer
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Bryan Dunlap	DOE, Physical Security Specialist
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Randy Bridges	FFPO, Process & Security Systems Control
Michael Sickmiller	FFPO, Site Director
Mike Cabiran	FFPO, Sr. Site Maintenance Engineer

Dennis Henderson	FFPO, Manager Site Operations
Timothy Kelley	FFPO, Manager Site Construction
Joseph Mravunich	FFPO, Manager Site Maintenance

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Constructability During On-Going Oil Deliveries

The selected alternative is able to be implemented with little or no impact to on-going oil delivery operations.

Weight: Most Important

Ease of Operations

The selected alternative when implemented will result in a system that is able to be operated without significant additional training and is similar to existing systems and equipment.

Weight: Most Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. Maintenance operations will require less attention as new equipment replaces legacy equipment.

Weight: Most Important

Safety During Construction

The selected alternative when implemented will be able to be constructed safely and operated safely. Ability to address Safety and Security concerns during implementation. The site's ability to address Safety and Security concerns during implementation shall not be impacted. Safety is of the greatest importance.

Weight: Most Important

Security During Construction

The selected alternative when implemented will be able to be constructed with minimal to zero impacts to Site Security detection systems.

Weight: Most Important

Sustainability

The selected alternative when implemented will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan. Energy consumption shall be considered in all upgraded equipment criteria.

Weight: Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

A. Status Quo

The status quo consists of continuing to maintain the ~30-year old high pressure sodium (HPS) lighting systems and to use portable lighting, when needed, in areas not well lit. This alternative includes accepting the risk of wooden pole deterioration/failure (~119), safety risks, and unscheduled maintenance/repair costs; lighting at Bryan Mound is at the end of its useful life. The determination that wooden poles are extremely susceptible to the predominantly wet, saline environment as well as woodpecker damage make them less than a viable option. Cabling associated with lighting is ~20-years old and will continue to be at risk of being severed and/or malfunctioning as ongoing major maintenance operations on the SPR continue.

Recent inspections from the Enterprise Assessment (EA) Team from DOE Headquarters found the SPR perimeter fence detection system lacked adequate scene illumination and was deficient in the number of light poles, fixtures, and light shielding. All of these issues negatively affect the PF's ability to assess and track intruder locations. The use of color cameras at nighttime, particularly when a scene is illuminated with HPS lamps, is problematic. The status quo will continue to provide for low visibility for night maintenance operations/security and allow for the risk of the deterioration/failure of wooden light poles. Areas of the site deemed inadequately lighted hinder maintenance efforts as well as pose a safety risk for night shift employees. The degraded ability of the PF to assess intruder location and intent due to poor lighting conditions will continue.

Viability: No Further Analysis

A. Replace Designated Utility Poles, All Lights and Associated Cabling (LED)

The (LED) alternative consists of replacing all wooden utility poles used for mounting lights and light fixtures with lights, along with the associated wiring/cabling. Under-lighted areas (i.e., main site, caverns, Raw Water Intake Structure (RWIS), Brine Disposal Wells, roadways, RPX pad, etc.) are to be identified, while considering light-emitting diodes (LED) lighting as a suitable replacement.

Viability: Continue Analysis

B. Replace Designated Utility Poles, All Lights and Associated Cabling (Induction)

The (Induction) alternative consists of replacing all wooden utility poles used for mounting lights and light fixtures with lights, along with the associated wiring/cabling. Under-lighted areas (i.e., main site, caverns, RWIS, Brine Disposal Wells, roadways, RPX pad, etc.) are to be identified, while considering induction lighting as a suitable replacement.

Viability: Continue Analysis

C. Replace Designated Utility Poles, All Lights and Associated Cabling (High Intensity Discharge - HID)

The (HID) alternative consists of replacing all wood utility poles used for mounting lights and light fixtures with lights, along with the associated wiring/cabling. Under-lighted areas (i.e., main site, caverns, RWIS, Brine Disposal Wells, roadways, RPX pad, etc.) are to be identified, while considering high intensity discharge (HID) lighting as a suitable replacement.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternative A is eliminated from further consideration. The remaining alternatives, B, C, and D are examined below as alternatives A, B, and C, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

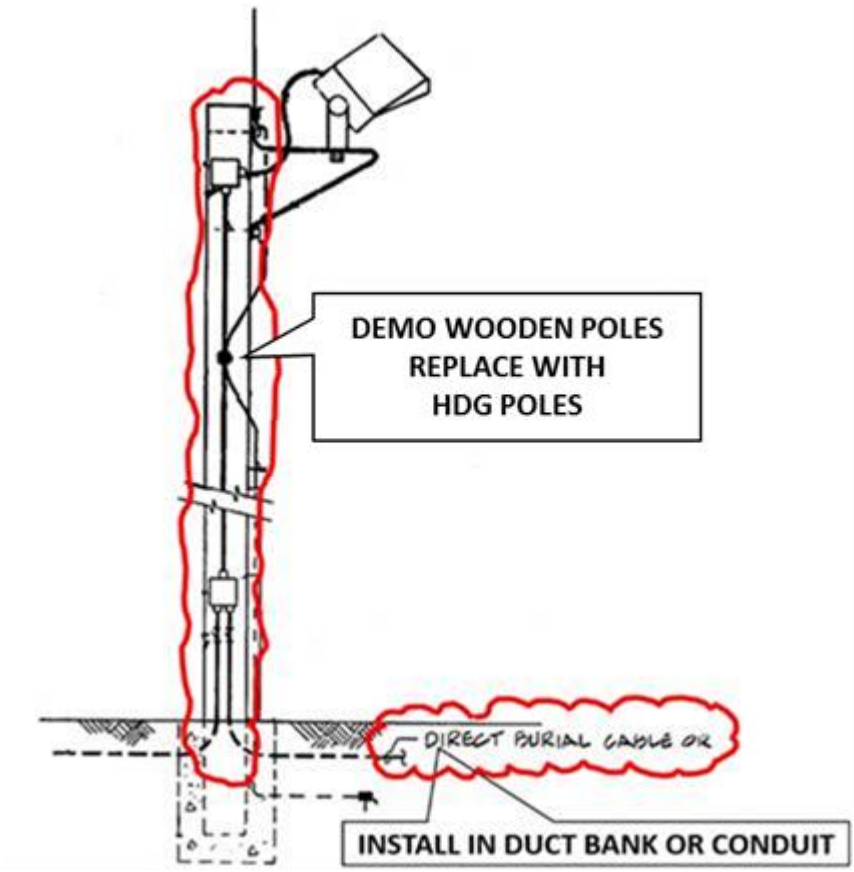

Figure 1 – Changes to Existing Light Poles

This figure demonstrates the procedure common to all three alternatives; all creosote wooden poles supporting lighting shall be demolished and associated cabling installed in duct bank, conduit or existing cable trays vs directly buried.

A. Replace Designated Utility Poles, All Lights and Associated Cabling (LED)

The (LED) alternative consists of replacing all lighting and fixtures with LED technology while replacing designated wooden utility poles (~119) and associated cabling at Bryan Mound.

A recent lighting evaluation conducted at Bryan Mound determined there were ~27 light deficient areas, ~8 of those on roadways. A lighting evaluation shall be performed to confirm the light deficient areas and also determine where lighting is no longer needed (main site, caverns, RWIS, ESS, RWIPP, RPX, brine disposal well pads, roadways, employee parking lots, etc.). Methods recommended by the IES shall be used to model expected light levels and to assist in the design and layout of all replacement lighting; the DOE Design Level III Criteria for roadway ground level lighting is 0.2 foot candles (fc), 5.0 fc for process and maintenance areas, 0.1 fc for parking areas, and 1.0 for cavern areas.

Department of Energy modeled uniformity comparisons of LED, Induction, and HPS produced results that suggested LED lighting displayed a 2:1 advantage in placement; this study was conducted using new luminaries, equal wattage, identical new utility poles and spaced for optimal performance. Visual uniformity comparisons of LED, Induction and HPS suggests that LED at maximum lux (luminous flux per unit area) of 27 lm/W (Lumens/Watt) characteristics performed better than Induction (11.2 lm/W) and HPS (24 lm/W). Negating obstacles such as above ground tanks and large buildings, it is reasonable to plan for a wooden pole replacement number to be much closer to ~60 versus the existing ~119 wooden pole replacement count. Additionally, assumptions may be made on the previously identified light deficient areas ~27 to estimate for the half that number, ~14.

It is important to note that proposed camera replacements shall dictate the type of lighting (or vice versa) identified to replace existing HPS and Induction lighting; lighting systems must meet the requirements listed in DOE Order 473.3 A.

All wooden roadway pole replacements (~8) shall be considered with hot dipped galvanized steel poles with extended hinged arms to allow for ease of maintenance. The remaining wooden utility poles (~52) shall be replaced with a more durable material than wood such as hot-dipped galvanized poles (HDP) or an approved equal. Hinged poles shall only be used in areas where a man-lift is not feasible. Cabling replacement shall be addressed by pulling new lighting cabling through existing duct banks or conduit. If there is no existing duct bank or conduit, options of using existing cable trays or installing new duct bank or conduit shall be examined.

Assumptions & Constraints

Assumptions:

- A lighting evaluation shall be done prior to detailed design.
- LED lighting should reduce the need for poles and additional lighting fixtures by half.
- Lighting and new camera lighting requirements/engineering shall be de-conflicted during detailed design.
- Where possible, unprotected cabling shall be installed in existing cable trays vs installing new duct banks or conduit.
- LED lighting at maximum burning hours (100K) retains 85% lumen output.
- LED fixtures are widely available with multiple light patterns and correlated color temperatures (CCT); available from 2000 to 10,000; eliminating light pollution (washout).
- Most cabling associated with lighting is located in conduit or duct bank.

Constraints:

- Available/existing cable trays within a suitable distance for use.
- Existing power sources for all new utility pole installation.

Benefits & Effectiveness

Identifying site lighting deficiencies, replacement of utility poles, old cabling, lights and fixture replacement with LED technology allows for multiple benefits and addresses current mission needs. Replacing the utility poles and addressing the lighting deficiencies also allows for optimal security and safety, which best supports the requirements described in DOE 473.3 A.

- Improved visibility for night maintenance (safety) and security operations; LED lights are instantly turned on with no warm up (DOE 473.3 A., Attachment 3, Section A 3-35 [3][b]).
- Allows for better PF intruder assessment capabilities due to the rapid and reliable assessment of alarms (DOE 473.3 A., Attachment 3, Section A 3-35 [3][a]).
- Improved lighting will complement the CCTV assessment system, allowing for improved security (DOE 473.3 A., Attachment 3, Section A 3-36 [3][g]).
- Alleviates safety risks from deteriorating wooden utility poles and increases performance of poles in poor weather (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Cabling with duct banks is the industry standard and prevents inadvertent cutting of cables (provides for a 20-year life span), which prevents unscheduled maintenance repairs and personnel safety concerns (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Deficiencies found by the EA Team, DOE Headquarters are addressed and corrected (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Employees feel safer with more adequately lighted areas; allows for a safe work environment per OSHA guidelines (DOE 473.3 A., Attachment 3, Section A 3-36 [3][h]).
- LED provides the ability to focus on exact luminous areas, allowing for a safer work environment (DOE 473.3 A., Attachment 3, Section A 3-36 [3][f]).
- LED lighting is more energy efficient (~44%) than HPS, easier to maintain and has a longer life cycle than the existing high pressure sodium (HPS) lighting; meeting DOE sustainability mandates. (U.S. DOE Solid State Lighting Technology Demonstration, June 2010)
- LED fixtures are widely available with multiple light patterns and correlated color temperatures (CCT); available from 2000 to 10,000; eliminating light pollution (washout).
- Color Rendering Indexes (CRI) of 60-90.
- LED lighting provides higher lighting acuity value per lumen/watt; 135 Lumens/watt.
- Extremely long life span, 100K hours at 70 Watt hours.
- No toxic materials used in manufacturing; low to no recycling costs.

Risk & Mitigation Factors

With new LED lighting, cabling and utility pole upgrades at the site come associated risks. Potential risks associated with replacing wooden utility poles, lights and cabling, as well as determining lighting deficiencies include reduced security capability during construction, failing to identify all inadequate lighting areas, maintaining a safe work environment, and having a loss of lighting in areas where poles are being replaced. The table below summarizes the mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing Utility Poles and Determining Lighting Deficiencies (LED)			
Risks	**Mitigation Strategy**	**Likelihood - Impact**	**Impact**
Reduced security capability during construction.	Close coordination with NOLA, site security and contractor during work plan development and scheduling.	Medium - Medium	Medium Risk Hazard
Lighting survey does not identify all inadequately lighted areas.	Use a computer based program to confirm lighting survey results.	Low - Low	Low Risk Hazard
Safety while installing new poles, lighting, and cables.	Ensure a job hazard analysis is prepared by contractors and for anyone onsite near the installation of the poles, lighting, or cables.	Medium - Medium	Medium Risk Hazard
Loss of lighting in areas while poles are being replaced.	Prepare a strategic plan for minimizing the effects, and use portable lighting as necessary.	High - Medium	Medium Risk Hazard
Lighting technology required to address both lighting and security (CCTV) needs.	Close coordination between maintenance and PF to determine the correct lighting technology.	Medium - High	Medium Risk Hazard

B. Replace Designated Utility Poles, All Lights and Associated Cabling (Induction)

The (Induction) alternative consists of replacing all lighting and fixtures with Induction lighting technology while replacing designated wooden utility poles (~119) and associated cabling at Bryan Mound, Texas. A lighting evaluation shall be performed to identify areas where lighting is inadequate or no longer needed (main site, caverns, RWIS, ESS, RWIPP, RPX, brine disposal well pads, roadways, employee parking lots, etc.). Methods recommended by the IES shall be used to model expected light levels and to assist in the design and layout of all replacement lighting.

A recent lighting evaluation conducted at Bryan Mound determined there were ~27 light deficient areas, ~8 of those on roadways. A lighting evaluation shall be performed to confirm the light deficient areas and also determine where lighting is no longer needed (main site, caverns, RWIS, ESS, RWIPP, RPX, brine disposal well pads, roadways, employee parking lots, etc.). Methods recommended by the IES shall be used to model expected light levels and to assist in the design and layout of all replacement lighting the DOE Design Level III Criteria for roadway ground level lighting is 0.2 foot candles (fc), 5.0 fc for process and maintenance areas, 0.1 fc for parking areas, and 1.0 for cavern areas. A Department of Energy gateway study (June 2010) concluded Induction lighting used 6% less energy than HPS. HPS maintenance requires lamp replacement on average of every 5 years, ballasts every 15 years, igniters every 20 years, the housing every 25 years and photocell every 15 years. Induction lighting is nearly maintenance free for the rated bulb/ballast, exhibits a high color rendering index (CRI) of 80+ (HPS CRI is ~20-22) that produces vivid colors versus the yellowing (washout) associated with HPS and induction contains just slightly less amalgam (mercury). Induction lighting is found to operate much cooler (150F- 180F than HPS (450-750F) presenting less environmental impact. Induction visual acuity (seeable lumens) is 191 lm/W while HPS has only 67 lm/W.

It is important to note that proposed camera replacements shall dictate the type of lighting (or vice versa) identified to replace existing lighting; lighting systems must meet the requirements listed in DOE Order 473.3 A.

All wooden roadway pole replacements (~8) shall be considered with hot dipped galvanized steel poles with extended hinged arms to allow for ease of maintenance. The remaining wooden utility poles (~111) shall be replaced with a more durable material than wood such as hot-dipped galvanized poles (HDP) or an approved equal. Hinged poles shall only be used in areas where a man-lift is not feasible. Cabling replacement shall be addressed by pulling new lighting cabling through existing duct banks or conduit. If there is no existing duct bank or conduit, options of using existing cable trays or installing new duct bank or conduit shall be examined.

Assumptions & Constraints

Assumptions:

- A lighting evaluation shall be done prior to detailed design.
- Lighting and new camera lighting requirements/engineering shall be de-conflicted during detailed design.
- Where possible, cabling shall be installed in existing cable trays vs installing new duct banks.
- Most cabling associated with lighting is located in conduit or duct bank.

Constraints:

- Possible existing power sources for all new utility pole installation.
- Available/existing cable trays within a suitable distance for use.
- Induction lighting is a mercury hazard; high recycling costs.
- Induction lighting is difficult to control optically.
- Very large in size compared to LED retrofit units.

Benefits & Effectiveness

The replacement of all utility poles and cabling, existing lighting, and identifying site lighting deficiencies allows for multiple benefits and addresses current mission needs. Replacing the utility poles and determining lighting deficiencies also allows for security and safety, which supports the requirements described in DOE 473.3 A.

- Improved lighting will complement the CCTV assessment system, allowing for improved security (DOE 473.3 A., Attachment 3, Section A 3-36 [3][g]).
- Alleviates safety risks from deteriorating wooden utility poles and increases performance of poles in poor weather. (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Cabling with duct banks or conduit is the industry standard and prevents inadvertent cutting of cables, which prevents unscheduled maintenance repairs and personnel safety concerns (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Requires relatively low maintenance efforts; Green Light Source.
- Rated life 60K hours (to 70% lumens, limited by ballast life); lamp and power supply are recommended as replaced at the same time.
- Color Rendering Index (CRI) of 80 and Correlated Color Temperature (CCT) of 3000K.

Risk & Mitigation Factors

With new induction lighting, cabling and utility pole upgrades at the site come associated risks. Potential risks associated with replacing wooden utility poles, lights and cabling, as well as determining lighting deficiencies include reduced security capability during construction, failing to identify all inadequate lighting areas, maintaining a safe work environment, and having a loss of lighting in areas where poles are being replaced. The table below summarizes the mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing Utility Poles/Lighting and Determining Lighting Deficiencies (Induction)

Risks	Mitigation Strategy	Likelihood - Impact	Impact
Reduced security capability during construction.	Close coordination with NOLA, site security and contractor during work plan development and scheduling.	Medium - Medium	Medium Risk Hazard
Lighting survey does not identify all inadequately lighted areas.	Use a computer based program to confirm lighting survey results.	Low - Low	Low Risk Hazard
Safety while installing new poles, lighting, and cables.	Ensure a job hazard analysis is prepared by contractors and for anyone onsite near the installation of the poles, lighting, or cables.	Medium - Medium	Medium Risk Hazard
Loss of lighting in areas while poles are being replaced.	Prepare a strategic plan for minimizing the effects, and use portable lighting as necessary.	High - Medium	Medium Risk Hazard
Lighting technology needed to address both lighting and security needs.	Close coordination between maintenance and PF to determine the correct lighting technology.	Medium - High	Medium Risk Hazard
Induction lighting contains mercury.	Maintenance on induction lighting should be conducted after complete cool down; address in an updated maintenance procedure.	Medium - High	Medium Risk Hazard

C. Replace Designated Utility Poles, All Lights and Associated Cabling (High Intensity Discharge - HID)

The (HID) alternative consists of replacing all lighting and fixtures with HID lighting technology while replacing designated wooden utility poles (~119) and associated cabling at Bryan Mound, Texas. A recent lighting evaluation conducted at Bryan Mound determined there were ~27 light deficient areas, ~8 of those on roadways. A lighting evaluation shall be performed to identify areas where lighting is inadequate or no longer needed (main site, caverns, RWIS, ESS, RWIPP, RPX, brine disposal well pads, roadways, employee parking lots, etc.). Methods recommended by the IES shall be used to model expected light levels and to assist in the design and layout of all replacement lighting; the DOE Design Level III Criteria for roadway ground level lighting is 0.2 foot candles (fc), 5.0 fc for process and maintenance areas, 0.1 fc for parking areas, and 1.0 for cavern areas.

The most common types of HID are mercury vapor lamps, metal halide lamps and HPS; HPS being the most common on the SPR. HID lighting lamps produce an arc for intense light, therefore requiring ballasts. HID ballast technology is old and highly inefficient, requiring time to establish the electric arc and is not easily controlled or dimmable while LED and Induction lighting can be integrated into a remote monitoring and dimming control system.

Mercury vapor lamps—the oldest types of high-intensity discharge lighting were formerly used for street lighting, but are now only rarely used for that purpose. Nearly all new lamps sold in North America today for street lighting are either metal halide or LEDs, which have also displaced mercury vapor lamps in sports arenas and gymnasiums. Mercury vapor lamps provide about 50 lumens per watt, but ballast loss can reduce the system efficacy to about 30 lumens per watt, which is not competitive with LEDs.

Metal halide lamps produce a bright, white light with the best color rendition among high-intensity (HID) lighting types. They are used to light large indoor areas, such as gymnasiums and sports arenas, and outdoor areas, such as parking lots. Metal halide lamps are similar in construction and appearance to mercury vapor lamps. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than from mercury gas alone.

High-pressure sodium (HPS) lighting is a type of HID lighting used for street and outdoor area lighting, parking garages, and some industrial applications. Although HPS lamps can be efficient and long-lasting, they typically have poor color rendering compared to other lamp types, and are being displaced by LEDs in many applications.

It is important to note that proposed camera replacements shall dictate the type of lighting (or vice versa) identified to replace existing lighting; lighting systems must meet the requirements listed in DOE Order 473.3 A.

All wooden roadway pole replacements (~8) shall be considered with hot dipped galvanized steel poles with extended hinged arms to allow for ease of maintenance. The remaining wooden utility poles (~111) shall be replaced with a more durable material than wood such as hot-dipped galvanized poles (HDP) or an approved equal. Hinged poles shall only be used in areas where a man-lift is not feasible. Cabling replacement shall be addressed by pulling new lighting cabling through existing duct banks or conduit. If there is no existing duct bank or conduit, options of using existing cable trays or installing new duct bank or conduit shall be examined (HID).

Assumptions & Constraints

Assumptions:

- A lighting evaluation shall be done prior to detailed design.
- Lighting and new camera lighting requirements/engineering shall be de-conflicted during detailed design.
- Where possible, cabling shall be installed in existing cable trays vs installing new duct banks or conduit.
- Most cabling associated with lighting is located in duct bank or conduit.

Constraints:

- Possible existing power sources for all new utility pole installation.
- Available/existing cable trays within a suitable distance for use.
- Source efficiency is typically 120 lumens/watt or higher. However, losses from trapped light, protective covers and lenses, inefficient ballasts and unfavorable operating temperature typically result in a measured system efficiency of 30 lumens/watt or less.
- HID lights are more fragile and have a warm up (15-20 seconds) during ignition.
- Contains mercury; relatively higher recycling cost.

Benefits & Effectiveness

The replacement of wooden utility poles and identifying site lighting deficiencies allows for multiple benefits and addresses current mission needs.

- Alleviates safety risks from deteriorating wooden utility poles and increases performance of poles in poor weather (hurricane force rain/wind) (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Cabling with duct banks or conduit is the industry standard and prevents inadvertent cutting of cables, which prevents unscheduled maintenance repairs and personnel safety concerns (DOE 473.3 A., Attachment 3, Section A 3-36 [3][d]).
- Employees feel safer with more adequately lighted areas; allows for a safe work environment per OSHA guidelines (DOE 473.3 A., Attachment 3, Section A 3-36 [3][h]).

Risk & Mitigation Factors

With new upgrade at the site come associated risks. Some potential risks associated with replacing utility poles and determining lighting deficiencies include reduced security capability during construction, failing to identify all inadequate lighting areas, maintaining a safe work environment, and having a loss of lighting in areas where poles are being replaced. The table below summarizes the mentioned risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Replacing Utility Poles and Determining Lighting Deficiencies

Risks	Mitigation Strategy	Likelihood - Impact	Risk Code
Reduced security capability during construction.	Close coordination with NOLA, site security and contractor during work plan development and scheduling.	Medium - Medium	Medium Risk Hazard
Lighting survey does not identify all inadequately lighted areas.	Use a computer based program to confirm lighting survey results.	Low - Low	Low Risk Hazard
Safety while installing new poles, lighting, and cables.	Ensure a job hazard analysis is prepared by contractors and for anyone onsite near the installation of the poles, lighting, or cables.	Medium - Medium	Medium Risk Hazard
Loss of lighting in areas while poles are being replaced.	Prepare a strategic plan for minimizing the effects, and use portable lighting as necessary.	High - Medium	Medium Risk Hazard
Lighting technology needed to address both lighting and security (CCTV) needs.	Close coordination between maintenance and PF to determine the correct lighting technology.	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. Replace Designated Utility Poles, All Lights and Associated Cabling (LED)

The (LED) alternative consists of replacing all wooden utility poles used for lighting and associated light fixtures and lights with LED technology, along with the associated wiring/cabling on the site. This option will also consist of identifying lighting deficiencies and replacing with more energy efficient lighting on Bryan Mound.

B. Replace Designated Utility Poles, All Lights and Associated Cabling (Induction)

Perform The (Induction) alternative consists of replacing all wooden utility poles used for lighting and associated light fixtures and lights with Induction technology, along with the associated wiring/cabling on the site. This option will also consist of identifying lighting deficiencies and replacing with more energy efficient lighting at Bryan Mound.

C. Replace Designated Utility Poles, All Lights and Associated Cabling (High Intensity Discharge)

The (HID) alternative consists of replacing all wooden utility poles used for lighting and associated light fixtures and lights with HID technology, along with the associated wiring/cabling on the site. This option will also consist of identifying lighting deficiencies and replacing with more energy efficient lighting at Bryan Mound.

Comparison of Alternatives

Core Team Member Ratings

	Constructability During Ongoing Oil Deliveries	**Ease of Operations**	**Ease of Maintenance**	**Safety During Construction**	**Security During Construction**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Most Important*	*Important*
Alternative A	*Excellent*	*Excellent*	*Excellent*	*Good*	*Good*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Good*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Good*	*Good*	*Excellent*
Alternative B	*Excellent*	*Excellent*	*Good*	*Good*	*Good*	*Good*
	Excellent	*Excellent*	*Good*	*Good*	*Excellent*	*Good*
	Excellent	*Excellent*	*Good*	*Good*	*Good*	*Good*
Alternative C	*Excellent*	*Good*	*Adequate*	*Good*	*Good*	*Good*
	Excellent	*Adequate*	*Adequate*	*Good*	*Excellent*	*Adequate*
	Excellent	*Excellent*	*Adequate*	*Good*	*Good*	*Adequate*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$2,319,349**	**$2,353,211**
Alternative B	**$4,724,379**	**$4,777,419**
Alternative C	**$4,740,636**	**$4,809,289**

Recommended Alternative

A. Replace Designated Utility Poles, All Lights and Associated Cabling (LED)

Based on the technical evaluation of the Core Team Members, Alternative A was clearly rated equal or superior on all evaluation criteria. The initial cost and life cycle cost of Alternative A were both lowest of the alternatives. Therefore, Alternative A is the recommended preferred alternative based on both technical and cost factors studied in the alternative analysis.

BM-MM-590

BM Raw Water Intake Pipeline #1

VCI Project Engineer: Bill Fogle

Recommended Alternative:

HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and North to Pump House at BMT-1. CS Aboveground at Pig Launcher and Receiver

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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B. Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House. CS Aboveground at Pig Launcher and Receiver. 13

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I. PROJECT CONCEPT

Mission Need

The crude oil drawdown rate at Bryan Mound (BM) is dependent on the rate of raw water used to displace the oil from the caverns. There are two raw water pipelines that were originally installed 40 years ago. The pipelines are unlined carbon steel. One of the pipelines is out of service and the other is in poor condition. The raw water rate will be limited if the existing raw water pipeline fails. Replacement of the raw water pipelines will ensure BM's ability to achieve Level I drawdown which the SPR is committed to maintaining.

Functional Requirements

- Pipeline(s) must provide a drawdown rate of 1.5 million barrels per day (MMBD) of crude oil. The raw water rate at the raw water injection pumps (RWIPs) is 1.63 MMBD at 75 pounds per square inch gauge (PSIG).
- The pipeline(s) material selection should provide a 25-year service life with minimum maintenance.
- The routing of the pipeline(s) should minimize additional pressure drops.
- The design should accommodate in-place inspection technique.

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for selection of the preferred alternative has been standardized for all AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Bill Fogle	VCI, Project Engineer
Chris Vedros	FFPO, Manager Pipeline and Equipment Integrity

Team Members

Jorge Aguinaga	DOE, Site Lead General Engineer
Laren Tushim	VCI, Mechanical Engineer
David Wilkins	VCI, Lead Process Engineer
Janet Robert	FFPO, Director Facilities Design and Integrity
Mike Cabiran	FFPO, Senior Site Maintenance Engineer
Michael Sickmiller	FFPO, Site Director
Joseph Mravunich	FFPO, Manager Site Maintenance
Dennis Henderson	FFPO, Manager Site Operations
Timothy Kelley	FFPO, Manager Site Construction

III. SELECTION CRITERIA

The AoA Team determined the below listed criteria as relevant to the Analysis of Alternatives. Once alternatives are analyzed by the AoA Team, these criteria are used to evaluate and select a recommended preferred alternative.

Technically Sound Solution

The selected alternative can be engineered to meet mission goals and the project functional requirements. The raw water drawdown rate is critical to meeting mission needs. The pipelines should provide adequate raw water on every drawdown over the 25-year life of LE 2.

Weight: Most Important

Constructability During On-Going Oil Deliveries

When implemented, the selected alternative will have little or no impact to on-going oil delivery operations. The site must be able to provide raw water to the caverns during the construction of the pipeline(s).

Weight: Important

Ease of Operations

When implemented, the selected alternative will result in a system that is similar to existing systems and equipment and operates without significant additional training. The pipeline(s) must provide adequate raw water during drawdown.

Weight: Important

Ease of Maintenance

The selected alternative is similar in nature to existing equipment resulting in commonality of similar systems for future maintenance and sparing consideration. The material section must meet or exceed the 25-year life of LE 2 with minimum maintenance.

Weight: Important

Safety During Construction

When implemented, the selected alternative will allow for safe construction and operation. Ability to address Safety and Security concerns during implementation.

Weight: Important

Sustainability

When implemented, the selected alternative will be able to achieve DOE Sustainability goals for energy consumption as outlined in the Strategic Sustainability Performance Plan.

Weight: Less Important

IV. ALTERNATIVES IDENTIFICATION

List of Alternatives

The below listed alternatives are considered for analysis. Initial screenings conducted by the AoA Team determine the viability of each alternative.

The Bryan Mound (BM) raw water system is supplied with water from the Brazos River. Raw water is sent from the Raw Water Intake Structure (RWIS), on the east side of the Brazos River, to the BM site Raw Water Injection Pumps (RWIPs) by pipeline. The RWIPs send raw water to the caverns for oil drawdown and cavern leaching.

The in-service pipeline is typically inspected yearly with a smart pig for Ultrasonic Testing (UT) to recalculate the maximum allowable pressure. It has not been inspected since May 2007.

In addition, it cannot supply the required drawdown rate of 1.7 MMBD raw water. A mechanical failure will significantly affect the Level 1 drawdown at BM.

A. Alternatives for Addressing Pipeline(s) Repair/Replacement

The project scope of work is set by considering alternatives for how to repair or replace the raw water pipeline(s).

1. Status Quo

Continue to use one of the existing raw water pipelines and leave the other out of service. The current system functions at only a portion of the system requirements. As a result, the BM SPR site cannot meet the 1.7 MMBD raw water drawdown rate as currently mandated. Also, the single 36-inch line that is in service is at the end of service life per design. There is no recent information on the mechanical integrity of the pipe.

The existing raw water pipeline cannot be monitored for conditions that could lead to loss of integrity. Drawdown would necessarily stop if the loss were severe. The time that it would take to locate, isolate, mobilize for repair, and repair the leak would severely impact drawdown capabilities. The system also remains prone to the threat of more frequent, subsequent failures following the initial failure of any one component in the system. This leads to a significant decline in system reliability which threatens the overall mission.

BM will not be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will not have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. This alternative does not meet mission need or functional requirements, therefore, this alternative is not feasible

Viability: <u>No Further Analysis</u>

2. Inspect and Refurbish Existing Pipeline

One of the original 36-inch lines remains in service, but is in poor condition. The other has been removed from service. A thorough inspection of both lines would be required to determine the remaining life of the metal and repairs required to extend the service life by 25 more years. The inactive pipeline may require a complete replacement. The pipe repairs may be extensive and will require excavations throughout the site. Hydraulics indicated that both 36-inch lines are needed to meet the performance flow rate criteria, so a single 36-inch line would not meet the performance criteria for flow rate.

The original pipelines may be beyond rehabilitation and would require either abandonment in place or replacement with similar lines. The geometry of the lines as they pass through the site would create too many obstacles to use the existing lines as casings. Sections of pipeline with inadequate mechanical integrity missed during inspection could lead to future leaks. The time that it would take to locate, isolate, mobilize for repair, and repair the leak would severely impact drawdown capabilities.

The extensive repairs of both pipelines may not provide the 25 years of service. Any additional failures in the future will limit the raw water rates for cavern drawdown or leaching. BM will not have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. This alternative does not meet mission need or functional requirements set by the project, therefore, this alternative is not feasible.

Viability: <u>No Further Analysis</u>

3. Pipeline Replacement with Carbon Steel and/or HDPE Pipe

The existing pipelines would be replaced with carbon steel (CS) and/or high-density polyethylene (HDPE) of adequate pipe diameter to provide the required drawdown rate. Three routes for the replacement pipeline are recommended. They are: Route 1 (Northern Route following existing pipeline on the north side of the tanks), Route 2 (Central Route on the south side of the tanks) and Route 3 (Southern Route) as shown in Figures 1 and 2.

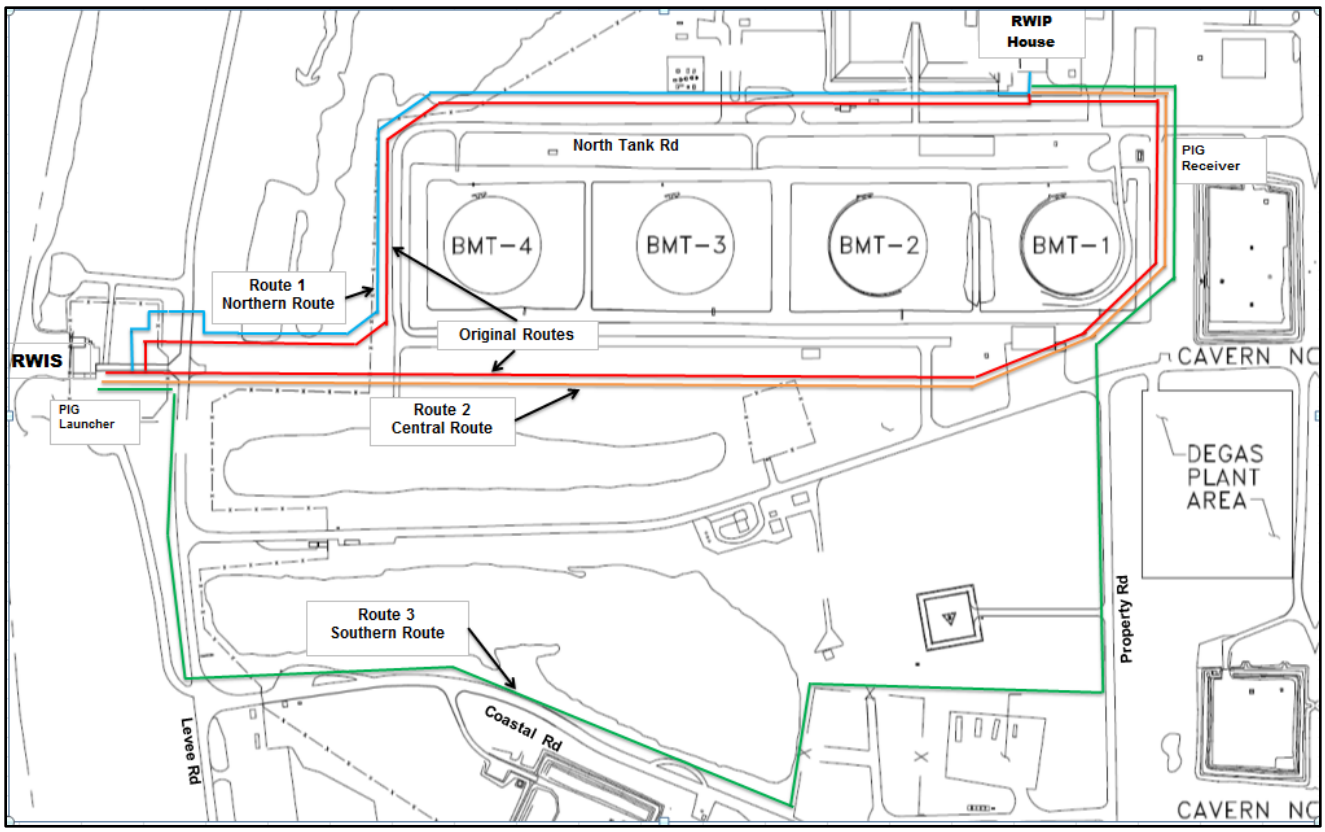

Figure 1 – Routes for Pipeline Replacements

Hydraulic calculations were done for various line sizes for CS and HDPE pipe for each of the routes. HDPE DR9 was selected since the maximum allowable working pressure of 235 PSIG exceeds the shut-off pressure of the intake pumps (206 PSIG). The raw water rate was 1.63 MMBD, and the intake pumps discharge pressure was 155 PSIG. The critical suction pressure for the Injection Pumps Nozzle was set at 75 PSIG. The maximum velocity for carbon steel was set at 13 feet per second (ft/s) and HDPE DR9 was 14.5 ft/s. For carbon steel, a size 42-inch diameter with 0.5-inch wall pipe is recommended. For HDPE DR9, a size 48-inch diameter pipe is recommended.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. This alternative meets mission need and functional requirements set by the project. Therefore, this alternative is feasible. The combination of pipe materials and routes will be explored in Section B. Alternatives for Pipeline Materials and Routes

Viability: Continue Analysis

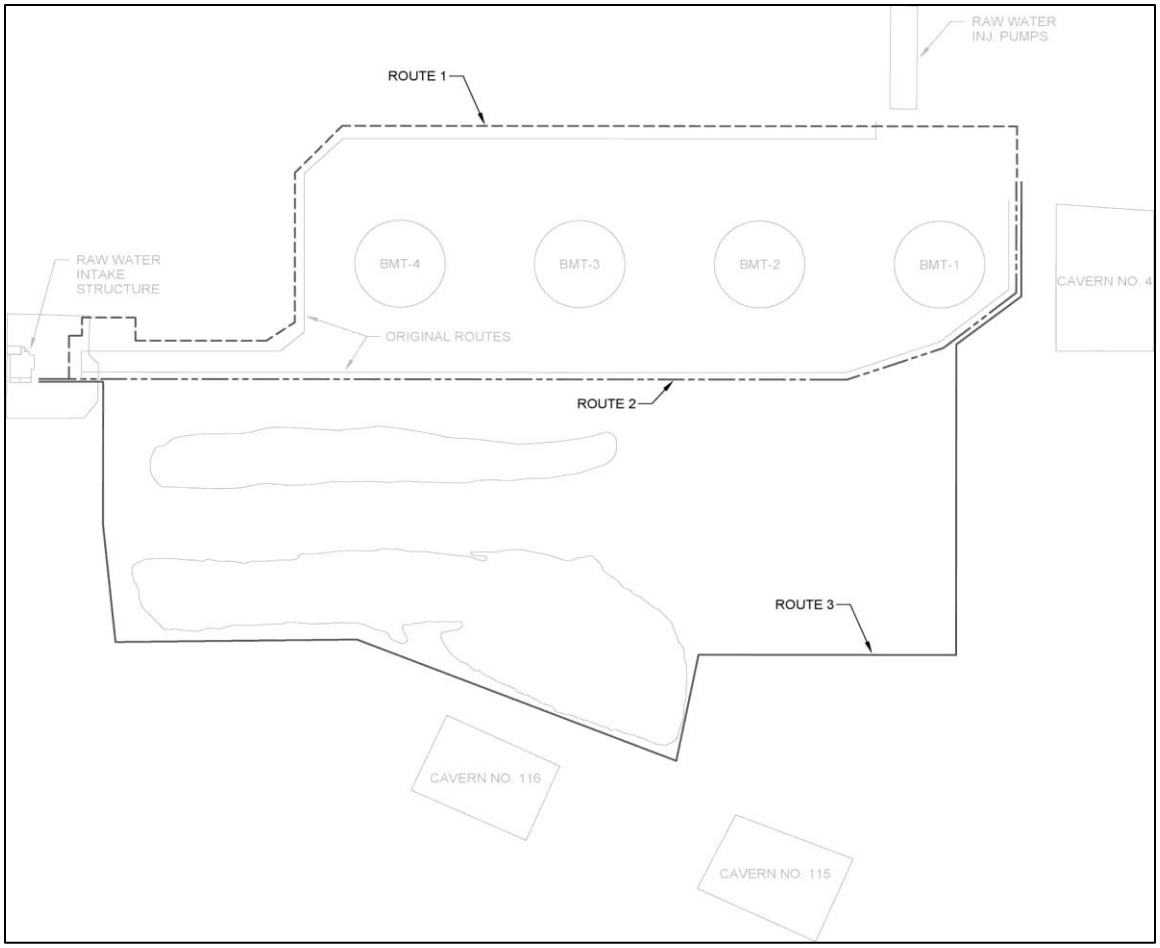

Figure 2 – Routes for Pipeline Replacements

B. Alternatives for Pipeline Materials and Routes

An alternative has been identified to replace pipeline with CS and/or HDPE (A-3). Now, the project scope of work is set by considering alternatives for pipe material and routing of the raw water pipeline(s).

1. Vertical Pipe Bridge Over the Levee and Use Route 1 (Northern Route) with CS Pipe Bridge Over Levee with Underground Carbon Steel Pipe Routed North of Storage Tanks (Route 1) to RWIP House

This option is to install a pipe bridge over the levee using carbon steel (CS) pipe for the entire route including the pipe bridge. The 42-inch diameter pipe will require a new pig launcher and receiver which will be installed near the existing one. The pipe bridge may need to have a truss support structure, which could create additional overhead obstruction. In-line inspection with smart pigging technology is recommended for CS pipe. All pipe fittings and bends should be designed to allow in-line inspections. The CS pipe installed belowground would also need to be cathodically protected against external corrosion.

After the pipe bridge, the underground pipeline would continue east towards the storage tanks and follow Route 1 in Figure 3. Then, the pipe will turn north at the corner by BMT-4 and South Tank Road (follow the existing 36-inch pipeline) and will be installed between the pipe rack and the road. The pipeline will continue north towards North Tank Road. At North Tank Road, the pipeline will turn east and run parallel with North Tank Road towards the Raw Water Injection Pumps House (RWIP House). For pipe installation under roads, the road would either be open cut or jack and bored. The pipe will come aboveground to the new pig receiver and run to the RWIP House. The total length of this alternative is approximately 2,600 feet, and

the pipe velocity is 11.5 ft/s. The line pressure drop is 12.9 PSI which correlates to the injection pump suction pressure of 141 PSIG.

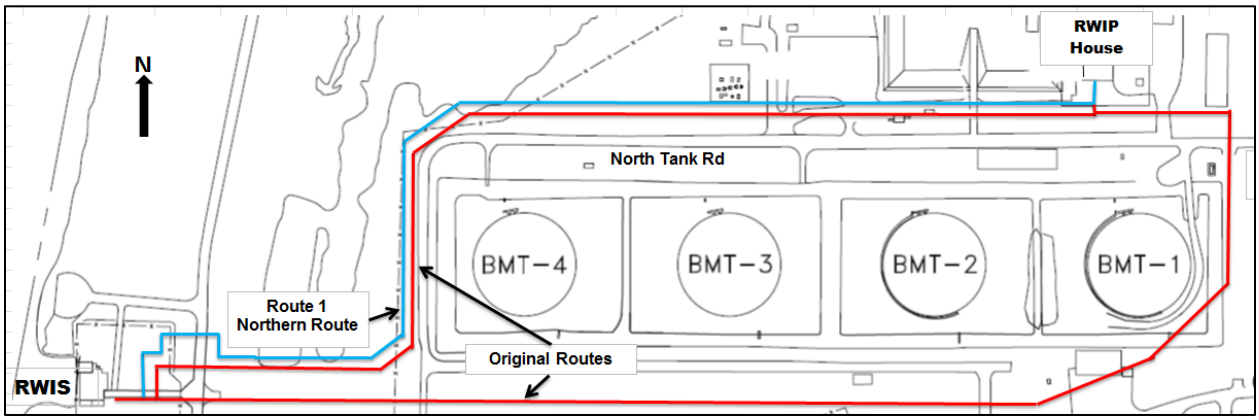

Figure 3 – Route 1 for Alternative B-1 for underground CS pipeline replacement

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The selected material of CS is affected by external corrosion as well as biological growth internally, and not chemically resistant. In addition, CS costs more for capital and maintenance. Truss support structures may be needed which could create additional overhead obstruction. This alternative meets the mission need; however, it does not meet all of the functional requirements of the project. Therefore, this alternative is not feasible.

Viability: <u>No Further Analysis</u>

2. Vertical Pipe Bridge Over Levee with Underground Carbon Steel Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP

This option is to install a pipe bridge over the levee using carbon steel (CS) pipe for the entire route including the pipe bridge. The 42-inch diameter pipe will require a new pig launcher and receiver which will be installed near the existing one. The pipe bridge may need to have a truss support structure, which could create additional overhead obstruction. In-line inspection with smart pigging technology is recommended for CS pipe. All pipe fittings and bends should be designed to allow in-line inspections. The CS pipe installed belowground would also need to be cathodically protected against external corrosion.

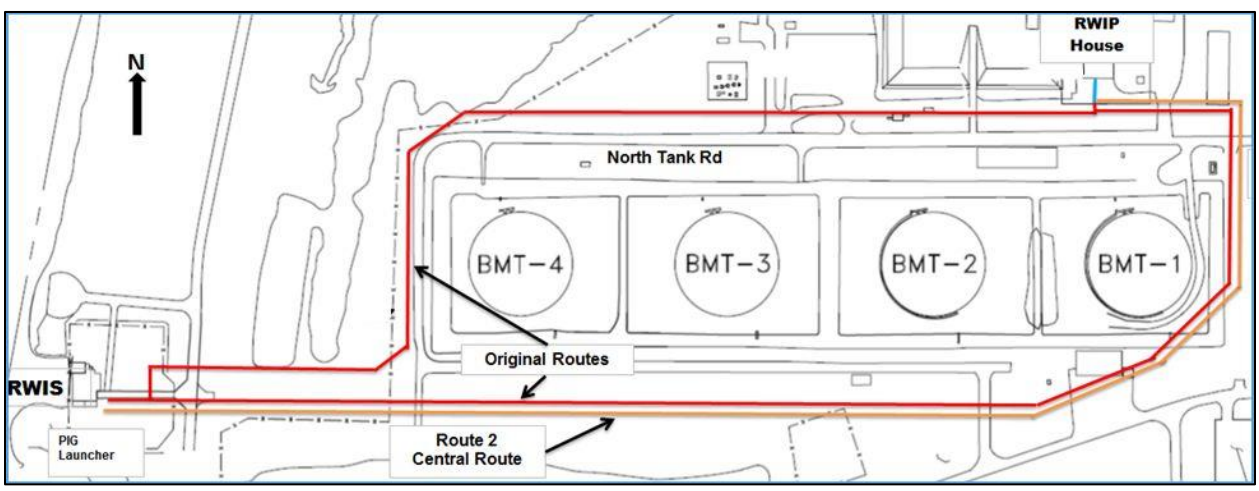

Figure 4 – Route 2 for Alternative B-2 for underground CS pipeline replacement

After the pipe bridge, the underground pipeline would continue east and follow the existing pipeline along Route 2 (See Figure 4) that is between the storage tanks and pond. Prior to reaching BMT-1, this route will cross under two roads and a parking lot that could all be open cut or jack and bored. After crossing the

parking lot, the line would turn northeast and cross under a pipe rack. Then, it turns north between BMT-1 and Cavern No. 4. From there, the line will run under another pipe rack to continue north towards North Tank Road. Then, the line would cross under North Tank Road and turn left (west) to run parallel to the road, between the road and a large pipe rack. Then, the line would cross under another road prior to reaching the RWIP House. The line has to cross several underground pipes before reaching the RWIP House. The depth of these lines would need to be determined to see whether the new line would cross under or above them. Next, the pipe will come aboveground to the new pig receiver and run to the RWIP House. The total installation length of this alternative is approximately 3,600 feet, and the pipe velocity is 11.5 ft/s. The line pressure drop is 16.3 PSI which correlates to the injection pump suction pressure of 138 PSIG.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The selected material of CS is affected by external corrosion as well as biological growth internally, and not chemically resistant. In addition, CS costs more for capita, and maintenance. This alternative meets the mission need; however, it does not meet all of the functional requirements of the project. Therefore, this alternative is not feasible.

Viability: No Further Analysis

3. HDD Under the Levee and Use Route 2 (Central Route) With CS HDD Under Levee with Underground Carbon Steel Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP House

The Horizontal Directional Drill (HDD) is a trenchless technology that minimizes surface disruption. This option will require a total length from the HDD entry to the HDD exit to be approximately 1635 linear feet (1700 feet underground due to radius) for a 42-inch diameter carbon steel pipeline. Cement lined CS pipe is not recommended for use with HDD due stress induced cracking of the lining. Permission and permit from Levee Drainage District will be required for levee work.

The 42-inch diameter pipe will require a new pig launcher and receiver which will be installed near the existing one. In-line inspection with smart pigging technology is recommended for CS pipe. All pipe fittings and bends should be designed to allow in-line inspections. The CS pipe installed belowground would also need to be cathodically protected against external corrosion.

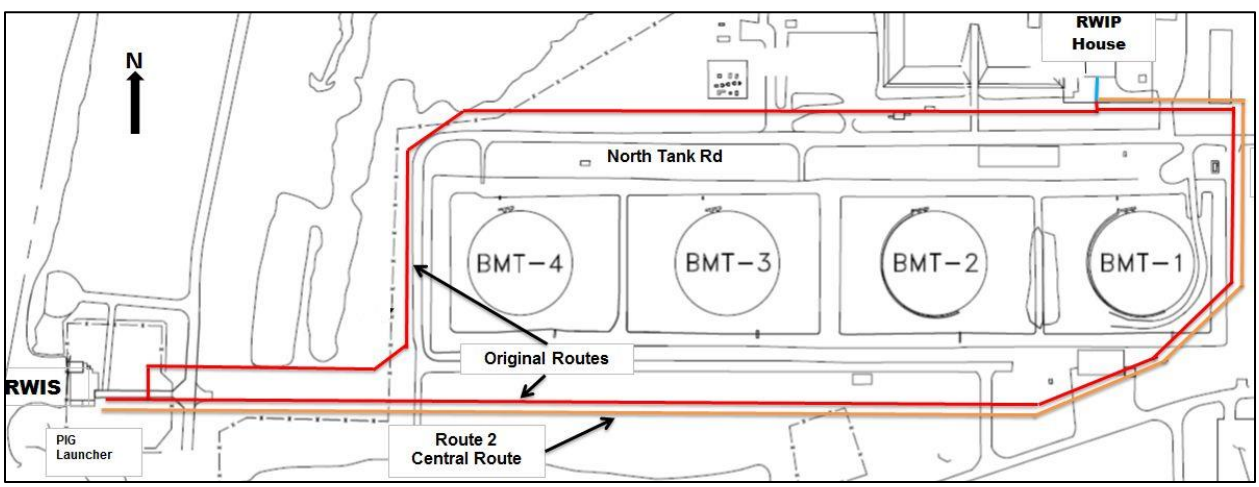

Figure 5 – Route 2 for Alternative B-3 for underground CS pipeline replacement

The new pig launcher would need to be installed upstream of the HDD entry for the 42-inch CS line. From there, the line would go belowground at the HDD entry. Downstream of the HDD exit, the underground pipeline would continue east and follow the existing pipeline along Route 2 (See Figure 5 above) that is between the storage tanks and pond. The line will then follow the same route as described above in Alternative B-2. The total installation length of this alternative is approximately 3,600 feet, and the pipe

velocity is 11.5 ft/s. The line pressure drop is 16.3 PSI which correlates to the injection pump suction pressure of 138 PSIG.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The selected material of CS is affected by external corrosion as well as biological growth internally, and not chemically resistant. In addition, CS costs more for capital and maintenance. This alternative meets the mission need; however, it does not meet all of the functional requirements of the project. Therefore, this alternative is not feasible.

Viability: No Further Analysis

4. Underground Carbon Steel Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground Carbon Steel Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House

The 42-inch diameter pipe will require a new pig launcher and receiver which will be installed near the existing one. In-line inspection with smart pigging technology is recommended for CS pipe. All pipe fittings and bends should be designed to allow in-line inspections. The CS pipe installed belowground would also need to be cathodically protected against external corrosion.

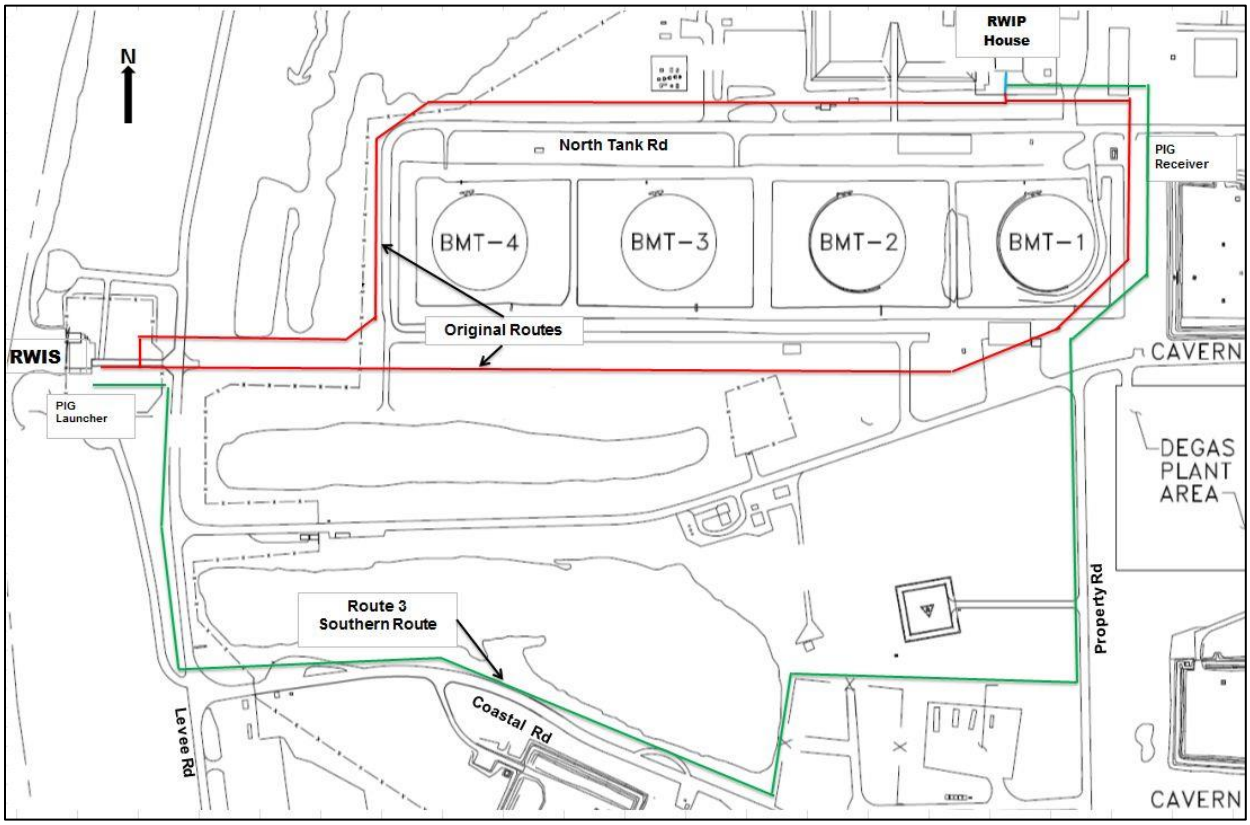

Figure 6 – Route 3 for Alternative B-4 for underground CS pipeline replacement

Downstream of the pig launcher, the CS line would go east for about 70 feet, just prior to reaching the levee (See Figure 6 for Route 3 routing). Then, it will turn south and runs parallel to the levee for about 650 feet and stops near the guard house. Next, the line would turn to the east towards the guard house, crossing under the Levee Road (open cut or jack and bore). Then, it will run parallel to Coastal Road for about 1440 feet. The line would turn north between the pond and a fenced in storage yard. To the north of the storage yard, the line would turn due east and run for about 640 feet to just before Property Road. Then, it will turn north and run parallel to this road for about 750 feet where it would continue on the Route 2 from its turn north between BMT-1 and Cavern No. 4" in Alternative B-2. The total installation length of this alternative

is approximately 4,900 feet, and the pipe velocity is 11.5 ft/s. The line pressure drop is 20.9 PSI which correlates to the injection pump suction pressure of 133 PSIG. Route 3 has the highest pressure drop and longest length. Permit will be required for work on Levee Road.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The selected material of CS is affected by external corrosion as well as biological growth internally, and not chemically resistant. In addition, CS costs more for capital and maintenance. This alternative meets the mission need; however, it does not meet all of the functional requirements of the project.

Viability: No Further Analysis

5. HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP House. CS Aboveground at Pig Launcher and Receiver.

The 48" diameter HDPE pipe will require a new pig launcher and receiver which will be installed near the existing one. Since the pig launcher and receiver are aboveground, HDPE pipe is not recommended; therefore, 48" CS pipe should be used at the pig launcher and receiver. In-line inspection with smart pigging technology is not needed for HDPE pipe. However, ploy pigs or foam pigs are needed for maintenance cleaning. Since HDPE pipe is not subject to external corrosion, cathodic protection is not needed.

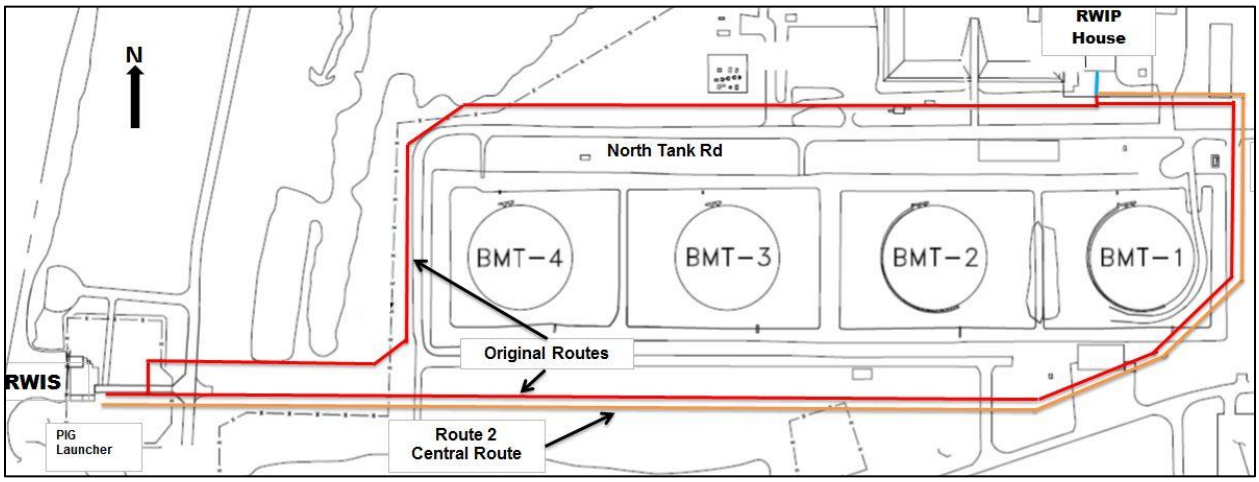

Figure 7 – Route 2 for Alternative B-5 for underground HDPE pipeline replacement

HDPE pipe can be used belowground from downstream of the launcher to upstream of the HDD entry point. This HDD option will require a total length from HDD entry to HDD exit to be approximately 1608 linear feet (1673 feet long underground due to radius) for a 48" diameter HDPE pipeline. Downstream of the HDD exit, the underground pipeline would continue east and follow the existing pipeline along Route 2 (See Figure 7 above) that is between the storage tanks and pond. The line will then follow the same route as described above in Alternative B-2. The total installation length of this alternative is approximately 3,600 feet, and the pipe velocity is 14.4 ft/s. The line pressure drop is 22.7 PSI which correlates to the injection pump suction pressure of 131 PSIG. Permission and permit from Levee Drainage District is required for levee work.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The majority of the selected pipe material is HDPE which is not affected by external corrosion, resistant to most chemicals, and has no biological growth internally. The piping at the pig launcher and receiver will be CS and aboveground. The use of CS is minimal, and it can be inspected and maintained. This alternative meets the mission need and all of the functional requirements of the project. Therefore, this alternative is feasible.

Viability: Continue Analysis

6. **Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House. CS Aboveground at Pig Launcher and Receiver.**

The 48" diameter HDPE pipe will require a new pig launcher and receiver which will be installed near the existing one. Since pig launcher and receiver are aboveground, HDPE pipe is not recommended; therefore, 48" CS pipe should be used at the pig launcher and receiver. In-line inspection with smart pigging technology is not needed for HDPE pipe. However, ploy pigs or foam pigs are needed for cleaning maintenance. Since HDPE pipe is not subject to external corrosion, cathodic protection is not needed.

Downstream of the pig launcher, the HDPE line would go east for about 70 feet, just prior to reaching levee road (See Figure 6 for Route 3 routing). Then, it will turn south and run parallel to the levee road for about 650 feet and stop where the levee road and maintenance road intersect. The line would continue on the Route 3 path described above in Alternative B-4. The total installation length of this alternative is approximately 4,900 feet, and the pipe velocity is 14.4 ft/s. The line pressure drop is 29.4 PSI which correlates to the injection pump suction pressure of 125 PSIG. Route 3 has the highest pressure drop and longest length. Permit will be required for Levee Road work.

BM will be able to provide the adequate raw water rates for cavern drawdown or leaching. BM will have the ability to maintain its Level I drawdown rate which the SPR is committed to maintaining. The majority of the selected pipe material is HDPE which is not affected by external corrosion, resistant to most chemicals, and has no biological growth internally. The piping at the pig launcher and receiver will be CS and aboveground. The use of CS is minimal, and it can be inspected and maintained. This alternative meets the mission need and all of the functional requirements of the project. Therefore, this alternative is feasible.

Viability: Continue Analysis

V. ALTERNATIVES ANALYSIS

Based on initial analysis of the alternatives, alternatives A-1, A-2, B-1, B-2, B-3, and B-4 are eliminated from further consideration. The remaining alternatives, B-5 and B-6 are examined below as alternatives A and B, respectively.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

Assumptions & Constraints

- HDPE DR9 was selected since the maximum allowable working pressure of 235 PSIG exceeds the shut off pressure of the intake pumps (206 PSIG).
- For the hydraulics calculation, the raw water rate was 1.63 MMBD, and the intake pumps discharge pressure was 155 PSIG. The critical suction pressure for the Injection Pumps Nozzle was set at 75 PSIG. The maximum velocity for HDPE DR9 is 14.5 ft/s.
- For HDPE DR9, a size 48-inch diameter pipe is recommended to be below maximum velocity.
- Route 2 installation length is approximately 3600 feet. The line pressure drop is 22.7 PSI which correlates to the injection pump suction pressure of 131 PSIG. The pipe velocity is 14.4 ft/s.
- Route 3 installation length is approximately 4900 feet. The line pressure drop is 29.4 PSI which correlates to the injection pump suction pressure of 125 PSIG. The pipe velocity is 14.4 ft/s.
- Total length required from HDD entry to HDD exit is to be approximately 1608 linear feet (1673 feet long underground due to radius) for a 48" diameter HDPE pipeline.
- In-line inspection with smart pigging technology is not needed for HDPE pipe.
- Since HDPE pipe is not subject to external corrosion, cathodic protection is not needed.

A. HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP House. CS Aboveground at Pig Launcher and Receiver.

This alternative will replace the belowground portion of the raw water line with a 48-inch diameter HDPE DR9 pipe and will replace the aboveground portion with 48-inch carbon steel. A Horizontal Directional Drill (HDD) will be used to penetrate the levee. The pipeline will follow Route 2, which is the Central Route.

Benefits & Effectiveness

Bryan Mound will replace the existing raw water pipelines, one of which is deemed out of service and the other near end of life. The new raw water supply pipeline will be able to provide 1500 MBD of water to the caverns for drawdown and cavern leaching. The HDPE pipe material is highly compatible with raw water and will withstand corrosion and biological growth; however, it cannot be used aboveground unless specially treated. It should last the duration of LE2. Carbon steel piping will be used in aboveground sections of the pipeline. Horizontal Directional Drill (HDD) is a trenchless technology that minimizes surface and social disruption, allows underground excavation without waterway crossings, and reduces reconstruction of paved surfaces for trenches.

Bryan Mound will be able to maintain Level 1 drawdown rate, committed by the Strategic Petroleum Reserve (SPR), by supplying the required amount of raw water to the caverns for oil drawdown and leaching.

Risk & Mitigation Factors

There are associated risks with the excavation and installation of underground pipelines. The proper equipment and planning are needed to ensure excavations are safely done. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP House. CS Aboveground at Pig Launcher and Receiver

Risks	Mitigation Strategy	Likelihood – Impact	Risk Code
Unknown subsurface	Geological study of subsurface of planned route to verify obstacles. Find available drawings of underground pipelines.	High – High	High Risk Hazard
Under-estimated cost	Make sure all possible costs have been analyzed in the life cycle cost.	Low – Low	Low Risk Hazard
Equipment availability	Procure contractor and equipment in advance once the schedule has been determined to avoid delays with equipment availability.	Low - Medium	Low Risk Hazard
Scheduled outage extended	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low – High	Low Risk Hazard
Reduced flow with additional pressure drop with new routing	Develop hydraulic system of planned pipe routing to determine pressure loss. Verify if the required pumping capacity and pressure will be met with the new pipe routing.	Low – High	Low Risk Hazard
HDPE pipe size availability	Contact pipe supply vendor on lead time for the required pipe size and length. Account for time during the planning period.	Low – Medium	Low Risk Hazard
Pipe material not compatible with raw water	Sample raw water and analyze for pH and corrosive chemicals. Verify with pipe supply vendor the compatibility of the raw water with the piping material.	Low – Medium	Low Risk Hazard

Risk and Mitigation Strategies for HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and Turns North at BMT-1 to RWIP House. CS Aboveground at Pig Launcher and Receiver (Continued)			
Risks	**Mitigation Strategy**	**Likelihood – Impact**	**Risk Code**
Installation and construction safety	For underground work, make sure area is barricaded with red “danger” tape. Follow proper excavation procedure with emphasis on trench support and exit routes.	Medium – High	Medium Risk Hazard
HDD installation limitations	Verify clearance to fit a total length from HDD entry to HDD exit to be approximately 1608 linear feet (1673 feet long underground due to radius) for a 48” diameter HDPE pipeline.	Low – High	Low Risk Hazard
Permission and permit not granted by the Levee Drainage District	Request permission from Levee Drainage District. Submit permit request and allow sufficient time for approval.	Medium – High	Medium Risk Hazard
Subsidence of Cavern 3 on pipeline route	Verify subsidence rates and chose alternate route if necessary	Medium - High	Medium Risk Hazard

B. Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House. CS Aboveground at Pig Launcher and Receiver.

This alternative will replace the belowground portion of the raw water line with a 48-inch diameter HDPE DR9 and the aboveground portion with 48-inch diameter carbon steel. The pipe will cross under the levee road. The pipeline will follow Route 3, which is the Southern Route.

Benefits & Effectiveness

Bryan Mound will replace the existing raw water pipelines, one of which is deemed out of service and the other near end of life. The new raw water supply pipeline will be able to provide 1500 MBD of water to the caverns for drawdown and cavern leaching. The HDPE pipe material is highly compatible with raw water and will withstand corrosion and biological growth; however, it cannot be used aboveground unless specially treated. It should last the duration of LE2. Carbon steel piping will be used in aboveground sections of the pipeline. The pipe will cross under the levee road which will not require a new permit from the Levee Drainage District. The levee remains undisturbed.

Bryan Mound will be able to maintain Level 1 drawdown rate, committed by the Strategic Petroleum Reserve (SPR), by supplying the required amount of raw water to the caverns for oil drawdown and cavern leaching.

Risk & Mitigation Factors

There are associated risks with the excavation and installation of underground pipelines. The proper equipment and planning are needed to ensure excavations are safely done. The table below summarizes the risks with the correlating mitigation strategy. The table also describes the likelihood of occurrence at the site, along with how great of an impact the event would cause if it were to occur.

Risk and Mitigation Strategies for Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House. CS Aboveground at Pig Launcher and Receiver

Risks	Mitigation Strategy	Likelihood – Impact	Risk Code
Under-estimated cost	Make sure all possible costs have been analyzed in the life cycle cost.	Low – Low	Low Risk Hazard
Unknown subsurface	Geological study of subsurface of planned route to verify obstacles. Find available drawings of underground pipelines.	High – High	High Risk Hazard
Equipment availability	Procure contractor and equipment in advance once the schedule has been determined to avoid delays with equipment availability.	Low – Medium	Low Risk Hazard
Scheduled outage extended	Ensure all equipment and parts have been delivered before beginning outage work. Verify availability of maintenance group to ensure schedules are aligned. Be aware of weather disturbances.	Low – High	Low Risk Hazard
Reduced flow with additional pressure drop with new routing	Develop hydraulic system of planned pipe routing to determine pressure loss. Verify if the required pumping capacity and pressure will be met with the new pipe routing.	Low – High	Low Risk Hazard
HDPE pipe size availability	Contact pipe supply vendor on lead time for the required pipe size and length. Account for time during the planning period.	Low – Medium	Low Risk Hazard

Risk and Mitigation Strategies for Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3) and Turns North on Property Road to RWIP House. CS Aboveground at Pig Launcher and Receiver (Continued)			
Risks	**Mitigation Strategy**	**Likelihood – Impact**	**Risk Code**
Pipe material not compatible with raw water	Sample raw water and analyze for pH and corrosive chemicals. Verify with pipe supply vendor the compatibility of the raw water with the piping material.	Low – Medium	Low Risk Hazard
Installation and construction safety	For underground work, make sure area is barricaded with red “danger” tape. Follow proper excavation procedure with emphasis on trench support and exit routes.	Medium – High	Medium Risk Hazard
Permit not granted for levee road work	Submit permit request levee road work and allow sufficient time for approval.	Low – High	Low Risk Hazard
Subsidence of Cavern 3 on pipeline route	Verify subsidence rates and chose alternate route if necessary	Medium - High	Medium Risk Hazard

VI. ALTERNATIVE SELECTION

List of Alternatives – Studied Alternatives

A. HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and North to Pump House at BMT-1. CS Aboveground at Pig Launcher and Receiver.

This alternative will replace the belowground portion of the raw water line with a 48-inch diameter HDPE DR9 pipe and will replace the aboveground portion with 48-inch carbon steel. A Horizontal Directional Drill (HDD) will be used to penetrate the levee. The pipeline will follow Route 2, which is the Central Route.

B. Underground HDPE Pipeline Runs South Along the Levee, Crosses into Site Near Guardhouse with Underground HDPE Pipe Routed South of Pond (Route 3). CS Aboveground at Pig Launcher and Receiver.

This alternative will replace the below ground portion of the raw water line with a 48-inch diameter HDPE DR9 and the aboveground portion with 48-inch diameter carbon steel. The pipe will cross under the levee road. The pipeline will follow Route 3, which is the Southern Route.

Comparison of Alternatives

Core Team Member Ratings

	Technically Sound Solution	**Constructability During Ongoing Oil Deliveries**	**Ease of Operations**	**Ease of Maintenance**	**Safety During Construction**	**Sustainability**
	Most Important	*Most Important*	*Most Important*	*Most Important*	*Less Important*	*Less Important*
Alternative A	*Not Rated*	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Excellent	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Good	*Good*	*Good*	*Good*	*Good*	*Good*
Alternative B	*Not Rated*	*Good*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Good	*Excellent*	*Excellent*	*Excellent*	*Excellent*	*Excellent*
	Good	*Good*	*Good*	*Good*	*Good*	*Good*

Cost Comparison

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$20,116,357**	**$20,147,626**
Alternative B	**$23,193,625**	**$23,232,707**

Recommended Alternative

A. HDD Under Levee with Underground HDPE Pipe Routed Through Center of Site (Route 2) and North to Pump House at BMT-1. CS Aboveground at Pig Launcher and Receiver.

Based on the technical evaluation of the Core Team Members, Alternative A was rated equal or superior on all evaluation criteria. The initial cost and life cycle cost of Alternative A were both lowest of the alternatives. Therefore, Alternative A is the recommended preferred alternative based on both technical and cost factors studied in the alternative analysis.

BM-MM-774, BM-MM-774A

Replace Actuators on Meter Skid Valves (Install and Government Furnished Equipment)

VCI Project Engineer: Bill Fogle

Recommended Go Project:

Replace Meter Skid Actuators at Bryan Mound Meter Station

Analysis of Alternatives
Life Extension 2

US Department of Energy
Strategic Petroleum Reserve

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I. PROJECT CONCEPT

Mission Need

Bryan Mound's crude oil Allocation Custody Transfer (ACT) meter skid is configured as a 7-train unit. The original 4-train station utilized electric motor actuators manufactured by EIM. A second 3-train station was added to increase the drawdown capabilities of the BM location to current drawdown levels. Reliability issues, operability issues, and part availability dictate the need to upgrade, particularly the EIM units, to more current technology. These valve actuators allow the ACT Unit facility to record the volumes of oil transfer for drawdown.

The EIM actuators on the MOVs were replaced with Rotork Mark III units several years ago. The associated Flow Control Valves, (FV) retain their original EIM actuators. The original EIM actuators have exceeded their intended design service life and have poor reliability, therefore they should be replaced. The replacement Rotork actuators are nearing their design life span, and should be replaced with the current Rotork Generation III units produced by Rotork to standardize the equipment across the metering and site pipeline systems.

This project will work in conjunction with similar efforts at the Big Hill and the West Hackberry SPR sites, along with the outlying Lake Charles Meter Station, and Sun Logistics Nederland Terminal locations.

Functional Requirements

- Actuators shall be US registered, i.e., UL, FM, or CSA-US for Class 1, Division 2; hazardous area locations.
- Actuator torque requirements are based on base valve vendor calculations for Breaking, Running, and Seating force requirements at 1.5X MAWP design pressure. Calculations shall also take into account the valve body orientation, particularly as applied to gate valves.
- The valve actuator selection should provide a 25-year service life with minimum maintenance.
- The valve actuator selection should provide standardization across the SPR sites, and associated metering locations.
- The design should accommodate in-place local and remote inspection/diagnostic testing

II. PROCESS

Alternatives Analysis Plan

The complete Analysis of Alternatives (AoA) Process Plan for Go/No Go Projects has been standardized for all Go/No Go AoA's and is detailed in Volume 1 of this Conceptual Design Report.

Alternative Analysis Team Members

Core Team Members

Claudia Carroll	DOE, Systems Engineer
Bill Fogle	VCI, Project Engineer
Chris Vedros	FFPO, Manager Pipeline and Equipment Integrity

Team Members

Jorge Aguinaga	DOE, Site Lead General Engineer
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Mike Cabiran	FFPO, Sr. Site Maintenance Engineer
Michael Sickmiller	FFPO, Site Director
Joseph Mravunich	FFPO, Manager Site Maintenance
Dennis Henderson	FFPO, Manager Site Operations
Tim Kelley	FFPO, Manager Site Construction

III. SELECTION CRITERIA

Formal selection criteria will not be applicable in a Go/No Go Project.

IV. ALTERNATIVES IDENTIFICATION

Alternatives Identification is not applicable in a Go/No-Go Project.

V. ALTERNATIVES ANALYSIS

The existing actuators on the seven meter runs on the meter skid headers would require continued repair and replacement of the actuators as they fail. This would require an acceptance of a lower level of reliability and subject the SPR to an unanticipated failure during an oil movement. The failure of any one actuator can take an entire meter train out of service and result in the inability to meet the Level I drawdown requirement.

The below analyses provide the research and technical information gathered by the AoA Team. These analyses are not evaluative or comparative.

A. Replace Meter Skid Actuators at Bryan Mound Meter Station

Replace the existing actuators on the meter skid isolation valves. The new replacement valve actuators will provide more reliability, reduce operations and maintenance down time, and provide accurate metered oil deliveries.

The intent of this alternative is twofold: first replace the outdated EIM actuators with Rotork gen III IQ actuators; secondly upgrade the older (circa 1975) Rotork Mark III actuators with similar, current technology actuators. (See Table 1 for Bryan Mound site actuator list.)

This effort will serve to standardize the actuator selection and sizing across the SPR which should reduce long term parts system-wide inventory requirements. The replacement of the valve actuators will also ensure BM's ability to meet its Level I drawdown which the SPR is committed to maintaining.

DOE TAG #	VALVE					ACTUATOR				PROJECT
	BRAND	MODEL	SIZE	CLASS	ORIENTATION	BRAND	MODEL	S/N	STATUS	RECOMMENDATION
BRYAN MOUND METERING STATION										
2M001 MOV 01	M&J	SLAB GATE	16	300	VERTICAL	ROTORK	30FA16A	HD3136010101		UPGRADE
2M001 MOV 02	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK	ILLEGIBLE	ILLEGIBLE		UPGRADE
2M001 MOV 03	GENERAL	TWIN-SEAL FIG C-821	16	300	VERTICAL	ROTORK	IQ-35FA16A	H220150101		UPGRADE
2M001 MOV 04	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK	30A	B6247.A2		UPGRADE
2M001 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
2M002 MOV 01	M&J	SLAB GATE	16	600	VERTICAL	ROTORK	IQ-FA35-16Z	B484250101	NEW ACT.	NONE REQUIRED
2M002 MOV 02	DAN-EX	SLIM BODY PLUG	16	300	HORIZONTAL	ROTORK	IQ-35FA-16A	H163500102	NEW ACT.	NONE REQUIRED
2M002 MOV 03	GENERAL	TWIN-SEAL FIG C-821	16	300	VERTICAL	ROTORK	IQ-35FA-16Z	HD59430103	NEW ACT.	NONE REQUIRED
2M002 MOV 04	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK	IQ-35FA-16Z	HD59430101	NEW ACT.	NONE REQUIRED
2M002 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
2M003 MOV 01	M&J	SLAB GATE	16	600	VERTICAL	ROTORK	ILLEGIBLE-	ILLEGIBLE-		UPGRADE
2M003 MOV 02	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK	ILLEGIBLE	ILLEGIBLE		UPGRADE
2M003 MOV 03	GENERAL	TWIN-SEAL FIG C-821	16	300	VERTICAL	ROTORK	IQ-35FA-16A	B35039010101		UPGRADE
2M003 MOV 04	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK	30a-248	B5254.A6		UPGRADE
2M003 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM	ILLEGIBLE-	ILLEGIBLE-		REPLACE
2M004 MOV 01	M&J	SLAB GATE	16	600	VERTICAL	ROTORK	ILLEGIBLE-	ILLEGIBLE-		UPGRADE
2M004 MOV 02	DAN-EX	FIG 273	16	300	VERTICAL	ROTORK		B13356.A1		UPGRADE
2M004 MOV 03	GENERAL	TWIN-SEAL FIG CA-821	16	300	HORIZONTAL	ROTORK	IQ-35FA-16A	H184860101	NEW ACT.	NONE REQUIRED
2M004 MOV 04	GENERAL	TWIN-SEAL FIG C-821	16	300	HORIZONTAL	ROTORK		B5254-A8		UPGRADE
2M004 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
2M005 MOV 01	M&J	SLAB GATE	16	600	VERTICAL	ROTORK	ILLEGIBLE-	ILLEGIBLE-		UPGRADE
2M005 MOV 02	GENERAL	TWIN-SEAL - FIG C821	16	300	VERTICAL	ROTORK	ILLEGIBLE	ILLEGIBLE		UPGRADE
2M005 MOV 03	GENERAL	TWIN-SEAL - FIG C821	16	300	HORIZONTAL	ROTORK	ILLEGIBLE	ILLEGIBLE		UPGRADE
2M005 MOV 04	GENERAL	TWIN-SEAL - FIG C821	16	300	HORIZONTAL	ROTORK	ILLEGIBLE	ILLEGIBLE		UPGRADE
2M005 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
2M006 MOV 01	M&J	M303 SLAB GATE	16	600	VERTICAL	ROTORK	ILLEGIBLE-	ILLEGIBLE-		UPGRADE

Table 1: Bryan Mound Meter Station Valve Actuators

DOE TAG #	VALVE					ACTUATOR				PROJECT
	BRAND	MODEL	SIZE	CLASS	ORIENTATION	BRAND	MODEL	S/N	STATUS	RECOMMENDATION
BRYAN MOUND METERING STATION (CONTINUED)										
2M006 MOV 02	DAN-EX	FIG 273	16	300	HORIZONTAL	ROTORK	1610XC1			UPGRADE
2M006 MOV 03	GENERAL	TWIN-SEAL - FIG C821G	16	300	VERTICAL	ROTORK	IQ-35FA-16A	H163500101	NEW ACT.	NONE REQUIRED
2M006 MOV 04	GENERAL	TWIN-SEAL - FIG C821	16	300	HORIZONTAL	ROTORK	IQ-35FA-16Z	B28178140101		UPGRADE
2M006 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
2M007 MOV 01	M&J	SLAB GATE	16	600	VERTICAL	ROTORK	ILLEGIBLE-	ILLEGIBLE-		UPGRADE
2M007 MOV 02	DAN-EX	FIG 273	16	600	HORIZONTAL	ROTORK	30A-FA16A	HD3136010102		UPGRADE
2M007 MOV 03	GENERAL	TWIN-SEAL - FIG C821	16	600	VERTICAL	ROTORK	30A	B12443.B3		UPGRADE
2M007 MOV 04	GENERAL	TWIN-SEAL - FIG C821	16	600	HORIZONTAL	ROTORK	30A			UPGRADE
2M007 FV 05	PBV	6760-01-22ZZ-ZY-NA-203	10	600	VERTICAL	EIM				REPLACE
SWITCHING VALVES										
3M000MOV20	ACV				HORIZONTAL	ROTORK				UPGRADE
3M000MOV21	ACV				HORIZ. / FLAT	ROTORK				UPGRADE
3M000MOV22	ACV				HORIZONTAL	ROTORK				UPGRADE
3M000MOV23	ACV				VERTICAL	ROTORK				UPGRADE
3M000MOV24	ACV				VERTICAL	ROTORK				UPGRADE
3M000MOV25	ACV				VERTICAL	ROTORK				UPGRADE

Table 1 (Continued): Bryan Mound Meter Station Valve Actuators

NOTES:

1. Adamson-Chronister Valves, (ACV) have not been in manufacture since early 1980's and there is a high probability that valve components are no longer available.
2. ACV bear a strong resemblance to Grove G3 gate valves, recommend using their parameters as a basis for actuator sizing and selection.

VI. ALTERNATIVE SELECTION

Recommended Go Project

A. Replace Meter Skid Actuators at Bryan Mound Meter Station

Replace the existing actuators on the meter skid isolation valves. The new replacement valve actuators will provide more reliability, reduce operations and maintenance down time, and provide accurate metered oil deliveries.

Cost

	Total Estimated Cost (TEC)	**Life Cycle Cost (LCC)**
Alternative A	**$3,282,891**	**$3,347,452**