

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION OF NAVIGATOR HEARTLAND GREENWAY, LLC FOR A PERMIT UNDER THE SOUTH DAKOTA ENERGY CONSERVATION AND TRANSMISSION FACILITIES ACT TO CONSTRUCT THE HEARTLAND GREENWAY PIPELINE IN SOUTH DAKOTA	HP22-002 DR. JOHN ABRAHAM SURREBUTTAL TESTIMONY IN SUPPORT OF LANDOWNER INTERVENORS
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1 **1. Please state your name, position, and business address.**

2 Answer: My name is John Abraham. I am a Professor of Mechanical Engineering at the
3 University of St. Thomas, 2115 Summit Avenue, St. Paul, MN 55105.

4 **2. Have you previously submitted testimony in this proceeding?**

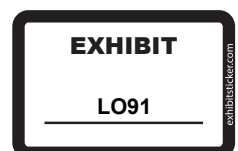
5 Answer: Yes. I submitted direct testimony dated May 26, 2023, on behalf of
6 Landowner Intervenors.

7 **3. To whose testimony are you responding in surrebuttal?**

8 Answer: I am responding to the June 23rd, 2023, rebuttal testimony of John Godfrey and
9 Stephen Lee, both of whom submitted rebuttal testimony to my direct testimony. Since Mr.
10 Godfrey relies on the Direct Testimony of Staff witness Mr. Byrd, I also discuss Mr. Byrd's
11 testimony.

12 **4. Please summarize your testimony.**

13 Answer: In brief, it is my opinion that computational fluid dynamics (“CFD”) calculations
14 are more able to accurately calculate the extent of a carbon dioxide pipeline rupture plume,
15 compared to PHAST modeling. It is further my opinion that pipeline safety should be assessed



1 using CFD modeling. and that reasonably accurate CFD modeling is readily available and can be
2 completed at reasonable cost and effort for Navigator Heartland Greenway’s (“NHG”) proposed
3 carbon dioxide pipeline.

4 **5. Do you agree with Mr. Godfrey’s characterization that CFD is “a catch-all term,” the**
5 **use of which is “problematic,” especially with respect to its application to the**
6 **proposed carbon dioxide pipeline?**

7 Answer: Mr. Godfrey states that CFD is a “comprehensive scientific and engineering
8 approach to model a variety of fluid flow scenarios, which for CO2 would include transport and
9 dispersion.” I agree with this statement. Mr. Godfrey also states that it is “problematic to refer to
10 CFD as a “catch-all term”, and in this, he is incorrect. CFD is not a catch all term, it refers to
11 calculations of the momentum, pressure, temperature, turbulence levels, *etc.* in a flowing fluid. In
12 this regard, the term “fluid dynamics” means flows of gaseous, liquid, and supercritical substances.
13 The term CFD is well known in the scientific community and its usage is not problematic. I have
14 published perhaps 200 studies involving CFD – it is a ubiquitous tool in use by the scientific
15 community.

16 Mr. Godfrey also states that there are “multiple methods, models, and computer programs
17 available for its application. Each has its own strengths and weaknesses.” While it is true that a
18 number of computer models exist that have strengths and weaknesses, this diversity does not make
19 the use of CFD problematic, but rather it’s a matter of exercising judgment about which models to
20 use and how to use them to accomplish specific tasks. With regard to carbon dioxide pipeline
21 public safety, the task is to provide a reasonable estimate of the maximum distance that hazardous
22 concentrations of carbon dioxide may spread following a rupture of a carbon dioxide pipeline.
23 While development of a highly accurate model that takes account of all factors that influence

1 carbon dioxide dispersion with great precision is certainly a useful undertaking, first responders
2 and citizens who would live and/or work near a proposed carbon dioxide pipeline do not need a
3 perfect CFD model. They need a model that will generate a reasonable estimate of the maximum
4 extent of the danger zone for their planning purposes. Likewise, the South Dakota Public Utilities
5 Commission (“Commission”) needs and should require NHG to conduct CFD modeling before a
6 siting permit is granted so that the Commission has a reasonable estimate of the persons, livestock,
7 and businesses potentially put at risk by a rupture. In the event of a rupture, real world factors will
8 determine the actual hazard zone for each rupture, and no two will be the same. Citizens, first
9 responders, and the Commission do not need a large number of model runs conducted for many
10 locations and conditions. They need a reasonable estimate of the hazard zone for a limited set of
11 representative locations and a limited set of high consequence areas.

12 Much of the proposed route of the NHG project would pass through crop and grazing land
13 with limited topographical variation. Applying CFD modeling to a location that is generally
14 representative of such land would provide a reasonable estimate of the hazard zone for much of
15 the pipeline route. This being said, there may be particular locations that due to topography and/or
16 population density require site-specific modeling. Given the rural nature of the proposed route, it
17 is likely that few if any locations along it would require site-specific modeling. However, the need
18 for site-specific modeling in high consequence areas should be carefully evaluated to avoid a risk
19 of mass casualties.

20 In response to the Satartia rupture, Denbury agreed to conduct an “overland spread
21 analysis” for all route locations within two miles of all “high consequence areas.” Pipeline and
22 Hazardous Materials Safety Administration (“PHMSA”) Consent Agreement and Order (March
23 24, 2023) at page 5, para. 19 (Attachment 1). That is, after that rupture, PHMSA determined that

1 a future rupture of that pipeline “could affect” high consequence areas up to two miles from the
2 pipeline. Given that CFD modeling can take account of topography and other types of dispersion
3 modeling does not, it is likely that the term “overland spread analysis” used in the Consent
4 Agreement refers to CFD modeling. If the term “overland spread analysis” does in fact refer to
5 CFD modeling, then PHMSA’s requirement for such modeling indicates that application of CFD
6 modeling is practical and necessary for identifying high consequence areas near carbon dioxide
7 pipelines. Since the proposed NHG pipelines would be constructed from six and eight-inch
8 diameter pipe, NHG Application at 1, whereas the Denbury pipeline was 24-inch pipe, the “could
9 affect” area for the NHG project would likely be substantially smaller, but nonetheless this area
10 should be determined by use of CFD modeling for both for public safety and pipeline safety
11 purposes.

12 While it would be theoretically possible to conduct high resolution modeling at each
13 milepost along the pipeline route, such modeling would be time consuming, expensive, and
14 unnecessarily precise. Instead, first responders, citizens, and the Commission need a reasonable
15 estimate of worst-case plume dispersion. The perfect should not be the enemy of the good.

16 It also should be noted that the assumptions made in applying any dispersion modeling to
17 a pipeline rupture may have as great or even greater impact on identification of the size of a hazard
18 zone. For example, assumptions about the mass of carbon dioxide that would be released upon
19 rupture depend on a number of factors, such as the distance between isolation valves and operating
20 pressure and temperature. What should be modeled is a worst-case scenario based on worst-case
21 assumptions, because to protect public safety, citizens and responders should assume the worst
22 with regard to the size of a hazard zone. Modeling for a worst-case release would ensure that
23 citizens evacuate to a safe distance, first responders don protective gear at a safe distance, and the

1 Commission understands the possible risks to human and animal life and economic interests along
2 the route. To ensure that NHG’s modeling is reasonable, it should disclose all of its assumptions
3 so that citizens, first responders, and the Commission can confirm that NHG’s modeling is
4 reasonable, both with regard to the type of modeling and its inputs.

5 **6. With regard to Mr. Godfrey’s statement that “comparison of a specific computer**
6 **model to a general engineering approach, PHAST to CFD, has the potential to be**
7 **misleading,” do you agree with it?**

8 Answer: Mr. Godfrey states that it is misleading to compare PHAST to CFD, because
9 PHAST is a specific form of computer model, whereas “CFD refers to a much broader
10 scientific approach to such modeling.” As I have already opined, both PHAST and CFD can be
11 used to predict the dispersion of carbon dioxide in an airflow. PHAST is the result of very limiting
12 mathematical simplifications. CFD models do not require use of these simplifications, such that
13 they have the capacity to be more accurate. For example, CFD models are able to accurately model
14 the effects of topography and the turbulent mixing of carbon dioxide and air. PHAST calculations,
15 on the other hand, are highly idealized, result in unrealistic calculations, and produce results that
16 should not be relied on to protect public safety. I have provided examples of the fatal flaws of
17 PHAST modeling in my initial report and I adopt that discussion here. To the extent I have
18 compared CFD and PHAST, it is to highlight the weaknesses of PHAST and its inappropriateness
19 for calculating dispersion of carbon dioxide from pipeline ruptures. Mr. Godfrey presents no basis
20 for his claim that a comparison between more accurate CFD modeling with less accurate PHAST
21 is “misleading”.

22 Mr. Godfrey also generally describes the PHAST model and claims that DNV updates and
23 validates its software based on the results of carbon dioxide release experiments. Such updates do

1 not change the fact that the mathematical underpinnings of the PHAST model are overly simplistic.
2 Mr. Godfrey also states that Navigator worked with DNV to determine the inputs to the PHAST
3 modeling effort, but does not state what these inputs were, such that he provides no evidence that
4 NHG and DNV selected reasonable worst-case inputs. As a consequence, Mr. Godfrey’s testimony
5 provides no empirical support for the quality of DNV’s modeling for NHG. Poor modeling
6 assumptions generally result in poor modeling results.

7 **7. Mr. Godfrey asserts that the fact that CFD modeling will produce more**
8 **comprehensive results is an “academic argument,” and that your direct testimony**
9 **failed to address the time and effort needed to produce just one CFD model for the**
10 **proposed pipeline. He asserted that a single scenario will take days to model using**
11 **CFD, and that modeling multiple locations would exponentially increase time and**
12 **effort, such that PHAST modeling is more practical. How do you respond?**

13 Answer: Mr. Godfrey admits that CFD will product more comprehensive results compared
14 to PHAST and I agree with him on this issue. However, Mr. Godfrey goes on to claim that the
15 time, effort, and presumably cost to produce CFD calculations is too large to be practical. He is
16 incorrect. The modeling time, effort, and cost of CFD modeling depends on the number of model
17 runs conducted, the range of scenarios modeled, and the precision of the model, with more precise
18 modeling requiring substantially more computer time than less precise modeling. The CFD
19 modeling needed by citizens, first responders, and the Commission need not be highly accurate,
20 because what is needed is a reasonable estimate of the worst-case hazard zone. A reasonable
21 estimate of the hazard zone size may be produced by a less time and effort-intensive model.
22 Further, the hazard area for most of the route through South Dakota could be assessed based on a
23 representative flatland scenario. While CFD modeling would take time, it would take a fraction of

1 the time needed for preconstruction development and permitting.

2 Some of my prior CFD modeling efforts have required very high precision, whereas other
3 modeling efforts have not. Determination of the need for precision is a matter of scientific and
4 professional judgement based on a thorough understanding of a model, its underlying mathematics,
5 and the purpose for the modeling.

6 Mr. Godfrey also claims that PHAST, even though it is less accurate, is “more practical”.
7 I disagree. A “practical” approach is one that balances accuracy and effort. That is, a “practical”
8 solution should be accurate enough to be useful and should be able to be performed with reasonable
9 effort. Since PHAST is not accurate, it cannot be considered “practical”, regardless of its ease-of-
10 use.

11 Highly accurate CFD calculations can easily be done to assess the risks of ruptures either
12 in the planning phase of a pipeline or after a pipeline has been constructed. When pipelines pass
13 close to inhabited locations, CFD calculations can easily be performed to determine whether such
14 locations are at risk given the topography and a range of weather conditions. Such calculations
15 could be routinely performed. Mr. Godfrey has no basis to support his claims that CFD is not
16 practical.

17 Mr. Godfrey implies that the time and effort to conduct CFD modeling would be unduly
18 burdensome in terms of cost. The cost of CFD modeling is highly dependent on the need for
19 precision and the number of scenarios modeled. I note that Mr. Godfrey has not provided any cost
20 estimate for performing CFD modeling for the proposed NHG pipeline or the specifications for
21 such estimate. In the absence of such estimate, the Commission should find his opinions about
22 time, effort, and burden to be unfounded. I also note that the cost of the proposed project is
23 estimated to be \$3.2 billion, with \$142 million of that to be expended in South Dakota. NHG

1 Application at 4. The cost of performing CFD modeling should be considered in light of total
2 project costs. Also, a representative flatland scenario could be applicable along most of the NHG
3 route in the states through which the pipeline would pass, which would further reduce costs.
4 Moreover, the cost of CFD modeling should be considered in light of the potential cost in lives
5 and property damage that could result from a pipeline rupture. CFD modeling would cost a very
6 small fraction of project costs and is justified by the public safety risks the project would create.

7 **8. Mr. Godfrey relies on the testimony of William Byrd, a staff expert, for the**
8 **proposition that “site specific modeling is expensive and time consuming and can’t be**
9 **performed until a site is selected.” How do you respond?**

10 Answer: Mr. Byrd states that CFD modeling “can’t be performed until a site is selected”
11 (emphasis added) and that “[o]nce the route is determined, based on a variety of considerations,
12 site-specific modeling can be performed for pipeline segments in proximity to important or
13 vulnerable areas.” This statement is clearly erroneous. In fact, CFD can be performed at any stage
14 in the development and planning of a pipeline project. Mr. Godfrey’s rebuttal testimony expressly
15 states that DNV has already conducted PHAST modeling for NHG. If NHG has already performed
16 PHAST modeling, then for the reasons discussed above, there is no practical reason why it could
17 not have instead performed higher quality worst-case scenario CFD modeling in a representative
18 location and also in locations where the pipelines travel close to higher population density areas.
19 That is, NHG could have used CFD modeling instead of PHAST modeling to estimate its buffer
20 zones and inform its pipeline design, integrity, and emergency planning efforts.

21 My understanding is that the Commission does not have routing authority, meaning that in
22 South Dakota the entity that selects the route would be the company that proposes it, and no state
23 agency could order a route change. Absent county action on route, this means that the route for the

1 proposed project has already been “selected” by NHG. Conducting CFD modeling instead of
2 PHAST modeling during the company’s route selection process would have been practical and
3 provided a more accurate estimate of hazard zones. Rather than rely on NHG’s inaccurate PHAST
4 modeling, the Commission should instead rely upon CFD modeling so as to better understand the
5 risks that carbon dioxide pipeline ruptures create, including their possible geographic scope of
6 impact.

7 Mr. Byrd’s argument might be better stated to be that CFD modeling should not be
8 performed before a pipeline is constructed, because the route might change and/or because doing
9 so at that time would be costly and/or inefficient. Since the Commission has no authority to order
10 a route change, it is unlikely that the vast majority of the route would change. Moreover, a
11 representative flatland model would adequately apply to most voluntary route changes. Therefore,
12 the possibility of limited voluntary route changes would not make performance of CFD modeling
13 during company route selection wasteful or inefficient. In any case, Mr. Byrd provided no time,
14 effort, or cost estimates for CFD modeling to support his opinion that “[s]ite specific modeling is
15 expensive and time consuming,” such that Mr. Godfrey’s opinion that “[w]ith respect to routing,
16 the use of CFD for site-specific modeling is not practical” appears to be unsupported by Mr. Byrd’s
17 testimony.

18 Finally, I note that Mr. Godfrey references Mr. Lee’s testimony to admit that NHG “intends
19 to use CFD modeling in the manner described by Mr. Byrd,” an admission that reveals that NHG
20 does not consider CFD modeling to be overly expensive or burdensome, but rather that it objects
21 to the timing of its use. Unsupported objections to the timing of use of CFD modeling do not justify
22 use of PHAST, which is a clearly inferior modeling technology. The Commission should require
23 NHG to perform CFD modeling so that the Commission, citizens, impacted landowners, and first

1 responders have a clearly superior assessment of the risks of the proposed pipelines.

2 **9. Mr. Godfrey asserts that “PHAST and similar programs when properly applied and**
3 **understood can be useful tools to evaluate a wide range of scenarios that are**
4 **important to routing a CO2 pipeline and that could not practically be done using**
5 **CFD.” Do you agree?**

6 Answer: No. PHAST is an inferior tool whose primary benefit is that it is faster, easier, and
7 therefore cheaper to use. Since a better modeling tool exists, the Commission should require that
8 it be used. While CFD modeling would likely require more time and money, the time and cost can
9 be mitigated by selection of appropriate levels of precision and the use of representative locations.
10 Moreover, the marginal increase in the time and cost needed for CFD modeling almost certainly
11 would not be significant relative to the project’s multi-year development schedule and \$3.2 billion
12 cost.

13 **10. Mr. Godfrey asserts that the PHAST modeling done for NHG by DNV is reliable and**
14 **useful, because “not every rupture scenario can be foreseen or predicted.” He also**
15 **states that, “[e]ven with CFD, there will be situations that the engineers implementing**
16 **the model could not foresee or predict.” He claims that by “hyper-focusing on a gold-**
17 **standard approach,” that you suggest that the proposed pipeline cannot be**
18 **constructed and operated without substantially impairing the health, safety, or**
19 **welfare of the inhabitants of the siting area.” How do you respond?**

20 Answer: Use of the PHAST model does not produce reliable predictions of potential
21 consequences. This conclusion was demonstrated by Denbury’s use of PHAST prior to the Satartia
22 rupture. The PHMSA Consent Agreement with Denbury states: “the earlier PHAST dispersion
23 analysis was wrong.” To correct this wrong, Denbury agreed to perform a different “overland

1 spread analysis.” Attachment 1 at page 5, para. 19. Denbury’s use of the PHAST model resulted
2 in Denbury failing to determine that its pipeline “could affect” Satartia. *Id.* This failure, in turn,
3 resulted in Denbury failure to include Satartia and its first responders in the company’s emergency
4 planning and public education efforts. These were real world adverse consequences of reliance on
5 the PHAST model. Prior to development and widespread use of CFD modeling, use of PHAST
6 may have been better than nothing, but now there is no reason to use this simplistic model except
7 to limit project expenses.

8 While CFD modeling, and for that matter no other type of modeling, can foresee and
9 predict all rupture scenarios, this is no reason not to use the best computer modeling approach
10 available.

11 Contrary to Mr. Godfrey’s claim, I do not suggest that “the proposed pipeline cannot be
12 constructed and operated without substantially impairing the health, safety, or welfare of the
13 inhabitants of the siting area.” Pipelines do in fact rupture, and safety regulations are intended to
14 mitigate the risk and consequences of such ruptures, but ruptures nonetheless happen. The
15 Commission should consider the potential impacts of carbon dioxide pipeline ruptures, as well as
16 NHG’s risk and integrity management efforts to reduce their likelihood, as part of its determination
17 of whether the proposed pipelines would substantially impair the health, safety, or welfare of South
18 Dakotans. CFD modeling is a superior way to determine the potential impacts of a pipeline rupture,
19 and it will provide superior information for emergency response planning purposes. Therefore,
20 the Commission should rely on it instead of the PHAST model.

21 **11. Mr. Godfrey asserts that use of CFD modeling would not have made any difference**
22 **in the response to the Satartia rupture. How do you respond?**

23 Answer: My understanding from review of PHMSA documents related to the Satartia

1 rupture is that one of the purposes for Denbury’s use of PHAST dispersion modeling was to
2 determine the locations of high consequence areas along its pipeline that could be affected by a
3 rupture of its pipeline. If a pipe segment “could affect” a high consequence area then additional
4 pipeline safety requirements apply, including public education and first responder outreach
5 requirements. The failure of the PHAST model to predict that Satartia was at risk appears to be the
6 primary reason that local first responders and its citizens were unaware that a CO₂ pipeline was
7 even in the county. If Denbury had used CFD modeling and it predicted that Satartia could be
8 affected by a rupture, then Denbury would have been required by federal regulation to include
9 Satartia in its public education and emergency response planning efforts. If Denbury had then
10 conducted a public education program and outreach to local emergency responders describing how
11 a rupture would look and smell, then the citizens and responders would have been less likely to
12 think that a chemical release from some other source had occurred, instead of the chemical release
13 from the pipeline. If local first responders had been informed of the risk and properly equipped
14 with carbon dioxide detectors, then air monitoring could have started much sooner; instead they
15 had to wait for Denbury’s air monitoring contractor to show up. The reason why first responders
16 were not forewarned and equipped in advance was because Denbury determined, based on its
17 PHAST modeling, that Satartia was not at risk, so Denbury conducted no training with local first
18 responders and provided no equipment or equipment recommendations to local first responders.

19 The purpose of plume dispersion modeling is to identify at-risk persons and communities
20 and trigger appropriate pipeline design, integrity, and emergency response planning efforts. Mr.
21 Godfrey seems to believe that the Denbury PHAST modeling failures were unrelated the
22 company’s emergency response and public education deficiencies. As Mr. Godfrey has admitted,
23 one purpose of dispersion modeling is to define the areas in which heightened pipeline integrity

1 and emergency and risk management activities must be implemented. It follows that Denbury's
2 reliance on the PHAST model was the root cause of all of the factors that Mr. Godfrey believes
3 were more consequential than Denbury's use of PHAST dispersion modeling.

4 **12. Mr. Lee asserts that the PHAST model is reliable and is appropriate for use in**
5 **modeling major carbon dioxide pipeline ruptures. Do you agree?**

6 Answer: Mr. Lee states that NHG conducted modeling using the PHAST and ALOHA
7 models. The ALOHA model is a different Gaussian model that suffers from the same types of
8 simplifications as the PHAST model. He also states that DNV validates the PHAST model by
9 using "real world research data" including but not limited to data collected by DNV's Spadeadam
10 planned release, which was an intentional rupture of a short test pipeline. Researchers have
11 conducted a handful of test ruptures, some of which are described in the 2015 paper referenced by
12 Mr. Lee's testimony: M. Ahmad *et al.*, *COSHER Joint Industry Project: Large Scale Pipeline*
13 *Rupture Tests to Study CO2 Release and Dispersion.*

14 For a more recent list and description of test ruptures, see the July 2021 study, M. Vitali,
15 *et al.*, *Risks and Safety of CO2 Transport via Pipeline: A Review of Risk Analysis and Modeling*
16 *Approaches for Accidental Releases*, Table 1 and related discussion, which study is available at:
17 <https://www.mdpi.com/1996-1073/14/15/4601>. It reports that the COSHER JIP test rupture
18 referenced by the paper cited by Mr. Lee involved the rupture of a 219 mm (8.6 inch) pipeline in
19 low wind conditions and flat terrain. *Id.* at 6. The rupture released 136 metric tons of CO₂ over the
20 course of 204 seconds. *Id.* The maximum plume height was 60 meters (197 feet) and it extended a
21 maximum of 400 meters (1,312 feet). A video of this test rupture has been widely circulated.

22 In comparison, Denbury reported that over approximately 4 hours the Satartia rupture
23 released 31,405 barrels of carbon dioxide, which PHMSA considers to be the minimum amount.

1 Depending on assumptions about the temperature of the carbon dioxide at the time of release and
2 Denbury’s stated pressure, I estimate that the Sartartia rupture released between 3,700 metric tons
3 and 4,500 metric tons of carbon dioxide. This is between 27 and 33 times more carbon dioxide
4 than the 2015 Spadeadam test rupture.

5 Researchers have also conducted test ruptures of 9, 24 and 36-inch diameter pipelines, but
6 the volumes released by these tests were also relatively small.

7 While these tests provide “real world research data,” the number of test ruptures is small,
8 such that they do not provide data in a substantial number of topographies and weather conditions.
9 Also, they do not release anywhere near the volume of carbon dioxide as do real-world high-
10 volume ruptures, such as the Satartia rupture, which released at least 31,405 barrels of liquid or
11 supercritical carbon dioxide. Even the largest test ruptures do not provide plume data that are
12 comparable to full bore ruptures of major carbon dioxide pipelines. As such, PHAST validation
13 efforts must be understood to be conducted based on limited experimental data.

14 In any case, the Satartia rupture provided the acid test for PHAST with regard to a high-
15 volume real-world rupture. As PHMSA found, the PHAST dispersion analysis was “wrong.”
16 Attachment 1, page 5, para. 18.

17 **13. Does this conclude your testimony?**

18 Answer: Yes. I reserve the right to amend or modify these opinions upon presentation of
19 any additional information that may justify such a change.

20

21

/s/ Dr. John Abraham

22

Dr. John Abraham



U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

March 24, 2023

VIA ELECTRONIC MAIL TO: david.sheppard@denbury.com

David E. Sheppard
Executive Vice President and Chief Operating Officer
Denbury Gulf Coast Pipelines, LLC
5851 Legacy Circle, Suite 1200
Plano, Texas 75024

Re: CPF No. 4-2022-017-NOPV

Dear Mr. Sheppard:

Enclosed please find the Consent Order incorporating the terms of the Consent Agreement between the Pipeline and Hazardous Materials Safety Administration (PHMSA) and Denbury Gulf Coast Pipelines, LLC, which was executed on March 24, 2023. Service of the Consent Order and Consent Agreement by electronic mail is deemed effective upon the date of transmission and acknowledgment of receipt, or as otherwise provided under 49 C.F.R. § 190.5.

Thank you for your cooperation in this matter.

Sincerely,

LINDA GAIL
DAUGHERTY
Digitally signed by LINDA GAIL
DAUGHERTY
Date: 2023.03.24 16:23:43 -04'00'

Alan K. Mayberry
Associate Administrator
for Pipeline Safety

Enclosure

cc: Mr. Bryan Lethcoe, Director, Southwest Region, Office of Pipeline Safety, PHMSA
Mr. George C. Hopkins, Counsel for Denbury Gulf Coast Pipelines, LLC, Vinson & Elkins,
ghopkins@velaw.com

CONFIRMATION OF RECEIPT REQUESTED

**U.S. DEPARTMENT OF TRANSPORTATION
PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION
OFFICE OF PIPELINE SAFETY
WASHINGTON, D.C. 20590**

In the Matter of)	
)	
Denbury Gulf Coast Pipelines, LLC,)	CPF No. 4-2022-017-NOPV
)	
Respondent.)	
)	

CONSENT ORDER

By letter dated May 26, 2022, the Pipeline and Hazardous Materials Safety Administration, Office of Pipeline Safety, issued a Notice of Probable Violation, Proposed Civil Penalty, and Proposed Compliance Order (“Notice”) to Denbury Gulf Coast Pipelines, LLC (“Denbury”).

On July 25, 2022, pursuant to 49 C.F.R. § 190.208, Denbury responded to the Notice by submitting a Request for Settlement Conference and Hearing, after which the parties engaged in settlement discussions that resulted in the Consent Agreement attached to this Consent Order (the “Order”) that settles all of the allegations in the Notice.

Accordingly, the Consent Agreement is hereby approved and incorporated by reference into this Order. Denbury is hereby ordered to comply with the terms of the Consent Agreement, effective immediately.

Pursuant to 49 U.S.C. § 60101, *et seq.*, failure to comply with this Order may result in the assessment of civil penalties as set forth in 49 C.F.R. § 190.223.

The terms and conditions of this Order are effective upon service in accordance with 49 C.F.R. § 190.5.

LINDA GAIL DAUGHERTY Digitally signed by LINDA GAIL DAUGHERTY
Date: 2023.03.24 16:24:13 -04'00'

March 24, 2023

Alan K. Mayberry
Associate Administrator
for Pipeline Safety

Date Issued

**U.S. DEPARTMENT OF TRANSPORTATION
PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMINISTRATION
OFFICE OF PIPELINE SAFETY
WASHINGTON, D.C. 20590**

In the Matter of)	
)	
Denbury Gulf Coast Pipelines, LLC,)	CPF No. 4-2022-017-NOPV
)	
Respondent.)	
)	

CONSENT AGREEMENT

On May 26, 2022, pursuant to 49 C.F.R. § 190.207, the Pipeline and Hazardous Materials Safety Administration (“PHMSA”), Office of Pipeline Safety (“OPS” or “Agency”), issued a Notice of Probable Violation, Proposed Civil Penalty, and Proposed Compliance Order (“Notice”) to Denbury Gulf Coast Pipelines, LLC (“Denbury” or “Respondent”). The Notice alleged that Respondent committed probable violations of 49 C.F.R. Part 195, proposed a civil penalty, and proposed certain actions be taken by Denbury. The claims in the Notice relate to a release of CO₂ on February 22, 2020, from Denbury’s pipeline in the vicinity of Satartia, Mississippi including Denbury’s associated response and reporting related to the incident (the “Satartia Release”).

After receiving an extension of time to respond, on July 25, 2022, Denbury responded to the Notice by timely submitting a Request for Settlement Conference and Hearing pursuant to 49 C.F.R. § 190.208(a)(4). Settlement discussions were held virtually on August 10, August 19, and September 22, 2022.

As a result of these settlement discussions, PHMSA and Denbury (collectively, the “Parties”) agreed that settlement of the Notice will avoid further administrative proceedings or litigation and will serve the public interest by promoting safety and protection of the environment. Pursuant to 49 C.F.R. Part 190, and upon consent and agreement of Denbury and PHMSA, the Parties hereby agree as follows:

I. General Provisions

1. Respondent acknowledges that it is the operator of a 111-mile CO₂ pipeline that runs from Jackson Dome, Mississippi to Delhi, Louisiana (the “Delta Pipeline”) and that the Delta Pipeline is subject to the jurisdiction of the federal pipeline safety laws, 49 U.S.C. § 60101, *et seq.*, including the regulations and administrative orders issued thereunder. For purposes of this Consent Agreement (“Agreement”), Respondent acknowledges that it received proper notice of PHMSA’s action in this proceeding and that the Notice states claims upon which relief may be

granted pursuant to 49 U.S.C. § 60101, *et seq.*, including the regulations and orders issued thereunder.

2. After Denbury returns this signed Agreement to PHMSA, the Agency's representative will present it to the Associate Administrator for Pipeline Safety, recommending that the Associate Administrator adopt the terms of this Agreement by issuing an administrative order ("Consent Order" or "Order") incorporating the terms of this Agreement. The terms of this Agreement constitute an offer of settlement until a Consent Order is issued by the Associate Administrator.

3. Respondent consents to the issuance of the Consent Order, and hereby waives any further procedural requirements with respect to its issuance. Respondent waives all rights to contest the adequacy of notice, or the validity of the Consent Order or this Agreement, including all rights to administrative or judicial hearings or appeals, except as set forth herein. Respondent agrees to withdraw its request for an administrative hearing regarding the Notice.

4. This Agreement shall apply to and be binding upon PHMSA, and upon Denbury, its officers, directors, and employees, and its successors, assigns, or other entities or persons otherwise bound by law. Respondent agrees to provide a copy of this Agreement and any incorporated compliance orders and schedules to all of Denbury's officers, employees, and agents whose duties might reasonably include compliance with this Agreement.

5. This Agreement constitutes the final, complete, and exclusive agreement and understanding between the Parties with respect to the settlement embodied in this Agreement. PHMSA acknowledges that the claims asserted in the Notice constitute all claims of probable violations that it will assert against Denbury arising out of the Satartia Release. The Parties acknowledge that there are no representations, agreements, or understandings relating to settlement other than those expressly contained in this Agreement, except that the terms of this Agreement may be construed by reference to the Notice.

6. Nothing in this Agreement affects or relieves Respondent of its responsibility to comply with all applicable requirements of the federal pipeline safety laws, 49 U.S.C. § 60101, *et seq.*, and the regulations and orders issued thereunder. Nothing in this Agreement alters PHMSA's right of access, entry, inspection, and information gathering or PHMSA's authority to bring enforcement actions against Denbury pursuant to the federal pipeline safety laws, the regulations and orders issued thereunder, or any other provision of federal or state law except as otherwise resolved through this Consent Order.

7. For all direct transfers of complete ownership or operating responsibility of the Delta Pipeline which occur while this Agreement is in effect, Denbury will provide a copy of this Agreement to the prospective transferee at least 30 days prior to such transfer. Denbury will provide written notice of the transfer to the Director no later than 60 days after the transfer occurs, provided, however, that nothing herein shall require Denbury to provide such notice to the Director in connection with financing or other commercial transactions involving the pipeline that include the creation of secured interests.

8. This Agreement does not waive or modify any federal, state, or local laws or regulations that are applicable to the Delta Pipeline. This Agreement is not a permit, or a modification of any permit, under any federal, state, or local laws or regulations. Denbury remains responsible for achieving and maintaining compliance with all applicable federal, state, and local laws, regulations, and permits.

9. This Agreement does not create rights in, or grant any cause of action to, any third party that is not a party to this Agreement. The U.S. Department of Transportation is not liable for any injuries or damages to persons or property arising from acts or omissions of Respondent or its officers, employees, or agents carrying out the work required by this Agreement. Denbury agrees to hold harmless the U.S. Department of Transportation, its officers, employees, agents, and representatives from any and all causes of action arising from any acts or omissions of Respondent or its contractors in carrying out any work required by this Agreement.

10. Respondent does not admit to any of the alleged violations or risks identified in the Notice and has provided PHMSA a detailed response outlining its position. However, for the purposes of this Agreement, Respondent agrees to the findings of violation, and agrees to address the alleged violations and risks identified in the Notice by completing the actions specified in Section VI of this Agreement (Compliance Requirements) and to abide by the terms of this Agreement.

11. Except as set forth herein, this Agreement does not constitute a finding of violation of any federal law or regulation and may not be used in any civil proceeding of any kind as evidence or proof of any fact, fault or liability, or as evidence of a violation of any law, rule, regulation, or requirement, except in a proceeding to enforce the provisions of this Agreement or in future PHMSA enforcement actions. Respondent does not admit any allegation or conclusion in the Notice or this Agreement and Order, but agrees, for purposes of this Agreement and Order, to address the alleged risk conditions by completing the terms of this Agreement.

II. Definitions

12. The “Director” means the Director, Pipeline and Hazardous Materials Safety Administration, Office of Pipeline Safety, Southwest Region. The Director’s address is 8701 S. Gessner, Suite 630, Houston, TX 77074.

13. The “Satartia Release” or “Failure” means the release of carbon dioxide that occurred on Denbury’s Delta Pipeline in the vicinity of Satartia, Mississippi, including Denbury’s associated response, which Denbury reported to the National Response Center on February 22, 2020.

III. Findings of Violations

14. **Item 2 of the Notice:** With respect to Item 2, the Notice alleged a violation of 49 C.F.R. § 195.401(b)(1), which Denbury contested. Denbury acknowledges that portions of its pipeline, including the segment of the Delta Pipeline near the failure site, were subject to erosion and sloughing type geohazard risks but failed to recognize this particular geohazard and the

associated risk prior to the Satartia Release. Given this acknowledgment, PHMSA instead finds that Denbury violated 49 C.F.R. § 195.402(c)(13) by failing to review its procedures for monitoring and addressing geohazard risks to determine their effectiveness and by failing to correct deficiencies in the geohazard program. Due to the failure to recognize certain geohazard risks, Denbury also failed to review and revise its procedures in order to ensure that they involved comprehensive measures to detect and mitigate these geohazard risks. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

15. **Item 3 of the Notice:** With respect to Item 3, the Notice alleged a violation of 49 C.F.R. § 195.402(c)(12) and (e)(7), which Denbury contested. PHMSA finds that Denbury violated 49 C.F.R. § 195.402(c)(12) and (e)(7) by its failure to formally meet with the Tri-Community Volunteer Fire Department as part of its liaison efforts. Information from Denbury demonstrates that Denbury met with relevant emergency responders at the Yazoo County level as part of its liaison efforts and Public Awareness program, but failed to meet formally with the Tri-Community Volunteer Fire Department because Denbury had not identified Satartia as a “could affect” High Consequence Area (“HCA”) for this segment. Although Denbury officials had informal contacts with the head of the Fire Department, those contacts were not sufficient to advise and consult on all topics required to be addressed. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

16. **Item 4 of the Notice:** With respect to Item 4, the Notice alleged a violation of 49 C.F.R. § 195.408, which Denbury contested. Notwithstanding Denbury’s objections and denial, PHMSA finds that Denbury violated 49 C.F.R. § 195.408 because it failed to establish communication with local fire, police, and other appropriate public officials during this emergency condition. Denbury became aware of SCADA data suggesting a potential significant pressure drop and immediately dispatched Operations Personnel to confirm whether there was a release and to identify its location. However, because the location of the release had not been confirmed or identified, Denbury did not immediately reach out to the local responders and no external contact with emergency responders occurred until Denbury staff were contacted by the local fire chief approximately 42 minutes after the SCADA indication. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

17. **Item 5 of the Notice:** With respect to Item 5, the Notice alleged a violation of 49 C.F.R. § 195.412, which Denbury contested. Notwithstanding Denbury’s objections and denial, PHMSA finds that Denbury violated 49 C.F.R. § 195.412 by failing to conduct adequate right-of-way inspections. The aerial patrolling program failed to record in at least one location on the Delta Pipeline the observation of a sloughing condition that reflected a potential geohazard condition that should have been recorded and followed-up on. In the area where the pipeline rupture occurred, Denbury had not identified any conditions associated with geohazards that were visible in the right-of-way before the event but that were not recorded on the aerial patrolling reports. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

18. **Item 6 of the Notice:** With respect to Item 6, the Notice alleged a violation of 49 C.F.R. § 195.440, which Denbury contested. PHMSA finds that with respect to the Satartia area, Denbury violated 49 C.F.R. § 195.440 by failing to conduct the activities described in both its written operations and maintenance (O&M) plan and its Public Awareness and Damage Prevention Program developed to comply with § 195.440 with respect to the town of Satartia. Specifically, the events of February 22, 2020 showed that the earlier PHAST dispersion analysis was wrong and that the town of Satartia was a “could-affect” HCA and should have been included in Denbury’s Public Awareness and Damage Prevention Program. Denbury also had not chosen as a discretionary matter to increase its buffer zone which it could have done under its policy, notwithstanding the modeling that showed Satartia to be outside the expected impact zone. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

19. **Item 7 of the Notice:** With respect to Item 7, the Notice alleged a violation of 49 C.F.R. § 195.452(d), which Denbury contested. Denbury now considers Satartia as being in a “could affect” HCA because Denbury has reassessed all segments on all of its lines that are located within two miles of an HCA where the terrain creates a risk that a leak of carbon dioxide “could affect” an HCA by supplementing its air dispersion modeling with an overland spread analysis. In consideration of Denbury’s agreement to the other findings of violation and remaining terms of the agreement, PHMSA withdraws the alleged violation of § 195.452(d). However, Denbury agrees to perform the proposed Compliance Requirements for Item 7, as described below.

20. **Item 8 of the Notice:** With respect to Item 8, the Notice alleged a violation of 49 C.F.R. § 195.452(f)(6) and (i)(1), which Denbury contested. Notwithstanding Denbury’s objections and denial, PHMSA finds that Denbury violated 49 C.F.R. § 195.452(f)(6) and (i)(1) by failing to conduct a risk analysis that evaluated geohazards and by failing to identify and take preventive and mitigative measures to address geohazard risks in all HCAs and “could affect” HCAs. This finding of violation shall be considered by PHMSA as a prior offense in any future PHMSA enforcement action taken against Respondent.

IV. Civil Penalties

21. **Item 2 of the Notice:** With respect to Item 2, the Notice proposed a civil penalty of \$2,251,334. With respect to culpability, Denbury asserted that the comments from the District Manager were not referring to geohazards at the failure location. Therefore, PHMSA finds it appropriate to reduce the culpability determination to “[t]he operator failed to comply with an applicable requirement.” Without admission, Respondent agrees to pay a reduced civil penalty of \$1,935,300 for Item 2 of the Notice.

22. **Item 3 of the Notice:** With respect to Item 3, the Notice proposed a civil penalty of \$46,600. Without admission, Respondent agrees to pay a civil penalty of \$46,600 for Item 3 as proposed in the Notice.

23. **Item 4 of the Notice:** With respect to Item 4, the Notice proposed a civil penalty of \$46,600. Without admission, Respondent agrees to pay a civil penalty of \$46,600 for Item 4 as proposed in the Notice.

24. **Item 5 of the Notice:** With respect to Item 5, the Notice proposed a civil penalty of \$46,600. Without admission, Respondent agrees to pay a civil penalty of \$46,600 for Item 5 as proposed in the Notice.

25. **Item 6 of the Notice:** With respect to Item 6, the Notice proposed a civil penalty of \$46,600. Without admission, Respondent agrees to pay a civil penalty of \$46,600 for Item 6 as proposed in the Notice.

26. **Item 7 of the Notice:** With respect to Item 7, the Notice proposed a civil penalty of \$46,600. For the reasons set forth above, PHMSA withdraws the underlying allegation of violation for this Item. As such, PHMSA also withdraws the civil penalty for Item 7 of the Notice.

27. **Item 8 of the Notice:** With respect to Item 8, the Notice proposed a civil penalty of \$1,382,400. With respect to gravity, PHMSA reduces the gravity of the violation from “increased the severity of an accident/incident” to “occurred within an HCA” in light of information presented that had Denbury conducted a geohazard risk analysis, it would not have decreased the “severity” of the release. Without admission, Respondent agrees to pay a reduced civil penalty of \$746,400 for Item 8 of the Notice.

28. Respondent agrees to pay an adjusted civil penalty amount of \$2,868,100 within 20 calendar days of the Effective Date pursuant to the instructions PHMSA has provided for payment.

V. **Warning Item**

29. **Item 1 of the Notice:** With respect to Item 1 of the Notice, alleging a probable violation of 49 C.F.R. § 195.52, this Item was issued as a warning item. Respondent accepts the warning as alleged in the Notice.

VI. **Compliance Requirements**

30. **Items 2 and 8 of the Notice:** Denbury agrees to update its geohazard program to address hazards on all of its pipelines as well as include preventative and mitigative measures to enhance public safety and safe operation of its pipeline system. The geohazard program must include substantive information regarding hazard identification on each pipeline, assessment, remediation, and hazard recognition training for employees responsible for identifying geohazard issues.

31. **Items 3 and 6 of the Notice:** Utilizing the revised dispersion modeling calculations performed following the Satartia Release and taking into account all newly identified HCAs or “could affect” HCAs pipeline segments, Denbury agrees to:

- i. Identify all federal, state, and local government organizations that may respond to a pipeline emergency that were not formerly identified and included within Denbury’s liaison program and ensure that they are included within Denbury’s liaison activities as specified in Denbury’s manual for operations pursuant to 49 C.F.R. § 195.402(c)(12) and § 195.402(e)(7);

ii. Identify all federal, state, and local government organizations that may respond to a pipeline emergency that were not formerly identified and included within Denbury's Public Awareness program and ensure that they are included within Denbury's Public Awareness program as specified in Denbury's manual for operations pursuant to 49 C.F.R. § 195.440;

iii. Identify a comprehensive list of stakeholders for the Delta Pipeline and revise its written procedure OMO 0232 Damage Prevention and Public Awareness Section 3.3 Stakeholder Groups (Revised 2/12/2012);

iv. Meet with all federal, state, and local government organizations that may respond to a pipeline emergency that were not formerly identified and included within either Denbury's liaison program or Public Awareness program, or that were not on the prior list of stakeholders in Section 3.3 Stakeholder Groups, in each case to ensure that they are aware of the Delta Pipeline in their response areas and provide a copy of the district area emergency response procedures.

v. Maintain documentation of its compliance with the requirements of paragraph 31 (i) through (iv) and submit such documentation to the Director; which shall include:

- (1) Record of invitation to each local responder;
- (2) Name and contact information (address, county, and phone numbers);
- (3) Attendance sheet with signatures of those in attendance;
- (4) Procedures and other information covered/discussed;
- (5) Record of documents provided to attendees; and
- (6) Record of documents mailed/provided to non-attendees.

32. **Item 5 of the Notice:** Denbury agrees to complete a review of its written procedure O&M 0215, Patrolling and Leak Detection, and, based on that review, to include within O&M 0215 additional guidance for the identification of potential geohazard sites and the training of personnel on the amended procedures.

33. **Items 7 and 8 of the Notice:** Denbury agrees to update its dispersion model and buffer zone assessment by employing a model that considers the characteristics of CO₂ and the effects of the specific terrain surrounding the Delta Pipeline, including effects of both elevation changes and channeling, upon the release of CO₂ to the atmosphere. Additionally, Denbury agrees to assess the extent and coverage of potential vapor cloud releases by updating its dispersion model to allow for variable inputs relating to foreseeable weather and pipeline operating conditions. Denbury agrees to incorporate newly identified HCAs or "could affect" HCA pipeline segments

in its Integrity Management Program and Public Awareness Program and conduct a baseline assessment. Denbury agrees to conduct a risk analysis and will identify additional preventive and mitigative measures to enhance public safety or environmental protection for all HCAs or “could affect” HCA pipeline segments.

34. If PHMSA disputes either the sufficiency of Denbury’s measures or the adequacy of its documentation with respect to the requirements of paragraphs 30 through 33, the parties shall first informally attempt to resolve any disputes before engaging in dispute resolution according to paragraph 38. Unless PHMSA presents any dispute regarding the sufficiency of Denbury’s measures or the adequacy of its documentation with respect to the above paragraphs within 60 days, the Director will promptly confirm in writing to Denbury that the obligations in paragraphs 30 through 33 are satisfied in accordance with paragraph 41.

35. Denbury must complete item v in paragraph 31 within 60 days of the Effective Date. The Director will determine if such compliance requirement is adequate within 60 days after submission and timely fulfill its obligations pursuant to Section XI.

36. Denbury agrees to maintain documentation of the safety improvement costs associated with fulfilling this Compliance Order and submit the total to the Director. It is requested that these costs be reported in two categories: 1) total cost associated with preparation/revision of plans, procedures, studies, and analyses, and 2) the total cost associated with replacements, additions, and other changes to pipeline infrastructure.

VII. Enforcement

37. This Agreement is subject to all enforcement authorities available to PHMSA under 49 U.S.C. § 60101, *et seq.*, and 49 C.F.R. Part 190, including administrative civil penalties as specified in 49 U.S.C. § 60122 and 49 C.F.R. § 190.223 (presently up to \$239,142 per violation for each day the violation continues) and referral of the case to the Attorney General for judicial enforcement, if PHMSA determines that Respondent is not complying with the terms of this Agreement in accordance with determinations made by the Director, or if appealed, in accordance with decisions of the Associate Administrator. The maximum administrative civil penalty amounts are adjusted annually for inflation. *See* 49 C.F.R. § 190.223.

VIII. Dispute Resolution

38. The Director and Denbury will informally attempt to resolve any disputes arising under this Agreement, including, but not limited to, any decision of the Director. If Denbury and the Director are unable to informally resolve the dispute within 15 calendar days after the dispute is first raised, in writing, Denbury may submit a written request for a determination resolving the dispute from the Associate Administrator for Pipeline Safety. The written request for a determination must be provided to the Director, counsel for the Southwest Region, and to the Associate Administrator no later than 10 calendar days after the 15-day deadline for informal resolution referenced in this paragraph. Along with its request, Denbury must provide the Associate Administrator with all information Denbury believes is relevant to the dispute. Determinations of the Associate Administrator under this paragraph constitute final Agency

action. The existence of a dispute and PHMSA's consideration of matters placed in dispute, will not excuse, toll, or suspend any term or timeframe for completion of any work to be performed under this Agreement during the pendency of the dispute resolution process, except as agreed upon by the Director or Associate Administrator in writing.

IX. Effective Date

39. The term "Effective Date," as used herein, is the date on which the Consent Order is issued by the Associate Administrator, PHMSA, incorporating the terms of this Agreement.

X. Modification

40. The terms of this Agreement may be modified by mutual agreement of the Parties. Such modifications must be in writing and signed by both parties.

XI. Termination

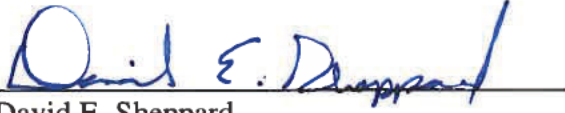
41. This Agreement will remain in effect until the Compliance Requirements in Section VI are satisfied, as reasonably and timely determined by the Director. The Consent Agreement shall not terminate until the Director confirms, in writing, that the Consent Agreement is terminated in accordance with this paragraph. Nothing in this Agreement prevents Respondent from completing any of the obligations earlier than the deadlines provided for in this Agreement or seeking dispute resolution regarding the question of whether the Compliance Requirements have been satisfied.

XII. Ratification

42. The Parties' undersigned representatives certify that they are fully authorized to enter into the terms and conditions of this Agreement and to execute and legally bind such party to this document.

43. The Parties hereby agree to all findings, conditions, and terms of this Agreement.

For Denbury Gulf Coast Pipelines, LLC:



David E. Sheppard
Executive Vice President and Chief Operating Officer

MARCH 23, 2023
Date

For PHMSA:
BRYAN JEFFERY
LETHCOE

Digitally signed by BRYAN
JEFFERY LETHCOE
Date: 2023.03.24 14:02:38 -05'00'

Bryan Lethcoe
Director, Southwest Region
March 24, 2023
Date