ProTechnics
A Division of Core Laboratories LP

6510 W. Sam Houston Pkwy N.
Houston, Texas 77401 USA
Tel: 713.328.2320
Fax: 713.328.2163
www.protechnics.com

DAVID TRINKER
Radiation Safety Officer
Director Health, Safety, and Environmental

November 2, 2022

Neil O'Keefe, Jr., Chief
Materials Licensing Branch
U.S. NRC Region IV
1600 East Lamar Boulevard
Arlington, Texas 76011-4511

Re: ProTechnics Request for Amendment to License No. 42-26928-01, Current Amendment No. 54

Dear Mr. O'Keefe:

ProTechnics, a Division of Core Laboratories L.P., hereby requests an amendment to our Nuclear Regulatory Commission (NRC) license cited above to obtain authorization to discharge well completion fluids containing de minimis amounts of short-lived radioactive tracers in offshore waters in the U.S. Outer Continental Shelf (OCS) of the Gulf of Mexico (GOM). In connection with well logging in the GOM, ProTechnics uses its Zero Wash™ radioisotope tracers, consisting of Iridium-192 and Scandium-46, in performing single well subsurface tracer studies for client well owners and/or operators onshore and well lease operators offshore in established oil and gas production basins located in OCS waters. These radioactive tracers have been and presently are licensed for use by both the NRC and various Agreement States where well logging activities are performed.

ProTechnics offshore well logging and tracing services are a recognized key element supporting the oil and gas industry's proven practice of efficiently developing, optimizing, and extracting U.S. held oil and gas resources in a manner that is safe to humans and environmentally sound. These services are vital to the U.S. oil and gas industry.

ProTechnics modeling of potential radiation exposure to humans using recognized International Atomic Energy Administration (IAEA) methodology indicates discharges of Zero Wash™ tracers to the GOM will have insignificant, if any, impact on human health and safety. Accordingly, this letter also serves to formally request NRC approval for ProTechnics to continue offshore oil and gas well tracer operations in the U.S. GOM during the period required for NRC to evaluate and make a formal determination of the acceptability of this request.

Disposal of similar concentrations of Zero Wash™ tracers contained in reversed-out well completion fluids in offshore applications has previously been authorized by NRC for on-land disposal in well-site earthen burial pits and licensed disposal facilities and is an established practice for disposal of such materials following frac'ing operations in onshore oil, gas, and geothermal wells.

Background

The NRC previously authorized ProTechnics to dispose of Zero Wash™ tracers onshore in limited concentrations up to 1,000 pCi/g. For offshore well logging and subsurface tracer studies, ProTechnics has been operating in good faith pursuant to authorization it received from the United States Environmental Protection Agency (USEPA) to discharge its Zero Wash™ radioisotope tracers containing Iridium-192 and Scandium-46 into offshore waters of the OCS. The USEPA indicated by letter dated August 19, 2003 that offshore discharge of these isotopes entrained in well treatment fluids in concentrations up to 2,000 pCi/g would be in compliance with National Pollutant Discharge Elimination System (NPDES) General Permit requirements in the Offshore Subcategory of Oil and Gas Extraction in the Western Outer Continental Shelf of the Gulf of Mexico (GMG290000), and as such no additional monitoring would be required.

However, in its proposed reissuance of NPDES General Permit No. GMG290000, the USEPA noted that the renewal permit will no longer authorize discharge of radioactive materials that are expressly within the jurisdiction of the NRC. The USEPA stated in its fact sheet supporting its proposed general permit that the discharge of Iridium-192 and Scandium-46 in the OCS, historically used in small amounts in connection with proppant injection, cannot be authorized by the USEPA unless separately authorized by the NRC. The current NPDES General Permit, re-issued on October 1, 2017, expired at midnight, Central Time, on September 30, 2022. Since the 2017 permit expired before its reissuance, the USEPA notified permittees that the 2017 permit would automatically enter administrative continuance as provided by the Administrative Procedures Act until reissuance. As of the date of this letter, the 2017 permit remains effective in "Administratively Continued Status" according to the USEPA.

ProTechnics is therefore seeking express approval from the NRC to discharge radioisotope tracers in offshore marine waters in accordance with the disposal methods covered in 10 CFR Subpart K – Waste Disposal - §20.2001, and supplemented by the IAEA's specific assessment procedure for discharge of radioactive materials at sea, as described in IAEA-TECDOC-1759, "*Determining the Suitability of Materials for Disposal at Sea Under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure*."

ProTechnics' assessment of individual and collective dose rates to humans is based on the IAEA's specific assessment procedure, which the IAEA describes as an "inherently conservative procedure" using "conservative models and cautious assumptions that result in the overestimation of the doses due to candidate materials that might be disposed of at sea in near coastal waters under de minimis provisions." ProTechnics' injection of licensed radioactive tracers occurs in wells at average depths of 1,000 meters or greater below the water surface and at distances averaging approximately 100 nautical miles offshore. As such, and consistent with IAEA guidance, the radiological consequence of disposal at sea would be expected to result in significantly lower radiation exposures than those calculated using the conservative IAEA methodology.

For purposes of calculating dose and expected impacts on human health and the environment, ProTechnics used the following concentrations:

- Routine (i.e., average) estimated radioisotope discharge concentrations up to 1,350 pCi/g, based on ProTechnics' "traditional" injection rate for historical GOM frac design tracer studies. These concentrations are approximately equivalent to an injection rate of 0.604 mCi per 1,000 lbs. of proppant sand.

- Routine (i.e., average) injected radioisotope concentrations approximating 1,000 pCi/g. This is the same concentration limit previously approved by NRC for disposal of onshore well completion flowback waste streams containing Zero Wash™ tracers using either (i) decay-in-storage inside local earthen-covered burial pits at a well-site or (ii) disposal in a landfill or Class II disposal well licensed to receive and store Zero Wash™ tracer waste.

- Estimated worst-case (i.e., maximum) injected radioisotope concentrations approximating values up to 1,550 pCi/g.

Analysis and Basis of Conclusions

Process Description

ZeroWash™ tracers are manufactured using a patented process that fixes non-water-soluble tracer metal oxide particles into the matrix of a non-water-soluble high strength ceramic bead. The ceramic bead is the size of typical frac'ing proppants (approximately 40/70 mesh size). This design is intended to decrease the impact on any environmental system, whether it's topographical, geological, meteorological, or hydrological. Documented testing from Texas A&M University confirms there is no leaching or wash-off of radioactive material into any fluids, including water tables, or mechanical equipment of wells or downstream production equipment. In other words, ZeroWash™ ceramic tracer beads, and radioisotope metal oxide particles affixed within the ceramic beads' structure, are chemically inert, insoluble, and molecularly non-binding to water or other solvents, as well as other solid materials contained inside frac and reverse-out well streams. The ZeroWash™ product will not contaminate ground or marine salt water as the ceramic beads and embedded radioactive metal particles will not dissolve or leach out of the bead to combine with water. Thus, the nature of adjacent environmental settings is of no consequence, and there are no adverse effects on the environment. Please refer to ProTechnics' Safety Data Sheet (SDS) for ZeroWash™ radioisotope tracers, attached as Appendix 1, and the test results performed by Texas A&M University, attached as Appendix 2.

ProTechnics performs tracer studies predominantly in single well applications. In the course of well logging operations, ZeroWash™ tracers are injected during the proppant pumping stages of the frac job. After the formation is sufficiently pressurized, tracer-laden solid proppant and completions fluids remaining in the well bore are returned to the surface during the fluid flush stage. For a well that goes to completion, the final flush stage of a frac schedule pushes as much of the proppant into the formation as possible, leaving approximately 5 barrels of proppant, tracer, and completions fluids outside of the formation. Generally speaking, all of the proppant and tracer material that enters the formation will be retained behind the screen mesh, which operates as a check valve, and will not return to the surface during reverse-out. Only the material remaining on the well bore side of the screen mesh, consisting of a slurry of tracer, proppant, and completions fluids, is returned to the surface. For safety reasons and principles of ALARA, the flushed-out fluid is pumped directly overboard into the GOM rather than contained in storage on a drilling rig or marine vessel. The weight of the traced proppant returned to the surface is accurately determined and reported on the post treatment field report for each frac job.

Please refer to Appendix 3 for a more detailed description of the reverse-out process as well as a basic frac system schematic of the fluid flow path.

Offshore Discharge (Disposal)

10 CFR §20.2001 authorizes various methods of radioactive (byproduct) material disposal, including by transfer to an authorized waste disposal site, by decay in storage, by release in effluent streams within prescribed limits, and as otherwise authorized pursuant to Subpart K, §20.2002 et seq.

10 CFR §20.2003, covering disposal by release into sanitary sewerage, is not applicable to ProTechnics' well logging and tracing activities for two reasons. The tracers are discharged directly in the GOM and therefore do not enter sewer systems offshore or on land, and furthermore, the tracers are not soluble in water.

Effluent disposal pursuant to the dose limits cited in 10 CFR §20.1301 and 1302 are applicable in the context of discharges into the general environment where it is assumed that the radioactive material will enter freshwater aquifers. The dose limits established by this disposal method are exceedingly low and arguably not applicable to discharge into marine waters. OCS discharge of ZeroWash™ tracers do not interface with inland surface water drainage systems, including streams, rivers, lakes, ponds, water tables, and other natural bodies or sources of freshwater that could become potential sources of potable water.

Appendix B to 10 CFR Part 20, Table 2, provides effluent concentration limits in water equal to 1.0×10^{-5} µCi/ml for both Iridium-192 and Scandium-46. The notes to Table 2 indicate that the water concentrations were derived "by taking the most restrictive occupational stochastic oral ingestion Annual Limit on Intake (ALI) and dividing by 7.3×10^{7} ml." The factor of 7.3×10^{7} (ml) includes the following components:

- a factor of 50 to relate the 5-rem annual occupational dose limit to the 0.1-rem limit for members of the public,
- a factor of 2 to adjust the occupational values (derived for adults) so that they are applicable to other age groups; and
- a factor of 7.3×10^{5} (ml), which is the annual water intake of "Reference Man."

Subpart D, §20.1302 provides that a licensee may demonstrate compliance with the annual dose limit in §20.1301 by demonstrating (i) that the annual average concentrations of radioactive material released in liquid effluents at the boundary of an unrestricted area do not exceed the values set forth in Table 2 of Appendix B to part 20, and (ii) that if an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year. §20.1302(c) further provides that the effluent concentrations in Appendix B may be adjusted, upon approval from the NRC, to take into account the actual chemical and physical characteristics of the effluents, including solubility, density, radioactive decay equilibrium and chemical form.

Importantly, the public would likely never be exposed to discharges into the GOM at distances tens of nautical miles offshore, and further still, any such discharge would not enter the public drinking water system. Therefore, we submit the effluent concentration limit of 1.0×10^{-5} µCi/ml should be adjusted to reduce the annual water intake assumption. According to the EPA's Exposure Factors handbook, the average amount of seawater ingested during a 45-minute swim is approximately 27 ml. Assuming an adult spends 1,600 hours on the shore and approximately twenty-five percent of that time in the water, the total amount of water ingested per year is 1.42×10^{4} ml. Making this adjustment, the revised effluent concentration limit would be 6.35×10^{-4} µCi/ml. This adjustment does not take into account two additional unique characteristics of ZeroWash™ tracers, that is, they are insoluble in water and therefore will not uniformly disperse in solution, and further the tracer beads have a specific gravity that is more than 2.5 times the density of seawater, causing the solid beads to settle out of the liquid phase. Using the IAEA methods, the projected external dose to the public from any radionuclide-bearing proppants that might wash up on the shore is well below the limit set out by the IAEA. Please refer to Appendix 5 for a summary of the calculation methodology and data supporting the adjusted effluent concentration limit.

The two Zero Wash™ tracers used in offshore GOM wells, Iridium-192 and Scandium-46, have radioactive half-lives of 74 and 84 days, respectively. From a public safety perspective, considering water depth and distance from land as well as the physical and radiological characteristics of the tracer beads, offshore disposal during isotope decay is arguably safer to humans given the exceedingly low probability of exposure.

Collection, transfer, and transport of completion fluids containing ZeroWash™ tracers to an authorized onshore land disposal facility has a significant disadvantage relating to safety compared to offshore discharge at sea, tens of nautical miles from human populations. Offshore collection and containment on surface oil rigs and transfer to marine service vessels for transport to land, followed by additional transfer from marine vessels to overland transport trucks, increases worker exposure and thus is contrary to ALARA principal objectives of minimizing human exposure. Such transport also increases the risk of spills to areas in close proximity to human populations and freshwater sources of drinking water.

IAEA Methodology and Results

ProTechnics also evaluated individual and collective dose limits in accordance with guidelines established by the IAEA (IAEA-TECDOC-1759, "*Determining the Suitability of Materials for Disposal at Sea Under the London Convention of 1972 and London Protocol 1996: A Radiological Assessment Procedure*"). The IAEA publication describes a comprehensive method for evaluating the impact on humans of releasing radioactive material into an ocean environment.

ProTechnics performed calculations using the IAEA methodology to estimate representative discharge concentrations for three discharge scenarios: (i) a routine case (average case) estimated discharge concentration based on its "traditional" frac design; (ii) a routine case (average case) estimated discharge concentration based on a redesigned well frac injection rate; and (iii) a worst credible case (maximum case) estimated discharge concentration. Both discharge concentrations are expressed as a ratio of tracer activity concentration in the solids component of reverse-out well completion fluids.

Calculations are based on job data specific to 20 actual frac jobs performed in the U.S GOM during CY2022, beginning January 2022 through early September 2022. The job data was extrapolated to estimate an expected forty jobs per year to assess potential Individual Dose to the Public and Collective Public Dose as outlined in IAEA-TECDOC-1759. For U.S GOM subsurface tracer studies, ProTechnics uses only two isotopes, Iridium-192 and Scandium-46. Scandium-46 is always injected first in the frac job, followed by Iridium-192. Once a well "screens-out", meaning the reservoir is pressurized to the point that it will not accept any additional injected proppant, residual proppant and tracer mix that has not passed through the downhole frac gravel pack assembly will be returned to the frac injection equipment located at the water surface. Reverse-out fluids flow is based on the last-in, first-out principle. Thus, in every offshore frac job, the reverse-out frac stream contains Iridium-192 in measurable quantities and only negligible, if any, quantities of Scandium-46.

ProTechnics performed three sets of calculations for each discharge case. The first set of discharge concentrations was performed based on a target design tracer injection value equal to 0.604 mCi Iridium-192 per 1,000 lbs. of proppant sand (approximately 1,350 pCi/g), representing a "traditional" frac design maximum injection concentration for GOM well frac designs. Subsequently, a redesigned frac design maximum injection concentration was calculated with the intent to limit discharge concentrations into OCS waters to 1,000 pCi/g or less. Finally, a third calculation was performed using a worst credible case discharge concentration of up to 1,550 pCi/g. Results of these calculations are presented in the tables below using the following concentrations:

- Routine estimated discharge concentration up to 1,350 pCi/g, based on "traditional" GOM frac design tracer injection rate approximately equivalent to 0.604 mCi per 1,000 lbs. of proppant sand.

- Routine estimated discharge concentration up to 1,000 pCi/g based on a redesign of well frac tracer injection rates. The "redesigned" frac design injection rate, effective October 1, 2022, is equal to 0.454 mCi per 1,000 lbs. of proppant sand.

- Worst credible case estimated discharge concentration up to 1,550 pCi/g based on a "traditional" GOM frac design tracer injection rate approximately equal to 0.697 mCi per 1,000 lbs. of proppant sand. This number represents the worst case of 20 jobs performed during CY2022 through early September.

Individual Public Doses Calculated for Redesigned, Traditional and Worst-Case Scenarios

		Calculated Value			
Individual Public Dose	**Symbol**	**Redesigned 1,000 pCi/g**	**Traditional 1,350 pCi/g**	**Worst 1,550 pCi/g**	**Units**
Dose from External Exposure	$E_{ext, public}$	8.93E-02	1.19E-01	1.37E-01	μSv/year
Dose from Ingestion of Seafood - fish	$E_{ing, food, public}$	1.74E-05	2.31E-05	2.67E-05	μSv/year
Dose from Ingestion of Seafood - shellfish	$E_{ing, food, public}$	2.61E-05	3.46E-05	4.01E-05	μSv/year
Dose from ingestion of Beach Sediment	$E_{ing\ shore, public}$	1.39E-05	1.85E-05	2.14E-05	μSv/year
Dose from inhalation of Beach Sediment	$E_{inh\ shore, public}$	2.77E-09	3.69E-09	4.26E-09	μSv/year
Dose from Inhalation of Sea Spray	$E_{inh, spray, public}$	1.88E-06	2.50E-06	2.89E-06	μSv/year
Dose from ingestion of seawater	$E_{ing, seawater}$	2.71E-06	3.61E-06	4.04E-06	μSv/year
Total Individual Dose to Members of the Public	$E_{ind, public}$	8.94E-02	1.19E-01	1.37E-01	μSv/year

Collective Public Dose Calculated for Redesigned, Traditional and Worst-Case Scenarios

		Calculated Value			
Collective Public Dose	**Symbol**	**Redesigned 1,000 pCi/g**	**Traditional 1,350 pCi/g**	**Worst 1,550 pCi/g**	**Units**
Collective Dose from Exposure on Shore	$E_{coll, shore, public}$	1.12E-03	1.48E-03	1.72E-03	man-Sv/year
Collective Dose from Seafood Consumption - fish	$E_{coll\ ing, public}$	3.32E-06	4.42E-06	4.42E-06	man-Sv/year
Collective Dose from Seafood Consumption - shellfish	$E_{coll\ ing, public}$	5.81E-06	7.73E-06	7.73E-06	man-Sv/year
Total Collective Dose	$E_{coll, Public}$	1.13E-03	1.50E-03	1.73E-03	man-Sv/year

The supporting calculations for the results in the foregoing tables are set forth in Appendix 5.

In both Individual Public Dose and Collective Public Dose, using actual sample data from ProTechnics' 2022 GOM tracer operations, the levels returned to surface were determined to be de minimis under the IAEA-TECDOC-1759 guidance. Please refer to Appendix 4 for a detailed discussion of the IAEA methodology, together with results and conclusions based on actual frac job data for ProTechnics' tracer studies in the GOM.

In closing, ProTechnics requests a license amendment pursuant to 10 C.F.R. §20.2002 approving the disposal of limited concentrations of short-lived radioactive tracers in the Gulf of Mexico. Because ProTechnics offshore well logging and tracing services are a vital element supporting the U.S. oil and gas industry, we ask that the Commission use its enforcement discretion to allow ProTechnics to continue offshore well logging and tracing services pending a final action on our request.

We appreciate your consideration of this matter and look forward to working with you toward resolution.

Sincerely,

David W. Trinker
Radiation Safety Officer
Core Laboratories – ProTechnics Division

List of Appendices:

Appendix 1	ProTechnics Safety Data Sheet (SDS) for ZeroWash™ Radioisotope Tracers
Appendix 2	Results of ZeroWash™ Tracer Testing Performed by Texas A&M University
Appendix 3	Offshore Oil and Gas Well Completions Fluids and Materials Reverse-Out Process Description and Schematic Flow Diagram
Appendix 4	Evaluation of Impacts Related to Discharging De Minimis Amounts of Short-Lived Radioisotopes to the Gulf of Mexico
Appendix 5	Public Dose Calculation and Supporting Data (Excel files)

APPENDIX 1

ProTechnics Safety Data Sheet (SDS) for ZeroWash™ Radioisotope Tracers

SAFETY DATA SHEET

Date-Issued: 05-2015
SDS Ref. No: ZW
Date-Revised: 5/12/2021
Revision No:003

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product Identifiers

Product name	:	Zero Wash Tracer
Product number	:	NA
Generic name	:	IRZW, SCZW, SBZW, and low Density (LD)

1.2 Relevant identified used of the substance or mixture and uses advised against

Identified uses	:	Diagnostic
Uses advised against	:	Not available

1.3 Details of the supplier of the safety data sheet

Company	:	ProTechnics Division of Core Laboratories 6510 W. Sam Houston Parkway N. Houston, Texas 77041
Telephone	:	713-328-2320

1.4 Emergency telephone number

Emergency phone number	:	713-328-2320
Transportation emergency	:	1-800-535-5053 (inside US) 1-352-323-3500 collect (outside US)

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS classification in accordance with 29 CFR 1910 (OSHA HCS)

Not Classified – Radioactive Material

2.2 GHS Label elements, including precautionary statements

Pictogram: None

Signal word: None Associated – Radioactive Material

Hazard statement(s): No hazard statement associated – Radioactive Material.
Zero Wash is a small bead that emits low gamma radiation in small quantities.

Precautionary statement(s)

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - Radioactive Material

3. COMPOSITION / INFORMATION ON INGREDIENTS

3.1 Substances

Substance/ mixture Mixture

Ingredient	CAS No.	Percent	Hazardous
Ceramic Proppant A mixture of inorganic earthen materials (Earthen Oxides)	Proprietary	100	Yes

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Move away from source. Use ALARA – Time, Distance, Shielding.

If inhaled
Not respirable.

In case of skin contact
Remove from contact with skin. Keep distance.

In case of eye contact
Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. If irritation continues, consult a physician.

If swallowed
Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed

No side effects known with short term, avoid long term exposure.

4.3 Indication of any immediate medical attention and special treatment needed

Remove bead and place in shielding or create distance.

5. FIRE FIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media

Carbon Dioxide (this reduces the spread of Zero Wash material).

5.2 Special hazards arising from the substance or mixture

NA

5.3 Advice for firefighters

Low activity Gamma emitting radioactive material-low exposure

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

6.2 Environmental precautions

CONTROL THE AREA. Rubber gloves, boots and safety glasses should be worn when handling.

6.3 Methods and materials for containment and cleanup

Clean up spill area by scooping up spilled material and transfer to a container. If clothing indicates the presence of Zero Wash material, remove the bead with adhesive tape, hold tape containing bead for decay in proper storage area. If numerous beads are found on clothing, remove clothing and place in a container for later cleaning or disposal. When any spill or release occurs, ProTechnics should be notified (713-328-2320) to supervise clean-up efforts.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Only ProTechnics Trained tracer supervisors should handle this material as they are trained in how to contain, remove and find the material.

7.2 Conditions for safe storage

Normal

7.3 Specific end uses(s)

Diagnostic.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Non radiation workers should avoid any contact with material. Restricted area for use should be set at 2mR/hr and prevent any unintentional exposure.

8.2 Exposure controls

Appropriate engineering controls
Material stored in lead lined containers and used in restricted areas only. Only trained Tracing supervisors have access and control of the material.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166. Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN166 (EU).

Skin protection
Handle with chemical-resistant gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body protection
Standard FRC should be adequate and use of proper surveying techniques used when material is being used.

Control of environmental exposure
All material should be captured and managed by ProTechnics, if material is noticed by survey please contact ProTechnics at 713-328-2320.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: Small grey colored ceramic bead Color: grey
b)	Odor	Odorless
c)	Boiling point	NA
d)	Freeze point	NA
e)	Density/Specific Gravity	2.6 g/mL
f)	Flash point	Not flammable
g)	pH	Not available
h)	Evaporation factor	Not determined
i)	Solubility	not Soluble in water
j)	Vapor pressure	Not determined
k)	Oxidizing properties	Not determined
l)	Vapor density	Not determined
m)	Viscosity	Not determined

9.2 Other safety information

No data available.

10. STABILITY AND REACTIVITY

10.1 Reactivity

NA

10.2 Chemical stability

The product is stable under normal ambient conditions of temperature and pressure.

10.3 Possibility of hazardous reactions

Will not polymerize.

10.4 Conditions to avoid

Combination of material with more like material could increase exposure levels. The smaller the amount the lower the exposure rates should be.

10.5 Incompatible materials

NA

10.6 Hazardous decomposition products

None. All ZW material decay to stable state.

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity – oral
May cause Eye and Mucous membrane irritation.
Ingestion is the only method of internal consumption.

Acute toxicity – dermal
Irritation or itching of the skin.

Acute toxicity – inhalation
ZERO WASH particle is too large to inhale.

Skin corrosion/irritation
NA

Serious eye damage/irritation
NA

Respiratory sensitization
ZERO WASH particle is too large to inhale.

Skin sensitization
Irritation or itching of the skin.

Germ cell mutagenicity

Genotoxicity – in vitro
Based on available data the classification criteria are not met.

Genotoxicity- in vivo
Based on available data the classification criteria are not met.

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

ACGIH: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.

NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

Reproductive toxicity – fertility
Based on available data the classification criteria are not met.

Reproductive toxicity – development
Based on available data the classification criteria are not met.

Specific target organ toxicity – single exposure
Low doses not applicable.

Specific target organ toxicity – repeated exposure
Internal – possible gamma exposure.

Aspiration hazard
Not anticipated to present an aspiration hazard, based on Physical structure.

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity

NA

12.2 Persistence and degradability

Half life: IRZW-74 days, SCZW-84 days, SBZW-60 days

12.3 Bioaccumulative potential

No data available.

12.4 Mobility in soil

Zero Wash does not plate and will not breakdown in soil.

12.5 Results of PBT and vPvB assessment

PBT/vPvB assessment is not available as chemical safety assessment not required/ not Conducted for radioactive isotopes.

12.6 Other adverse effects

No data available.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product

DISPOSAL METHOD: Dispose of waste at an appropriate waste disposal facility according to current applicable laws and regulations.

PRODUCT DISPOSAL: Dispose of at a supervised appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

EMPTY CONTAINER: Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

GENERAL COMMENTS: Refer to Section 6, Accidental Release Measures for additional information.

Contaminated packaging

Contaminated containers should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations. Please contact ProTechnics for Disposal guidance at 713-328-2320.

14. TRANSPORT INFORMATION

DOT (US)
DOT (DEPARTMENT OF TRANSPORTATION)
PROPER SHIPPING NAME: Radioactive material, Type A package
TECHNICAL NAME: Zero Wash Tracer
LABEL: Diamond.
Hazard Class/Division: 7
United Nations number: 2915

IMDG
VESSEL (IMO/IMDG)
PROPER SHIPPING NAME: Radioactive material, Type A package
TECHNICAL NAME: Zero Wash Tracer
LABEL: Diamond.
United Nations number: 2915

IATA
AIR – Forbidden on Passenger carrying aircraft.
PROPER SHIPPING NAME: Radioactive material, Type A package
TECHNICAL NAME: Zero Wash Tracer
LABEL: Diamond
Hazard Class/Division: 7
United Nations number: 2915
.

15. REGULATORY INFORMATION

SARA 302 Components
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
SAR 311/312: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 311/312.

CERCLA (Comprehensive Response, Compensation, and Liability Act)
Not Applicable.

TSCA (Toxic Substance Control Act)
Not Applicable.

16. OTHER INFORMATION

HMIS Rating

Health Hazard:	1
Chronic Health Hazard:	1
Flammability:	0
Physical Hazard:	0

NFPA Rating

Health Hazard:	1
Fire Hazard:	0
Reactivity Hazard:	0

MANUFACTURER DISCLAIMER: Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.

Prepared by: ProTechnics Environmental Compliance Department, Houston, Texas USA

Date of revision: 05/12/2021

Contact information: 713-328-2320

APPENDIX 2

Results of ZeroWash™ Tracer Testing
Performed by Texas A&M University

TEXAS ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

COLLEGE STATION TEXAS 77843-3575

NUCLEAR SCIENCE CENTER
409/845-7551

11 July 1991

ProTechnics International
14760 Memorial Drive, Suite 206
Houston, Texas 77079

We have completed the wash test on your patent pending radioactive carrier PTI-ZW under the testing criteria that you included in your guidelines and our input that we discussed. The test was performed and completed on June 19, 1991. Listed below are the test results.

Sincerely,

RECEIVED 13 JUL 1991

John L. Krohn
Assistant Director

JLK/ym

Radioactive Wash Test Results
(PTI-ZW)

	Temp	KCL Water	15% HCL
Washoff	80° F	12/1000 of 1%	17/1000 of 1 %
Washoff	180° F	40/1000 of 1%	41/1000 of 1 %

Note : These washoff amounts could be considered negligible in view of the probability of filter washby of production fines.

APPENDIX 3

Offshore Oil and Gas Well Completions Fluids and Materials Reverse-Out Process Description and Schematic Flow Diagram

This Appendix provides a high-level description of the well frac reverse-out process and a schematic flow diagram for reference.

<u>Location of Frac and Tracing Equipment</u>

Frac equipment typically belongs to the client operating company's well completions service contractor. Drilling rigs generally are located on either (1) the client operating company's combined drilling and production platform (which is in a fixed geo-coordinate location) or (B) the drilling contractor's temporary floating drilling ship used for servicing deep water wells, or a temporary jack-up rig used for servicing shallow water wells.

The frac service contractor's frac'ing equipment (tanks, pumps, and piping) can be located on either the drilling contractor's drilling ship or jack-up rig or floating barge / work boat. These floating or jack-up temporary work "platforms" are temporarily stationed (positioned) adjacent to the client's combined drilling and production platform or the drilling contractor's floating or jack-up drill rig. Typically, frac proppant (sand) tanks and pumps are located on floating barges, which are temporarily positioned adjacent to the permanent platform or temporary drill rig. Frac proppant/sand is located on the barge or work boat. Temporary piping and/or hose (CoFlex hose) connections are made between these vessels to complete the flow path during injection of proppant, tracer, associated frac fluids, and well completion reverse-out fluids.

ProTechnics' frac tracing equipment and supplies are co-located with the frac service contractor's frac equipment and supplies.

<u>Summary Description of Well Frac Completion Fluids and Materials Reverse-Out Process</u>

On a normal job, once stage 1 of the actual frac schedule has been completed the following tracer injection stages are executed during the period while proppant is injected into the well. Proppant is added until commencement of the final flush stage, which begins immediately when the proppant slurry injection process is stopped.

The frac company will accomplish three schedules, a primary schedule based on well information, a redesign schedule adjusted for onsite information and an actual schedule compiled from data collected during the actual job. Below is an example of a typical tracing operation.

Actual Schedule						
Stage	Description	Clean Volume (BBl)	Pump Rate (BPM)	Average PPA	Slurry Volume (BBL)	Stage Proppant (Lbs.)
1	PAD	166.10	18.70	0.00	166.10	0.00
2	0.5 PPA Hold	48.20	18.70	0.54	49.30	1086.00
3	1 PPA Hold	48.34	18.70	1.00	50.40	2038.00
4	2 PPA Hold	48.05	18.70	2.04	52.20	4115.00
5	3 PPA Hold	48.16	18.70	3.06	54.40	6185.00
6	3 to 10 PPA Ramp	191.13	18.70	6.42	243.10	51513.00
7	10 PPA Hold	47.89	18.70	10.01	68.20	20136.00
8	10 PPA Hold	90.98	18.70	10.54	131.60	40267.00
9	Flush	532.70	18.70	0.00	532.70	0.00
Actual Schedule Totals		**1221.56**			**1348.00**	**125340**

PPA = Pounds of Proppant Added Max (pounds of proppant/gallon of fluid)

Stage 1

- No proppant is added. The well is being prepped for the following stages.

Stages 2 – 8

(0.5 – 6 PPA, Sc-46 injected)
- The main frac begins adding proppant to the fluid.
- Start trace as per schedule adding Sc-46 in the first half of the proppant stages 0.5 to 6 PPA.
- Sc-46 is traced during the first half of the frac stages and out into the formation for its ability to read at further distances from the well bore.

(7 – 10 PPA, Ir-192 injected)
- Ir-192 is traced during the second half of the frac stages 7 to 10 PPA until completion and therefore will account for most all tracer material reversed-out. There could be negligible amounts of Sc-46 if any material should adhere to the well bore or equipment.
- When the boat supervisor calls the end of sand stages, proppant injection is stopped by the Operator and ProTechnics stops tracing.

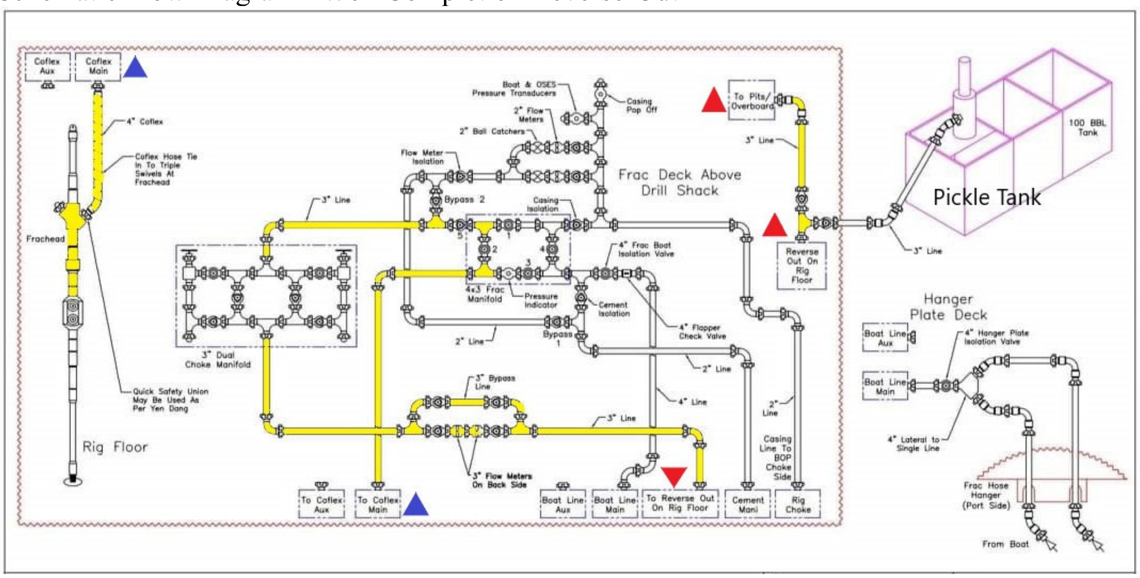
Stage 9

Flush
- A flush is performed to displace the frac material in the well down to the cross-over without over-displacing the frac treatment.
- Once a screen-out is achieved or induced resulting in a rapid rise in pump pressure, proppant pumping will be shut down.

Reverse-out
- An announcement is broadcast restricting all non-essential personnel from the high-pressure reverse-out operations areas prior to commencement.

- The drill rig shifts the tool to the reverse position and starts reversing out the flush and the remaining sand/proppants left above the cross-over. While reverse-out volume is variable, displacement is typically just above 5 barrels of pipe volume from the crossover for wells that go to completion.
- The only tracer-laden fluids returned to the surface during reverse-out are those fluids remaining above the gravel pack assembly after the well screens out.
- Reverse-out travels through the restricted area and will go overboard until clear of sand/proppants.
- ProTechnics representatives on location will monitor the isotope activity to make sure reverse-out is clean of activity before returning flow back to the rig.
- During the reverse-out, and throughout the frac operation, no fluids or materials return to the frac boat. Flowback to frac boat is prevented by check valves in all lines. All reverse-out operations and responsibilities, including lines, valves and overboard piping are located and operated on the drilling rig itself.

Schematic Flow Diagram - Well Completion Reverse-Out



APPENDIX 4

Evaluation of Impacts Related to Discharging De Minimis Amounts of Short-lived Radioisotopes to the Gulf of Mexico

Core Laboratories has completed an assessment to determine the radiological impacts of discharging *de minimis* amounts of short-lived radioactive tracers in the Gulf of Mexico. Results show that there is no significant impact on human health and safety.

The analysis was conducted using the methodology set out in the IAEA's publication, "*Determining the Suitability of Materials for Disposal at Sea Under the London Convention of 1972 and London Protocol 1996: A Radiological Assessment Procedure*." This publication describes a comprehensive method for evaluating the impact of releasing radioactive material into an ocean environment. According to the IAEA, this document "… is expected to be used mainly by national regulatory authorities responsible for authorizing disposal at sea of candidate materials, as well as those companies and individuals applying to obtain permission from such authorities to dispose of these materials at sea. It is also intended to provide guidance to national radiological protection authorities that might become involved in determining whether candidate materials can be designated as de minimis for the purpose of the London Convention and Protocol."

The assessment process described in the report is inherently very conservative as provided in the London Convention and the London Protocol, both of which address the prevention of marine pollution by dumping of wastes and other matter at sea. In conducting the analysis described in this report, Core Laboratories has incorporated these conservative parameters and methods, except where site specific parameters were available and defensible.

The analysis was conducted using the procedure outlined in Section 5 and appendices I and II of the IAEA document. The specific inputs to the procedure consisted primarily of the fractional amount and quantity by dry weight of the reverse-out proppants from the well, and the measured quantity of the 74-day half-life, Ir-192, which is the radioisotope of concern. Because Core Laboratories is already licensed for the handling of the radioisotope and because doses to marine biota and fauna are not required in the applicable NRC regulations, the assessment was limited to impact on the public.

According to the IAEA, "… candidate materials comprising sediments containing only relatively minor amounts of artificial radionuclides may not need to be subjected to an unnecessarily detailed or complex assessment process." In that regard, Core Laboratories conducted a screening assessment as suggested by the IAEA. Using the screening coefficients and the activity concentration of the candidate material (irradiated Ir-192 oxide metal particles contained within insoluble high-strength ceramic Zero Wash™ tracer beads), the calculated public individual dose and the collective public dose were well below the reference dose. Nonetheless, Core Laboratories has chosen to conduct a specific assessment in the interest of completeness.

Analysis

For this analysis, the methodology described in the IAEA document was used to assess radiation doses to members of the public most exposed to radionuclides from the material released from offshore platforms through the ingestion of marine foods, caught in the vicinity of the platform, and occupancy on adjacent beaches.

Generally speaking, all of the proppant and tracer material that enters the formation is retained behind the screen mesh and not returned to the surface during reverse-out under normal well operation. Only the material remaining on the well bore side of the screen mesh, consisting of a slurry of tracer, proppant, and completions fluids, is returned to the surface. For purposes of calculating dose and expected impacts on human health and the environment, ProTechnics used the following three concentrations:

- Routine estimated discharge concentration up to 1,350 pCi/g, based on "traditional" GOM frac design tracer injection rate approximately equal to an average value of 0.604 mCi per 1,000 lbs. of proppant sand.
- Routine estimated discharge concentration up to 1,000 pCi/g based on redesign of well frac tracer injection rates. The "redesigned" frac design injection rate is equal to 0.454 mCi per 1,000 lbs. of proppant sand.
- Worst credible case estimated discharge concentration up to 1,550 pCi/g based on a "traditional" GOM frac design tracer injection rate approximately equal to 0.697 mCi per 1,000 lbs. of proppant sand. This number represents the highest case of 20 jobs performed during CY2022 through early September.

The IAEA method calculates doses to the public for the following pathways:

- External exposure to radionuclides deposited on the shore.
- Ingestion of seafood caught in the area around the dumping site.
- Inadvertent ingestion of beach sediments.
- Inhalation of particles resuspended from beach sediments.
- Inhalation of sea spray.

One additional pathway evaluated was ingestion of seawater by adults, while wading or swimming near the shore in the Gulf of Mexico.

In this analysis, disposal occurs in deep water exceeding 1000-meter depth and averaging more than 185 km from the coast. The material discharged is exclusively ZeroWash™ ceramic tracer beads tagged with the radioisotope Ir-192. These beads are chemically inert, insoluble, and molecularly non-binding to water.

A rectangular box model 10^4 x 10^4 x 10^3 meters is used to simulate the dispersion and dilution of the radionuclides in the water column surrounding the platform. The model assumes instantaneous mixing throughout the volume of water in the box and instantaneous equilibrium between radionuclides in the soluble phase and those adsorbed on particles suspended in the water column and on particles in the top sediment boundary layer. This is a very conservative assumption as the Ir-192 absorbed on the tracers is insoluble.

Where possible, site-specific parameters were substituted for generic values given in the IAEA technical document. These specific parameters are shown in the table below.

Specific Parameters			
Depth of Water Column	D	1.10E+03	meters
Volume of Seawater in Box	V	1.10E+11	m^3
Annual mass of material disposed	M	5.18E+05	kg
Average concentration of Ir-192	C	4.95E+04	Bq/kg
Number of disposal sites	N_{sites}	4.00E+01	sites
Density of seawater	ρ_w	1.05E+03	kg/m^3

When site-specific parameters were not available, the following recommended generic values were incorporated.

Generic Parameters			
Flux of water through region	F	4.00E+10	m^3/year
Radioactive decay constant Ir-192	λ_{rad}	4.93E+00	yr^{-1}
Thickness of boundary sediment layer in box	L_B	1.00E-02	m
Effective sediment thickness	d_s	1.00E-01	m
Bulk sediment and waste density	ρ_s, ρ_B	1.50E+03	kg/m^3
Suspended sediment concentration	S	3.00E-03	kg/m^3
Sediment Distribution Factor	K_d	1.00E+02	m3/kg
Dust loading on shore (kg/m^3)	DL_{shore}	2.30E-10	kg/m_3
Sea spray concentration in air (kg/m^3)	C_{spray}	1.20E-02	kg/m^3
Density of seawater (Kg/m^3)	ρ_w	1.05E+03	kg/m^3
Annual collective shore occupancy per unit length	$O_{coll,\ shore}$	5.00E+01	man-h/yr/m
Coastline length for one site	L_{shore}	1.00E+04	m
Annual fish catch in the area of a single site	N_B(fish)	5.00E+05	kg/year
Annual shellfish catch in the area of a single site	N_B(shellfish)	2.50E+05	kg/year
Fraction of fish utilized for human consumption	f_B(fish)	5.00E-01	
Fraction of shellfish utilized for human consumption	f_B(shellfish)	3.50E-01	

External and internal dose coefficients, concentration factors and inhalation and ingestion coefficients were taken from IAEA-TECDOC-1759, Appendix II, Tables 5 through 9.

The partitioning of radionuclides between water and sediment is described by element dependent sediment distribution coefficients, K_{ds}. Removal of radioactivity from the water column to seabed sediments due to scavenging processes is not considered.

Calculation of radionuclide concentrations in water, sediment, and edible marine biota

The following discussion sets out the procedural steps outlined in the IAEA's technical document for assessing the impact of disposing radioactive material at sea in conformance with the London Convention and London Protocol.

The three scenarios considered for this analysis are the redesigned, traditional and worst-case scenarios, as set forth above.

The activity concentration of a radionuclide in the box depends on the rate of input of the radionuclide to the box, its radioactive decay, and its dispersion. The rate constant due to dispersion, λ_{dis}, (in 1/yr) is the reciprocal of the mean residence time in the area of the platform and is obtained from the equation:

$$\lambda_{dis} = F / V$$

where:

V is the volume of seawater in the box (in m^3);
F is the average flux of water through the area of the platform (in m^3/yr).

The annual average input of activity of Iridium-192, Q (in Bq), is obtained from the equation:

$$Q = M \times C$$

where:

M is the annual mass of the reverse-out disposed of (in kg).
C is the average concentration of Iridium-192 in the reverse-out (in Bq/kg, dry weight).

The equilibrium concentration of Iridium-192 in the box, C_{BOX} (in Bq/m^3), is given by:

$$C_{box} = Q/(V*(\lambda_{rad} + \lambda_{dis}))$$

where:

λ_{rad} is the radioactive decay constant for Iridium-192 (in 1/yr).

The concentration C_{BOX} includes radioactivity in the dissolved phase of seawater and radioactivity associated with the suspended sediment particles and the sediment boundary layer. The concentration by volume of Iridium-192 in the dissolved phase of seawater, C_{DW} (in Bq/m^3), is given by:

$$C_{DW} = C_{box}/(1+K_d(S+(L_B*p_B/D))$$

where:

K_d is the sediment distribution coefficient for Iridium-192(in m^3/kg);
S is the suspended sediment concentration (in kg/m^3);
L_B is the thickness of the sediment boundary layer (in m);
ρ_B is the density of the sediment boundary layer (in kg/m^3);
D is the depth of the water column (m).
The concentration, by mass, in the suspended particles, C_P (in Bq/kg, dry weight), is obtained from the equation:

$$C_p = K_d*C_{DW}$$

The total concentration in seawater, C_W (in Bq/m^3), is given by:

$$C_w = (1+K_d*S) * C_{DW}$$

The activity concentration of Iridium-192 in marine biota is given by:

$$C_B = CR*(C_{DW}/p_w)$$

Transfer of radioactivity to edible marine biota is calculated from the concentration of dissolved radioactivity in the water using element dependent concentration factors for biological material. Radionuclide concentrations in edible parts of the marine biota k are obtained from the concentrations in the dissolved phase in seawater, C_{DW}, multiplied by the appropriate concentration factors (CFs):

$$C_{EB} = CF*C_{DW}$$

where:

C_{EB} (k) is the activity concentration of Iridium-192 in the edible fraction of marine biota k (in Bq/kg, fresh weight).
CF(k) is the concentration factor of Iridium-192 in edible marine biota k (in m^3/kg).

For the calculation of the external exposure from contaminated beach sediments, the radionuclide concentration in coastal sediment is assumed to be a factor of 10 lower than that in suspended particles in the water column. The surface contamination in the coastal sediment of Iridium-192, C_S (in Bq/m^2), is obtained from the equation:

$$Cs = (Cp*p_s*d_s)/10$$

where:

ρ_S is the density of coastal sediment (in kg/m3);
d_S is the effective thickness of coastal sediment (in m).

Airborne fine coastal sediment particles considered for the inhalation pathway are assumed to have characteristics similar to suspended particles in the water column. Airborne particles and marine suspended material are fine-grained. Therefore, no allowance for differences in grainsize distributions between such particles and marine suspended matter is warranted.

The annual intake of seawater, $AI_{seawater}$ (Bq/L), from recreational activities at the shoreline can be obtained from the equation:

$$AI_{seawater} = (C_{box}/1000) * (AS*.18)$$

where:

C_{box}/1000 is the concentration of Iridium-192 in seawater (Bq/L)
AS is the annual amount of seawater consumed during recreational activities (in L)
0.18 is the fractional amount of the year spent in the water (1/yr)

Calculation of individual doses to members of the public

According to the IAEA guidance, a practice may be exempted without further consideration provided the following criteria are met for all feasible considerations:

- The effective dose to any one individual is less than 10 µSv/year, or
- The annual collective dose does not exceed 1 man-Sievert.

The annual effective dose to members of the public from external exposure to radionuclides deposited on the shore, $E_{ext,\ public}$ (in Sv), can be calculated by:

$$E_{ext,\ public} = t_{public}*C_s*DC_{gr}$$

where:

t_{public} is the time spent by members of the public on the shore in a year (in h);
DC_{gr} is the dose coefficient for ground contamination of Iridium-192 in Sv/h per Bq/m^2);
C_S is the surface contamination of Iridium-192 in the shore sediments (in Bq/m^2).

The total annual effective dose from the ingestion of seafood, $E_{ing,\ food,\ public}$ (in Sv), can be calculated by:

$$E_{ing,\ food,\ public} = H_B*C_{EB}*DC_{ing}$$

where:

H_B (k) is the annual human consumption of seafood k (in kg);
DC_{ing} is the dose coefficient for ingestion of Irdiumm-192 (in Sv/Bq);
C_{EB} (k) is the concentration of Iridium-192 in the edible fraction of seafood k (in Bq/kg, fresh weight)

The annual dose from inadvertent ingestion of shore sediments, $E_{ing,\ shore,\ public}$ (in Sv), can be calculated by:

$$E_{ing\ shore,\ public} = t_{public}*H_{shore}*((C_s/(p_s*L_B) * DC_{ing})$$

where:

H shore is the hourly ingestion rate of beach sediment by humans (in kg/h).

The dose from inhalation of resuspended beach sediments, $E_{inh,\ shore,\ public}$ (in Sv) can be calculated using

$$E_{inh\ shore,\ public} = t_{public}*R_{inh,\ public}*DL_{shore}*C_p*DC_{inh}$$

where:

$R_{inh,\ public}$ is the inhalation rate of members of the public (in m^3/h);
DL_{shore} is the dust loading factor for beach sediments (in kg/m^3);
DC_{inh} is the dose coefficient for inhalation for iridium-192 (in Sv/Bq).

The annual dose to members of the public from inhalation of airborne sea spray on the shore, $E_{inh,\ spray,\ public}$ (in Sv/yr), can be calculated by:

$$E_{inh,\ spray,\ public} = t_{public}*R_{inh,public}*(C_{spray}/p_w)*C_w*DC_{inh}$$

where:

C_{spray} is the concentration of sea spray in the air (in kg/m^3);
ρ_W is the density of seawater (in kg/m^3);
C_W is the concentration of Iridium-192 in seawater (in Bq/m^3).

The annual dose to members of the public from ingestion of seawater on the shore, $E_{ing,\ seawater}$ (μSv/year) can be estimated from:

$$E_{ing,\ seawater} = AI_{seawater}*DC_{ing}$$

The total individual dose to a member of the public, $E_{ind,public}$ (in Sv), exposed to Iridium-192 released from materials disposed at sea, may be estimated as the sum of the dose contributions calculated

$$E_{ind,\ public} = E_{food}+E_{ing,shore}+E_{ihn,shore}+E_{inh,spray}+E_{ing,\ seawater}$$

Results and Analysis

Calculated results are set out in the following tables.

- Factors Calculated for Redesigned, Traditional and Worst-Case Scenarios
- Individual Doses Calculated for Redesigned, Traditional and Worst-Case Scenarios
- Collective Dose Calculated for Redesigned, Traditional and Worst-Case Scenarios

The calculated results show the annual doses to individuals and the collective doses are well below the IAEA's benchmark doses. Moreover, the calculated doses are very conservative for the following reasons:

- ZeroWash proppants are insoluble in water. Therefore, the assumption that there will be a soluble portion in the seawater box is very conservative.

- The model assumes consumption of fish and shellfish. At the locations of the offshore wells, 185 km from shore, commercial and recreational fishing is limited. Therefore, the generic estimated consumption of fish and shellfish that might have ingested proppants containing Ir-192 is overestimated.

- The calculated recreational dose due to swimming, shore contamination, sea spray and seawater ingestion are overestimated because the shoreline is not likely to be contaminated by discharges from platforms that are on average 185 km from shore.

Conclusion

Both the individual doses and the collective doses for all three scenarios are well below the IAEA limits. Results show that there is no significant impact on human health and safety from the discharge of small quantities of short-lived radioisotopes from tracer operations offshore in the Gulf of Mexico.

APPENDIX 5

Public Dose Calculation and Supporting Data
(Excel files)

Annual Intake (Bq) = average concentration (Bq/L) x annual intake (L)

AI =	1.87E-03	Bq/year
	2.49E-03	Bq/year
	2.89E-03	Bq/year

Annual Dose = Annual Intake (Bq) x Dose Conversion Factor (Sv/Bq)

Internal dose coefficient =	1.40E-09	Sv/Bq

Model	Dose				
Redesigned	2.62E-06	µSv/year	2.62E-07	mrem/year	2.62E-12
Current	3.49E-06	µSv/year	3.49E-07	mrem/year	3.49E-12
High	4.04E-06	µSv/year	4.04E-07	mrem/year	4.04E-12

E19. Datasets of activity concentration in drinking water collected by MHLW from May 2011 to April 2012 were used.

E20. Doses for each radionuclide were calculated as follows:

$$\text{Dose}_{DW}\,(\text{Sv}) = \sum_{\text{radionuclides}} \text{annual intake (Bq)} \times \text{dose coefficient}_{\text{ing}}$$

where the annual intake (AI) is determined by:

$$\text{Annual intake (Bq)} = \sum_{\text{weeks/months}} \text{average concentration (Bq/L)} \times \text{weekly or monthly intake (L)}$$

TABLE III.2A. WORKERS: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e(g)$ VIA INHALATION AND INGESTION (Sv/Bq) (cont.)

Radionuclide[a]	Physical half-life	Inhalation				Ingestion	
		Type	f_1	$e(g)_{1\,\mu m}$	$e(g)_{5\,\mu m}$	f_1	$e(g)$
Ir-189	13.3 d	F	0.010	1.1×10^{-10}	1.7×10^{-10}	0.010	2.4×10^{-10}
		M	0.010	4.8×10^{-10}	4.1×10^{-10}		
		S	0.010	5.5×10^{-10}	4.6×10^{-10}		
Ir-190	12.1 d	F	0.010	7.9×10^{-10}	1.2×10^{-9}	0.010	1.2×10^{-9}
		M	0.010	2.0×10^{-9}	2.3×10^{-9}		
		S	0.010	2.3×10^{-9}	2.5×10^{-9}		
Ir-190m	3.10 h	F	0.010	5.3×10^{-11}	9.7×10^{-11}	0.010	1.2×10^{-10}
		M	0.010	8.3×10^{-11}	1.4×10^{-10}		
		S	0.010	8.6×10^{-11}	1.4×10^{-10}		
Ir-190m'	1.20 h	F	0.010	3.7×10^{-12}	5.6×10^{-12}	0.010	8.0×10^{-12}
		M	0.010	9.0×10^{-12}	1.0×10^{-11}		
		S	0.010	1.0×10^{-11}	1.1×10^{-11}		
Ir-192	74.0 d	F	0.010	1.8×10^{-9}	2.2×10^{-9}	0.010	1.4×10^{-9}
		M	0.010	4.9×10^{-9}	4.1×10^{-9}		
		S	0.010	6.2×10^{-9}	4.9×10^{-9}		
Ir-192m	2.41×10^{2} a	F	0.010	4.8×10^{-9}	5.6×10^{-9}	0.010	3.1×10^{-10}
		M	0.010	5.4×10^{-9}	3.4×10^{-9}		
		S	0.010	3.6×10^{-8}	1.9×10^{-8}		
Ir-193m	11.9 d	F	0.010	1.0×10^{-10}	1.6×10^{-10}	0.010	2.7×10^{-10}
		M	0.010	1.0×10^{-9}	9.1×10^{-10}		
		S	0.010	1.2×10^{-9}	1.0×10^{-9}		

189

TABLE 5. RADIONUCLIDE DECAY CONSTANTS AND EFFECTIVE DOSE COEFFICIENTS FOR EXTERNAL AND INTERNAL EXPOSURE TO HUMANS

Radio-nuclide	Radioactive decay constant (1/a)	External dose coefficients (Sv/h per Bq/kg)		Internal dose coefficients (Sv/Bq)			
				Ingestion, DC_{ing}		Inhalation, DC_{inh}	
		Surface deposit, DC_{gr}	Material on ship, DC_{ship}	Infants (1–2 years)	Adults	Infants (1–2 years)	Adults
Artificial radionuclides							
Ag-110m	1.01×10^{0}	9.7×10^{-12}	5.4×10^{-11}	1.4×10^{-8}	2.8×10^{-9}	2.8×10^{-8}	7.6×10^{-9}
Am-241	1.60×10^{-3}	1.0×10^{-13}	0.0	3.7×10^{-7}	2.0×10^{-7}	6.9×10^{-5}	4.2×10^{-5}
Ca-45	1.55×10^{0}	1.7×10^{-16}	0.0	4.9×10^{-9}	7.1×10^{-10}	8.8×10^{-9}	2.7×10^{-9}
Ce-141	7.78×10^{0}	2.7×10^{-13}	6.3×10^{-14}	5.1×10^{-9}	7.1×10^{-10}	1.1×10^{-8}	3.2×10^{-9}
Ce-144	8.90×10^{-1}	6.6×10^{-13}	1.4×10^{-14}	3.9×10^{-8}	5.2×10^{-9}	1.6×10^{-7}	3.6×10^{-8}
Cl-36	2.30×10^{-6}	4.1×10^{-14}	0.0	6.3×10^{-9}	9.3×10^{-10}	2.6×10^{-8}	7.3×10^{-9}
Cm-242	1.55×10^{0}	3.8×10^{-15}	0.0	7.6×10^{-8}	1.2×10^{-8}	1.8×10^{-5}	5.2×10^{-6}
Cm-243	2.43×10^{-2}	4.6×10^{-13}	3.9×10^{-13}	3.3×10^{-7}	1.5×10^{-7}	6.1×10^{-5}	3.1×10^{-5}
Cm-244	3.83×10^{-2}	3.4×10^{-15}	0.0	2.9×10^{-7}	1.2×10^{-7}	5.7×10^{-5}	2.7×10^{-5}
Co-57	9.34×10^{-1}	4.2×10^{-13}	3.3×10^{-14}	1.6×10^{-9}	2.1×10^{-10}	2.2×10^{-9}	5.5×10^{-10}
Co-58	3.57×10^{0}	3.4×10^{-12}	1.8×10^{-11}	4.4×10^{-9}	7.4×10^{-10}	6.5×10^{-9}	1.6×10^{-9}
Co-60	1.32×10^{-1}	8.6×10^{-12}	6.2×10^{-11}	2.7×10^{-8}	3.4×10^{-9}	3.4×10^{-8}	1.0×10^{-8}
Cr-51	9.13×10^{0}	1.1×10^{-13}	2.1×10^{-13}	2.3×10^{-10}	3.8×10^{-11}	2.1×10^{-10}	3.7×10^{-11}
Cs-134	3.36×10^{-1}	5.6×10^{-12}	2.8×10^{-11}	1.6×10^{-8}	1.9×10^{-8}	7.3×10^{-9}	6.6×10^{-9}
Cs-137	2.31×10^{-2}	2.2×10^{-12}	8.0×10^{-12}	1.2×10^{-8}	1.3×10^{-8}	5.4×10^{-9}	4.6×10^{-9}
Fe-55	2.57×10^{-1}	0.0	0.0	2.4×10^{-9}	3.3×10^{-10}	1.4×10^{-9}	3.8×10^{-10}
Fe-59	5.68×10^{0}	4.1×10^{-12}	3.0×10^{-11}	1.3×10^{-8}	1.8×10^{-9}	1.3×10^{-8}	3.7×10^{-9}
Hg-203	5.43×10^{0}	8.5×10^{-13}	1.6×10^{-12}	1.1×10^{-8}	1.9×10^{-9}	7.9×10^{-9}	2.4×10^{-9}
I-125	4.21×10^{0}	1.6×10^{-13}	0.0	5.7×10^{-8}	1.5×10^{-8}	3.7×10^{-9}	5.6×10^{-10}
I-129	4.41×10^{-8}	9.5×10^{-14}	0.0	2.2×10^{-7}	1.1×10^{-7}	8.6×10^{-8}	3.6×10^{-8}
I-131	3.15×10^{1}	1.4×10^{-12}	4.5×10^{-12}	1.8×10^{-7}	2.2×10^{-8}	7.2×10^{-8}	7.4×10^{-9}
Ir-192	3.42×10^{0}	3.0×10^{-12}	8.3×10^{-12}	8.7×10^{-9}	1.4×10^{-9}	2.2×10^{-8}	6.6×10^{-9}

II.3.5.2. Time of exposure of members of the public on the shore, t_{public}

If site specific values for the time per year spent by members of the public on the shore are not available, it is recommended that 1600 h/a for adults and 1000 h/a for infants be used [26] (see Table 8).

According to Schets et al. (2011), the mean volume of water ingested by children (<15 years) during an average swimming pool event lasting 81 minutes was 51 mL or 0.63 mL/min (38 mL/hour). The values for children were slightly lower for swimming in freshwater and seawater. For adults, the mean volume of water ingested ranged from 0.5 to 0.6 mL/min (30 to 36 mL/hour) for men and 0.3 to 0.4 mL/min (20 to 26 mL/hour) for women (see Table 3-92).

Research highlights

► Less than 2% of limited-contact recreators at surface waters swallow a teaspoon or more of water.► Swimmers in a pool are 25–50 times more likely to swallow a teaspoon of water compared to limited-contact recreators at a pool.► Water ingestion during limited-contact recreation is determined in large part by whether or not capsize occurs.► Mean and upper confidence estimates of water ingestion are about 3–4 mL and 10–12 mL during limited-contact recreation at surface waters.► Mean and upper confidence estimates of water ingestion are about 10 mL and 35 mL during swimming at a pool.

Chapter 3—Ingestion of Water and Other Select Liquids

Table 3-92. Exposure Parameters for Swimmers in Swimming Pools, Freshwater, and Seawater

Parameter	Adults				Children <15 years	
	Men		Women			
	Mean	95% UCI	Mean	95% UCI	Mean	95% UCI
Swimming Duration (min)						
Swimming Pool	68	180	67	170	81	200
Freshwater	54	200	54	220	79	270
Seawater	45	160	41	180	65	240
Volume Water Swallowed (mL)						
Swimming Pool	34	170	23	110	51	200
Freshwater	27	140	18	86	37	170
Seawater	27	140	18	90	31	140

UCL = Upper confidence interval.

Source: Schets et al. (2011).

8760	365	0.18
1600	67	

adult	0.6 ml/min
chile	0.5

Table 3-93. Estimated Water Ingestion During Water Recreation Activities (mL/hr)

Activity	Surface Water Study				Swimming Pool Study			
	N	Median	Mean	UCL	N	Median	Mean	UCL
Limited Contact Scenarios								
Boating	316	2.1	3.7	11.2	0	-	-	-
Canoeing	766				76			
no capsize		2.2	3.8	11.4		2.1	3.6	11.0
with capsize		3.6	6.0	19.9		3.9	6.6	22.4
all activities		2.3	3.9	11.8		2.6	4.4	14.1
Fishing	600	2.0	3.6	10.8	121	2.0	3.5	10.6
Kayaking	801				104			
no capsize		2.2	3.8	11.4		2.1	3.6	10.9
with capsize		2.9	5.0	16.5		4.8	7.9	26.8
all activities		2.3	3.8	11.6		3.1	5.2	17.0
Rowing	222				0			
no capsize		2.3	3.9	11.8		-	-	-
with capsize		2.0	3.5	10.6		-	-	-
all activities		2.3	3.9	11.8		-	-	-
Wading/splashing	0	-	-	-	112	2.2	3.7	1.0
Walking	0	-	-	-	23	2.0	3.5	1.0
Full Contact Scenarios								
Immersion	0	-	-	-	112	3.2	5.1	15.3
Swimming	0	-	-	-	114	6.0	10.0	34.8
TOTAL	2,705				662			

N = Number of participants.
UCL = Upper confidence limit (i.e. mean +1.96 × standard deviation).
\- = No data.

Source: Dorevitch et al. (2011).

C_{box} =	3.30E-02	Bq/m^3
	4.39E-02	Bq/m^3
	5.08E-02	Bq/m^3

L/m^3 =	1.00E+03

C_{box} =	3.30E-05	Bq/L
	4.39E-05	Bq/L
	5.08E-05	Bq/L

Annual Intake seawater =	ml/min*min/yr*.18*L/ml =	5.68E+01	L/year

Effluent Discharge Limit per NRC is	1.00E-05	uCi/ml
Actual Discharge per Flush Pumped	2.53E-04	uCi/ml
Adjusted NRC limit	6.34E-04	µCi/ml

NRC Limit is based on	ALI for Ir-192	9.00E+02	µCi
	Dose correction from occupational to public	5.00E+01	
	Correction to cover all ages [	2.00E+00	
	Annual ingestion of drinking water	7.30E+05	ml/yr
Seawater ingestion	Seawater ingested per minute	2.70E+01	ml
	Time spent swimming	4.50E+01	minutes
	Time spent at beach per year	1.60E+03	hours
	Fractional time spent at beach 1600/8760	1.80E-01	
	Fraction time spent in water per year	2.50E-01	
Dose Limit	Annual public dose limit per NRC	1.00E-01	mrem
Seawater ingestion	Seawater ingestion ml per minute	6.00E-01	mi/min
	minutes per day	1440	min/day
	days per yesr	365	days/year
	Seawater ingestion per year	3.15E+05	ml/yr
	Fractional time spent at beach	0.180	
	Fraction time spent in water	0.250	
	Total seawater ingested	1.42E+04	ml/yr
Adjusted NRC limit	NRC limit based on seawater ingested	6.34E-04	

Seawater ingested per swim	27	ml
Total minutes swimming	45	minurtes

Individual Public Dose		
Reference Dose	1.00E+01	µSv/yr
Dose from External Exposure	9.58E-04	µSv/yr
Dose from Ingestion of Seafood	4.66E-07	µSv/yr
Dose from Ingestion of Beach Sediment	1.49E-07	µSv/yr
Dose from Inhalatio of Beach Sediment	2.97E-11	µSv/yr
Dose from Inhalation of Sea Spray	2.02E-08	µSv/yr
Total Individual Dose	9.58E-04	µSv/yr

Collective Public Dose		
Reference Dose	1.00E+00	man-Sv/year
Collective Dose from Exposure on shore	1.20E-05	man-Sv/year
Collefctive Dose from Seafood Consumption	0.00E+00	man-Sv/year
Total Collective Dose	1.20E-05	man-Sv/year

Individual Dose to the Public				
Concentration Factors				
The activity concentration of a radionuclide in the box depends on the rate of input of the radionuclide to the box, its radioactive decay and its dispersion. The rate constant due to dispersion, λ_{dis}, (in 1/a) is the reciprocal of the mean residence time in the coastal region and is obtained from the equation:				
λ_{dis} = F / V		3.63E-03		
The annual average input of activity of radionuclide j, Q(j) (in Bq), is obtained from the equation:				
Q = M x C		1.93E+10		
The equilibrium concentration of Ir-192 in the box volume is given by				
$C_{box} = Q/(V*(\lambda_{rad}+\lambda_{dis}))$		3.54E-04		
The concentration C_{BOX}(j) in the box includes radioactivity in the dissolved phase of seawater and radioactivity associated with the suspended sediment particles and the sediment boundary layer. The concentration by volume of radionuclide j in the dissolved phase of seawater, C_{DW}(j) (in Bq/m3), is given by:				
$C_{DW} = C_{box}/(1+K_d(S+(L_B*p_B/D))$		1.33E-04		
The concentration, by mass, in the suspended particles, CP obtained from the equation:				
$C_p = K_d*C_{dw}$		1.33E-02		
The total concentration in seawater, C_W, (in Bq/m3), is given by:				
$C_w = (1+K_d*S)*C_{DW}$		1.73E-04		
Activity concentration of radionuclide j in marine biota				
$C_B = CR*(C_{DW}/p_w)$				
$C_B = CR*(C_{DW}/p_w)$ (fish)		2.54E-06		
$C_B = CR*(C_{DW}/p_w)$ (shellfish)		1.27E-05		
Transfer of radioactivity to edible marine biota is calculated from the concentration of dissolved radioactivity in the water using element dependent concentration factors for biological material. Radionuclide concentrations in edible parts of the marine biota k are obtained from the concentrations in the dissolved phase in seawater, CDW(j), multiplied by the appropriate concentration factors (CFs):				
$C_{EB} = C_F*C_{DW}$				
$C_{EB} = CF(fish)*C_{DW}$		2.66E-06		
$C_{EB} = CF(crab)*C_{DW}$		1.33E-05		
$C_{EB} = CF(oyster)*C_{DW}$		1.33E-05		
For the calculation of the external exposure from contaminated beach sediments the radionuclide concentration in coastal sediment is assumed to be a factor of 10 lower than that in suspended particles in the water column [16]. The surface contamination in the coastal sediment of radionuclide j, C_S(j) (in Bq/m2), is obtained from the equation (25):				
$C_s = (C_p*p_s*d_s)/10$		2.00E-01		
Dose Calculation				
Dose from External Exposure				
$E_{ext,\ public} = t_{public}*C_s*DC_{gr}$		9.58E-10	9.58E-05	mrem/yr
Dose from Ingestion of Seafood				
$E_{ing,\ food,\ public} = H_B*C_{EB}*DC_{ing}$				
$E_{ing,\ food,\ public} = H_B*C_{EB}*DC_{ing}$ - fish		1.86E-13	1.86E-08	mrem/yr
$E_{ing,\ food,\ public} = H_B*C_{EB}$*DCing - shell fish		2.79E-13	2.79E-08	mrem/yr
Dose from ingestion of Beach Sediment				
$E_{ing\ shore,\ public} = t_{public}*H_{shore}*((C_s/(p_s*L_B)*DC_{ing})$		1.49E-13	1.49E-08	mrem/yr
Dose from inhalation of Beach Sediment				
$E_{inh\ shore,\ public} = t_{public}*R_{inh,\ public}*D_{lshore}*C_p*DC_{inh}$		2.97E-17	2.97E-12	mrem/yr
Dose from Inhalation of Sea Spray				
$E_{inh,\ spray,\ public} = t_{public}*R_{inh,public}*(C_{spray}/p_w)*Cw*DC_{inh}$		2.02E-14	2.02E-09	mrem/yr
Total Individual Dose to Members of the Public				
$E_{ind,\ public} = E_{food}+E_{ing,shore}+E_{ihn,shore}+E_{inh,spray}$		9.58E-10	9.58E-05	mrem/year
Reference Dose, if cell D58 ≤ 10 uSv acceptable, if >10 uSv not acceptable; If cell F58 ≤ 1 mrem acceptable, if > 1 mrem not acceptable.		10	1	mrem/year

4.66E-13

Collective Public Dose					
The collective dose to members of the public is the combination of collective doses from exposures on the shore and the consumption of seafood.					
Collective Dose from Exposure on Shore					
$E_{coll,\ shore,\ public} = (E_{ext,\ public} + E_{inh\ shore,\ public} + E_{inh\ spray,\ public}) * ((O_{coll,\ public} * L_{shore} * N_{sites})/t_{public})$		1.20E-05	man-Sv/year		
Collective Dose from Seafood Consumption					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DC_{ing}$					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (fish)		3.56E-08	man-Sv/year		
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (shellfish)		6.23E-08	man-Sv/year		
Total Collective Dose					
$E_{coll,public} = E_{coll\ shore,\ pubic} + E_{coll\ ing,\ public}$		1.21E-05	man-Sv/year	1.21E-03	man-rem/year
Reference Dose, if cell D19 ≤ D21 acceptable, if D19 > D21 not acceptable; If cell F19 ≤ F21 acceptable, if > F21 not acceptable.		1	man-Sv/year	100	man-rem/year

Specific Parameters			
Depth of Water Column	D	1.10E+03	meters
Volume of Seawater in Box	V	1.10E+13	m^3
Annual mass of material disposed	M	5.17E+05	kg
Avg concentration of Ir-192	C	3.72E+04	Bq/kg
Number of dump sites	N_{sites}	4.00E+01	sites
Density of seawater	ρ_w	1.05E+03	kg/m3

Generic Parameters			
Flux of water through region	F	4.00E+10	m^3/year
Radioactive decay constant Ir-192	λ_{rad}	4.93E+00	$year^{-1}$
Thickness of boundary sediment layer in box	L_B	1.00E-02	m
Effective sediment thickness	d_s	1.00E-01	m
Bulk sediment and waste density	ρ_s, ρ_B	1.50E+03	kg/m3
Suspended sediment concentration	S	3.00E-03	kg/m3
Sediment Distribution Factor	K_d	1.00E+02	m3/kg
Dust loading on shore (kg/m3)	DL_{shore}	2.30E-10	kg/m3
Seaspray concentration in air (kg/m3)	C_{spray}	1.20E-02	kg/m3
Density of seawater (Kg/m^3)	ρ_w	1.05E+03	kg/m3
Annual collective shore occupancy per unit length	$O_{coll, shore}$	5.00E+01	man-h/yr/m
Coastline length for one site	L_{shore}	1.00E+04	m
Annual fish catch in the area of a single site	N_B(fish)	5.00E+05	kg/year
Annual shellfish catch in the area of a single site	N_B(shellfish)	2.50E+05	kg/year
Fraction of fish utilized for human consumption	f_B(fish)	5.00E-01	
Fraction of shellfish utilized for human consumption	f_B(shellfish)	3.50E-01	

Element	Concentration Factor			Concentration Ratio		
	(m3/kg)			(Bq/Kg per Bq/Kg)		
	CF			CR		
	Fish	Crustracean	Mollusc	Flatfish	Shellfish	Seaweed
Iridium	2.00E-02	1.00E-01	1.00E-01	2.00E+01	1.00E+02	1.00E+03

External dose coefficients		Internal dose coefficients			
(Sv/h per Bq/kg)		(Sv/Bq)			
DC_{gr}	DC_{ship}	DC_{ing}		DC_{inh}	
		Infants	Adults	Infants	Adults
3.00E-12	8.30E-12	8.70E-09	1.40E-09	2.20E-09	6.60E-09

Public				
Annual time spent on sediments on shore	t_{public}	1.60E+03	1.00E+03	hours
Public breathing rate	$R_{inh, public}$	9.20E-01	2.20E-01	m3/hour
Annual ingestion of fish	H_B(fish)	5.00E+01	2.50E+01	Kg
Annual ingestion of shellfish	H_B(shellfish)	1.50E+01	0.00E+00	Kg
Ingestion rate of sediment on beach	H_{shore}	5.00E-06	3.00E-05	Kg/hour

Conversions	
mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

Average Summary Frac Jobs YTD Jan-Sep 2nd (20 Wells) - Redesigned to 0.454 mCi/k

Tracers			SI Units	
Sc-46 1st Tracing (Avg)				
Proppant Traced Sc-46	48,111	lbs	2.17E+04	kg
Sc-46 Total Injected	23	mCi	8.69E+08	Bq
Conc. Sc-46 mCi	0	mCi/k lbs proppant		
Sc-46 pCi	1,092	pCi/gm		
Ir-192 2nd Tracing (Avg)				
Proppant Traced Ir-192	97,585	lbs	4.39E+04	kg
Ir-192 Total Injected	42	mCi	1.56E+09	Bq
Conc. Ir-192 mCi	0.454	mCi/k lbs proppant		
Ir-192 pCi	1,336	pCi/gm		
Total Proppant Traced (Avg)	141,010	lbs	6.35E+04	kg
Total Ir-192 & Sc-46	65.681	mCi	2.43E+09	Bq
Material Returned to Surface (Avg)				
Proppant Reversed-out	28,733	lbs	1.29E+04	kg
Reverse-out Ir-192	13.052	mCi	4.83E+08	Bq
Flush Pumped	475.35	bbl		

Concentrations (Avg)				
Reverse-out Ir-192	1.31E+01	mCi	4.83E+08	Bq
Reverse-out Ir-192	1.31E+04	µCi	4.83E+08	Bq
Reverse-out Ir-192	1.73E-04	µCi/ml		

Well & Job Data (Avg)				
Well Depth	3620	ft	1.09E+03	m
Well Depth	1103	meters	1.10E+03	m
Distance to Shore	102	miles	1.64E+02	km
Pumping Time Minutes	707	min		
Pumping Time Hours	12	hr		

Est. Jobs/Year # 40

Tracers			SI Units	
Sc-46 1st Tracing (Total)				
Proppant Traced Sc-46	1,924,459	lbs	8.66E+05	kg
Sc-46 Total Injected	939	mCi	3.48E+10	Bq
Conc. Sc-46 mCi	0.488	mCi/k lbs proppant		
Sc-46 pCi	1,092	pCi/gm		
Ir-192 2nd Tracing (Total)				
Proppant Traced Ir-192	3,903,396	lbs.	1.76E+06	kg
Ir-192 Total Injected	1,688	mCi	6.25E+10	Bq
Conc. Ir-192 mCi	0.454	mCi/k lbs proppant	3.72E+04	Bq/kg
Ir-192 pCi	1,335.976	pCi/gm		
Total Proppant Traced (Avg)	5,640,394	lbs	2.54E+06	kg
Total Ir-192 & Sc-46	65.681			
Material Returned to Surface (Total)				
Proppant Reversed-out	1,149,338	lbs	5.17E+05	kg
Reverse-out Ir-192	522	mCi	1.93E+10	Bq
Flush Pumped	19,014	bbl		

Well & Job Data (Total)		
Well Depth	144784	ft
Well Depth	44130	meters
Distance to Shore	4066	miles
Pumping Time Minutes	28267	min
Pumping Time Hours	471	hr

Conversions

mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

**Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118

Last 10-20-30 Jobs conducted from Broussard, LA

	Date	API #	Depth (ft)	Depth (m)	Pumping Time (min)	Pumping Time (Hours)	Surface Latitude	Surface Longitude	Miles to Shore**	Amount Traced Sc-46	Sc-46 (mCi)	Conc. Sc-46 (mCi/k)	Sc-46 Picocuries/gram	Amount Traced Ir-192	Ir-192 (mCi)	Conc. Ir-192 (mCi/k)	Ir-192 Picocuries/gram	Total Picocuries/gram	Total Proppant	Reverse-out Pounds	Reverse-out Ir-192 (mCi) *	Flush pumped bbl.	Flush Pumped ml	µCi	µCi/ml
1	1/1/2022	608114067901	3604	1098.5	564.57	9.41	27.56045503	-90.10466997	101	36,269	18	0.496	1094.137	89071	53	0.595	1311.820	1248.830	125,340	8,314	4.95E+00	533	8.47E+07	4.95E+03	5.84E-05
2	1/7/2022	608164029901	1290	393.192	295.5	4.93	28.97308168	-88.62599537	74	26,700	13	0.487	1073.413	105600	63	0.597	1315.259	1266.451	132,300	13,879	8.28E+00	170	2.70E+07	8.28E+03	3.06E-04
3	3/5/2022	608114068801	3603	1098.19	815.58	13.59	27.56045859	-90.10493052	101	33,604	17	0.506	1115.302	110973	67	0.604	1331.043	1280.898	144,577	8,694	5.25E+00	578	9.19E+07	5.25E+03	5.71E-05
4	3/7/2022	608164035601	1290	393.192	226.39	3.77	28.97302946	-88.62599143	74	24,662	12	0.487	1072.723	100529	60	0.597	1315.814	1267.926	125,191	21,064	1.26E+01	176	2.80E+07	1.26E+04	4.49E-04
5	3/10/2022	608114008703	760	231.648	341.41	5.69	27.94369889	-91.0291754	95	36,827	18	0.489	1077.558	167676	101	0.602	1327.960	1282.868	204,503	24,772	1.49E+01	174	2.77E+07	1.49E+04	5.39E-04
6	3/29/2022	608104016400	1570	478.536	374.9	6.25	28.07837889	-89.98232167	69	31,875	16	0.502	1106.635	70054	42	0.600	1321.755	1254.483	101,929	31,608	1.90E+01	182	2.89E+07	1.90E+04	6.55E-04
7	4/1/2022	608114071200	4958	1511.2	322.71	5.38	27.15409583	-90.30964083	126	93,605	47	0.502	1106.964	139951	84	0.600	1323.238	1236.559	233,556	89,075	5.35E+01	539	8.57E+07	5.35E+04	6.24E-04
8	4/11/2022	608114071200	4958	1511.2	181.32	3.02	27.15409583	-90.30964083	126	42,375	21	0.496	1092.557	57750	35	0.606	1336.136	1233.048	100,125	33,145	2.01E+01	530	8.43E+07	2.01E+04	2.38E-04
9	4/19/2022	608114074802	3606	1099.11	784.43	13.07	27.56100318	-90.10413894	101	34,260	17	0.496	1093.947	90378	63	0.697	1536.783	1415.058	124,638	12,289	8.57E+00	489	7.77E+07	8.57E+03	1.10E-04
10	4/19/2022	608174142901	3223	982.37	265.1	4.42	28.47060823	-88.9400004	72	80,992	40	0.494	1088.811	123511	74	0.599	1320.872	1228.966	204,503	42,258	2.53E+01	421	6.69E+07	2.53E+04	3.78E-04
11	4/25/2022	608114074802	3606	1099.11	754.13	12.57	27.56100318	-90.10413894	101	22,000	11	0.500	1102.312	66743	40	0.599	1321.262	1266.983	88,743	4,656	2.79E+00	498	7.92E+07	2.79E+03	3.52E-05
12	5/7/2022	608114065800	4979	1517.6	311.55	5.19	27.14571806	-90.319515	126	46,724	23	0.492	1085.232	122335	73	0.597	1315.548	1251.894	169,059	26,077	1.56E+01	603	9.59E+07	1.56E+04	1.62E-04
13	5/23/2022	608114071900	4987	1520.04	311.55	5.19	27.14567167	-90.31935528	126	42,375	21	0.496	1092.557	62322	37	0.594	1308.865	1221.317	104,697	26,697	1.58E+01	595	9.46E+07	1.58E+04	1.68E-04
14	6/4/2022	608114068000	3788	1154.58	1207.42	20.12	27.49509917	-90.06402528	104	33,000	17	0.515	1135.716	57033	34	0.596	1314.278	1248.829	90,033	30,381	1.81E+01	621	9.87E+07	1.81E+04	1.83E-04
15	6/6/2022	60812400680	5190	1581.91	969.75	16.16	26.93265556	-90.520285	141	67,301	34	0.505	1113.761	55322	33	0.597	1315.075	1204.585	122,623	4,457	2.66E+00	571	9.08E+07	2.66E+03	2.93E-05
16	6/11/2022	608114068000	3788	1154.58	924.1	15.40	27.49509917	-90.06402528	104	45,151	23	0.509	1123.040	121582	73	0.600	1323.696	1269.358	166,733	4,416	2.65E+00	547	8.70E+07	2.65E+03	3.05E-05
17	7/16/2022	608174120900	3036	925.373	1109.54	18.49	28.15991111	-89.23903278	76	23,326	12	0.514	1134.163	142095	85	0.598	1318.787	1292.753	165,421	95,629	5.72E+01	99	1.57E+07	5.72E+04	3.63E-03
18	7/18/2022	608114068901	3760	1146.05	1522.16	25.37	27.49786711	-90.06045106	104	52,657	26	0.494	1088.559	123505	74	0.599	1320.936	1251.476	176,162	14,776	8.85E+00	529	8.41E+07	8.85E+03	1.05E-04
19	8/15/2022	608174108401	6946	2117.14	1857.18	30.95	28.30785016	-88.20155808	110	106,000	46	0.434	956.724	93500	56	0.599	1320.417	1127.176	199,500	80,914	4.85E+01	135	2.15E+07	4.85E+04	2.26E-03
20	9/2/2022	608114074701	3450	1051.56	994.05	16.57	27.53643558	-90.16512122	102	26,360	13	0.493	1087.258	51768	31	0.599	1320.185	1241.597	78,128	2,219	1.33E+00	640	1.02E+08	1.33E+03	1.31E-05
21																									
22																									
23																									
24																									
25																									
26																									
27																									
	Averages		**3,620**	1103.25	**707**	**11.78**			**102**	**45,303**	**22**	**0.491**	**1,092**	**97,585**	**59**	**0.604**	**1,331**	**1,255**	**142,888**	**28,766**	**1.74E+01**	**432**	**6.86E+07**	**1.74E+04**	**2.53E-04**

* Ir-192 is always pumped after the Sc-46 and should be the only tracer remaining above the crossover.
**Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118

For redesigned job at .454 mCi/k pounds of proppant																							
		3,620	1103.25	**707**	11.78			**102**	**48,111**	**23**	**0.488**	**1,092**	**92,898**	**42.2**	**0.454**	**1,336**	**1,252**	**141,010**	**28,733**	**1.31E+01**	**475**	**7.56E+07**	**1.31E+04**	**1.73E-04**

Individual Public Dose		
Reference Dose	1.00E+01	µSv/yr
Dose from External Exposure	1.27E-03	µSv/yr
Dose from Ingestion of Seafood	0.00E+00	µSv/yr
Dose from Ingestion of Beach Sediment	1.98E-07	µSv/yr
Dose from Inhalatio of Beach Sediment	3.95E-11	µSv/yr
Dose from Inhalation of Sea Spray	2.68E-08	µSv/yr
Total Individual Dose	1.27E-03	µSv/yr

Collective Public Dose		
Reference Dose	1.00E+00	man-Sv/year
Collective Dose from Exposure on shore	1.59E-05	man-Sv/year
Collefctive Dose from Seafood Consumption	0.00E+00	man-Sv/year
Total Collective Dose	1.59E-05	man-Sv/year

Individual Dose to the Public				
<u>Concentration Factors</u>				
The activity concentration of a radionuclide in the box depends on the rate of input of the radionuclide to the box, its radioactive decay and its dispersion. The rate constant due to dispersion, λ_{dis}, (in 1/a) is the reciprocal of the mean residence time in the coastal region and is obtained from the equation:				
$\lambda_{dis} = F / V$		3.63E-03		
The annual average input of activity of radionuclide j, Q(j) (in Bq), is obtained from the equation:				
$Q = M \times C$		2.56E+10		
The equilibrium concentration of Ir-192 in the box volume is given by				
$C_{box} = Q/(V^*(\lambda_{rad}+\lambda_{dis}))$		4.71E-04		
The concentration C_{BOX}(j) in the box includes radioactivity in the dissolved phase of seawater and radioactivity associated with the suspended sediment particles and the sediment boundary layer. The concentration by volume of radionuclide j in the dissolved phase of seawater, C_{DW}(j) (in Bq/m3), is given by:				
$C_{DW} = C_{box}/(1+K_d(S+(L_B{}^*p_B/D))$		1.77E-04		
The concentration, by mass, in the suspended particles, CP obtained from the equation:				
$C_p = K_d{}^*C_{dw}$		1.77E-02		
The total concentration in seawater, C_W, (in Bq/m3), is given by:				
$C_w = (1+K_d{}^*S)^*C_{DW}$		2.30E-04		
Activity concentration of radionuclide j in marine biota				
$C_B = CR^*(C_{DW}/p_w)$				
$C_B = CR^*(C_{DW}/p_w)$ (fish)		3.38E-06		
$C_B = CR^*(C_{DW}/p_w)$ (shellfish)		1.69E-05		
Transfer of radioactivity to edible marine biota is calculated from the concentration of dissolved radioactivity in the water using element dependent concentration factors for biological material. Radionuclide concentrations in edible parts of the marine biota k are obtained from the concentrations in the dissolved phase in seawater, CDW(j), multiplied by the appropriate concentration factors (CFs):				
$C_{EB} = C_F{}^*C_{DW}$				
$C_{EB} = CF(fish)^*C_{DW}$		3.54E-06		
$C_{EB} = CF(crab)^*C_{DW}$		1.77E-05		
$C_{EB} = CF(oyster)^*C_{DW}$		1.77E-05		
For the calculation of the external exposure from contaminated beach sediments the radionuclide concentration in coastal sediment is assumed to be a factor of 10 lower than that in suspended particles in the water column [16]. The surface contamination in the coastal sediment of radionuclide j, C_S(j) (in Bq/m2), is obtained from the equation (25):				
$C_s = (C_p{}^*p_s{}^*d_s)/10$		2.65E-01		
<u>Dose Calculation</u>				
Dose from External Exposure				
$E_{ext,\ public} = t_{public}{}^*C_s{}^*DC_{gr}$		1.27E-09	1.27E-04	mrem/yr
Dose from Ingestion of Seafood				
$E_{ing,\ food,\ public} = H_B{}^*C_{EB}{}^*DC_{ing}$				
$E_{ing,\ food,\ public} = H_B{}^*C_{EB}{}^*DC_{ing}$ - fish		2.48E-13	2.48E-08	mrem/yr
$E_{ing,\ food,\ public} = H_B{}^*C_{EB}{}^*$DCing - shell fish		3.72E-13	3.72E-08	mrem/yr
Dose from ingestion of Beach Sediment				
$E_{ing\ shore,\ public} = t_{public}{}^*H_{shore}{}^*((C_s/(p_s{}^*L_B)^*DC_{ing})$		1.98E-13	1.98E-08	mrem/yr
Dose from inhalation of Beach Sediment				
$E_{inh\ shore,\ public} = t_{public}{}^*R_{inh,\ public}{}^*D_{lshore}{}^*C_p{}^*DC_{inh}$		3.95E-17	3.95E-12	mrem/yr
Dose from Inhalation of Sea Spray				
$E_{inh,\ spray,\ public} = t_{public}{}^*R_{inh,public}{}^*(C_{spra}y/p_w)^*Cw^*DC_{inh}$		2.68E-14	2.68E-09	mrem/yr
Total Individual Dose to Members of the Public				
$E_{ind,\ public} = E_{food}+E_{ing,shore}+E_{ihn,shore}+E_{inh,spray}$		1.27E-09	1.27E-04	mrem/year
Reference Dose, if cell D58 ≤ 10 uSv acceptable, if >10 uSv not acceptable; If cell F58 ≤ 1 mrem acceptable, if > 1 mrem not acceptable.		10	1	mrem/year

Collective Public Dose					
The collective dose to members of the public is the combination of collective doses from exposures on the shore and the consumption of seafood.					
Collective Dose from Exposure on Shore					
$E_{coll,\ shore,\ public} = (E_{ext,\ public} + E_{inh\ shore,\ public} + E_{inh\ spray,\ public}) * ((O_{coll,\ public} * L_{shore} * N_{sites})/t_{public})$		1.59E-05	man-Sv/year		
Collective Dose from Seafood Consumption					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DC_{ing}$					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (fish)		4.74E-08	man-Sv/year		
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (shellfish)		8.29E-08	man-Sv/year		
Total Collective Dose					
$E_{coll,public} = E_{coll\ shore,\ pubic} + E_{coll\ ing,\ public}$		1.61E-05	man-Sv/year	1.61E-03	man-rem/year
Reference Dose, if cell D19 ≤ D21 acceptable, if D19 > D21 not acceptable; If cell F19 ≤ F21 acceptable, if > F21 not acceptable.		1	man-Sv/year	100	man-rem/year

Specific Parameters			
Depth of Water Column	D	1.10E+03	meters
Volume of Seawater in Box	V	1.10E+13	m^3
Annual mass of material disposed	M	5.18E+05	kg
Avg concentration of Ir-192	C	4.95E+04	Bq/kg
Number of dump sites	N_{sites}	4.00E+01	sites
Density of seawater	ρ_w	1.05E+03	kg/m3

Generic Parameters			
Flux of water through region	F	4.00E+10	m^3/year
Radioactive decay constant Ir-192	λ_{rad}	4.93E+00	$year^{-1}$
Thickness of boundary sediment layer in box	L_B	1.00E-02	m
Effective sediment thickness	d_s	1.00E-01	m
Bulk sediment and waste density	ρ_s, ρ_B	1.50E+03	kg/m3
Suspended sediment concentration	S	3.00E-03	kg/m3
Sediment Distribution Factor	K_d	1.00E+02	m3/kg
Dust loading on shore (kg/m3)	DL_{shore}	2.30E-10	kg/m3
Seaspray concentration in air (kg/m3)	C_{spray}	1.20E-02	kg/m3
Density of seawater (Kg/m^3)	ρ_w	1.05E+03	kg/m3
Annual collective shore occupancy per unit length	$O_{coll, shore}$	5.00E+01	man-h/yr/m
Coastline length for one site	L_{shore}	1.00E+04	m
Annual fish catch in the area of a single site	N_B(fish)	5.00E+05	kg/year
Annual shellfish catch in the area of a single site	N_B(shellfish)	2.50E+05	kg/year
Fraction of fish utilized for human consumption	f_B(fish)	5.00E-01	
Fraction of shellfish utilized for human consumption	f_B(shellfish)	3.50E-01	

Element	Concentration Factor			Concentration Ratio		
	(m3/kg)			(Bq/Kg per Bq/Kg)		
	CF			CR		
	Fish	Crustacean	Mollusc	Flatfish	Shellfish	Seaweed
Iridium	2.00E-02	1.00E-01	1.00E-01	2.00E+01	1.00E+02	1.00E+03

External dose coefficients		Internal dose coefficients			
(Sv/h per Bq/kg)		(Sv/Bq)			
DC_{gr}	DC_{ship}	DC_{ing}		DC_{inh}	
		Infants	Adults	Infants	Adults
3.00E-12	8.30E-12	8.70E-09	1.40E-09	2.20E-09	6.60E-09

Public				
Annual time spent on sediments on shore	t_{public}	1.60E+03	1.00E+03	hours
Public breathing rate	$R_{inh, public}$	9.20E-01	2.20E-01	m3/hour
Annual ingestion of fish	H_B(fish)	5.00E+01	2.50E+01	Kg
Annual ingestion of shellfish	H_B(shellfish)	1.50E+01	0.00E+00	Kg
Ingestion rate of sediment on beach	H_{shore}	5.00E-06	3.00E-05	Kg/hour

Conversions	
mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

Average Summary Frac Jobs YTD Jan-Sep 2nd (20 Wells)

Est. Jobs/Year # 40

Tracers			SI Units	
Sc-46 1st Tracing (Avg)				
Proppant Traced Sc-46	45,303	lbs	2.04E+04	kg
Sc-46 Total Injected	22.250	mCi	8.23E+08	Bq
Conc. Sc-46 mCi	0.491	mCi/k lbs proppant		
Sc-46 pCi	1,092.068	pCi/gm		
Ir-192 2nd Tracing (Avg)				
Proppant Traced Ir-192	97,585	lbs	4.39E+04	kg
Ir-192 Total Injected	58.900	mCi	2.18E+09	Bq
Conc. Ir-192 mCi	0.604	mCi/k lbs proppant		
Ir-192 pCi	1,330.986	pCi/gm		
Total Proppant Traced (Avg)	142,888	lbs	6.43E+04	kg
Total Ir-192 & Sc-46	81.150	mCi	3.00E+09	Bq
Material Returned to Surface (Avg)				
Proppant Reversed-out	28,766	lbs	1.29E+04	kg
Reverse-out Ir-192	17.362	mCi	6.42E+08	Bq
Flush Pumped	431.50	bbl		
Concentrations (Avg)				
Reverse-out Ir-192	1.74E+01	mCi	6.42E+08	Bq
Reverse-out Ir-192	1.74E+04	µCi	6.42E+08	Bq
Reverse-out Ir-192	2.53E-04	µCi/ml		
Well & Job Data (Avg)				
Well Depth	3619.6	ft	1.09E+03	m
Well Depth	1103.25	meters	1.10E+03	m
Distance to Shore	101.65	miles	1.64E+02	km
Pumping Time Minutes	706.67	min		
Pumping Time Hours	11.78	hr		

**Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118

Tracers			SI Units	
Sc-46 1st Tracing (Total)				
Proppant Traced Sc-46	1,812,126	lbs	8.15E+05	kg
Sc-46 Total Injected	890	mCi	3.29E+10	Bq
Conc. Sc-46 mCi	0.491	mCi/k lbs proppant		
Sc-46 pCi	1,092	pCi/gm		
Ir-192 2nd Tracing (Total)				
Proppant Traced Ir-192	3,903,396	lbs.	1.76E+06	kg
Ir-192 Total Injected	2,356	mCi	8.72E+10	Bq
Conc. Ir-192 mCi	0.604	mCi/k lbs proppant	4.95E+04	Bq/kg
Ir-192 pCi	1,330.986	pCi/gm		
Total Proppant Traced (Avg)	5,715,522	lbs	2.57E+06	kg
Total Ir-192 & Sc-46	81.150			
Material Returned to Surface (Total)				
Proppant Reversed-out	1,150,640	lbs	5.18E+05	kg
Reverse-out Ir-192	694	mCi	2.57E+10	Bq
Flush Pumped	17,260	bbl		
Well & Job Data (Total)				
Well Depth	144784	ft		
Well Depth	44130	meters		
Distance to Shore	4066	miles		
Pumping Time Minutes	28267	min		
Pumping Time Hours	471	hr		

Conversions

mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

Last 10-20-30 Jobs conducted from Broussard, LA

	Date	API #	Depth (ft)	Depth (m)	Pumping Time (min)	Pumping Time (Hours)	Surface Latitude	Surface Longitude	Miles to Shore**	Amount Traced Sc-46	Sc-46 (mCi)	Conc. Sc-46 (mCi/k)	Sc-46 Picocuries/gram	Amount Traced Ir-192	Ir-192 (mCi)	Conc. Ir-192 (mCi/k)	Ir-192 Picocuries/gram	Total Picocuries/gram	Total Proppant	Reverse-out Pounds	Reverse-out Ir-192 (mCi) *	Flush pumped bbl.	Flush Pumped ml	µCi	µCi/ml
1	1/1/2022	608114067901	3604	1098.5	564.57	9.41	27.560455	-90.10466997	101	36,269	18	0.496	1094.137	89071	53	0.595	1311.820	1248.830	125,340	8,314	4.95E+00	533	8.47E+07	4.95E+03	5.84E-05
2	1/7/2022	608164029901	1290	393.192	295.5	4.93	28.9730817	-88.62599537	74	26,700	13	0.487	1073.413	105600	63	0.597	1315.259	1266.451	132,300	13,879	8.28E+00	170	2.70E+07	8.28E+03	3.06E-04
3	3/5/2022	608114068801	3603	1098.19	815.58	13.59	27.5604586	-90.10493052	101	33,604	17	0.506	1115.302	110973	67	0.604	1331.043	1280.898	144,577	8,694	5.25E+00	578	9.19E+07	5.25E+03	5.71E-05
4	3/7/2022	608164035601	1290	393.192	226.39	3.77	28.9730295	-88.62599143	74	24,662	12	0.487	1072.723	100529	60	0.597	1315.814	1267.926	125,191	21,064	1.26E+01	176	2.80E+07	1.26E+04	4.49E-04
5	3/10/2022	608114008703	760	231.648	341.41	5.69	27.9436989	-91.0291754	95	36,827	18	0.489	1077.558	167676	101	0.602	1327.960	1282.868	204,503	24,772	1.49E+01	174	2.77E+07	1.49E+04	5.39E-04
6	3/29/2022	608104016400	1570	478.536	374.9	6.25	28.0783789	-89.98232167	69	31,875	16	0.502	1106.635	70054	42	0.600	1321.755	1254.483	101,929	31,608	1.90E+01	182	2.89E+07	1.90E+04	6.55E-04
7	4/1/2022	608114071200	4958	1511.2	322.71	5.38	27.1540958	-90.30964083	126	93,605	47	0.502	1106.964	139951	84	0.600	1323.238	1236.559	233,556	89,075	5.35E+01	539	8.57E+07	5.35E+04	6.24E-04
8	4/11/2022	608114071200	4958	1511.2	181.32	3.02	27.1540958	-90.30964083	126	42,375	21	0.496	1092.557	57750	35	0.606	1336.136	1233.048	100,125	33,145	2.01E+01	530	8.43E+07	2.01E+04	2.38E-04
9	4/19/2022	608114074802	3606	1099.11	784.43	13.07	27.5610032	-90.10413894	101	34,260	17	0.496	1093.947	90378	63	0.697	1536.783	1415.058	124,638	12,289	8.57E+00	489	7.77E+07	8.57E+03	1.10E-04
10	4/19/2022	608174142901	3223	982.37	265.1	4.42	28.4706082	-88.9400004	72	80,992	40	0.494	1088.811	123511	74	0.599	1320.872	1228.966	204,503	42,258	2.53E+01	421	6.69E+07	2.53E+04	3.78E-04
11	4/25/2022	608114074802	3606	1099.11	754.13	12.57	27.5610032	-90.10413894	101	22,000	11	0.500	1102.312	66743	40	0.599	1321.262	1266.983	88,743	4,656	2.79E+00	498	7.92E+07	2.79E+03	3.52E-05
12	5/7/2022	608114065800	4979	1517.6	311.55	5.19	27.1457181	-90.319515	126	46,724	23	0.492	1085.232	122335	73	0.597	1315.548	1251.894	169,059	26,077	1.56E+01	603	9.59E+07	1.56E+04	1.62E-04
13	5/23/2022	608114071900	4987	1520.04	311.55	5.19	27.1456717	-90.31935528	126	42,375	21	0.496	1092.557	62322	37	0.594	1308.865	1221.317	104,697	26,697	1.58E+01	595	9.46E+07	1.58E+04	1.68E-04
14	6/4/2022	608114068000	3788	1154.58	1207.42	20.12	27.4950992	-90.06402528	104	33,000	17	0.515	1135.716	57033	34	0.596	1314.278	1248.829	90,033	30,381	1.81E+01	621	9.87E+07	1.81E+04	1.83E-04
15	6/6/2022	60812400680	5190	1581.91	969.75	16.16	26.9326556	-90.520285	141	67,301	34	0.505	1113.761	55322	33	0.597	1315.075	1204.585	122,623	4,457	2.66E+00	571	9.08E+07	2.66E+03	2.93E-05
16	6/11/2022	608114068000	3788	1154.58	924.1	15.40	27.4950992	-90.06402528	104	45,151	23	0.509	1123.040	121582	73	0.600	1323.696	1269.358	166,733	4,416	2.65E+00	547	8.70E+07	2.65E+03	3.05E-05
17	7/16/2022	608174120900	3036	925.373	1109.54	18.49	28.1599111	-89.23903278	76	23,326	12	0.514	1134.163	142095	85	0.598	1318.787	1292.753	165,421	95,629	5.72E+01	99	1.57E+07	5.72E+04	3.63E-03
18	7/18/2022	608114068901	3760	1146.05	1522.16	25.37	27.4978671	-90.06045106	104	52,657	26	0.494	1088.559	123505	74	0.599	1320.936	1251.476	176,162	14,776	8.85E+00	529	8.41E+07	8.85E+03	1.05E-04
19	8/15/2022	608174108401	6946	2117.14	1857.18	30.95	28.3078502	-88.20155808	110	106,000	46	0.434	956.724	93500	56	0.599	1320.417	1127.176	199,500	80,914	4.85E+01	135	2.15E+07	4.85E+04	2.26E-03
20	9/2/2022	608114074701	3450	1051.56	994.05	16.57	27.5364356	-90.16512122	102	26,360	13	0.493	1087.258	51768	31	0.599	1320.185	1241.597	78,128	2,219	1.33E+00	640	1.02E+08	1.33E+03	1.31E-05
21																									
22																									
23																									
24																									
25																									
26																									
27																									
	Averages		**3,620**	1103.25	**707**	11.78			**102**	**45,303**	**22**	**0.491**	**1,092**	**97,585**	**59**	**0.604**	**1,331**	**1,255**	**142,888**	**28,766**	**1.74E+01**	**432**	**6.86E+07**	**1.74E+04**	**2.53E-04**

* Ir-192 is always pumped after the Sc-46 and should be the only tracer remaining above the crossover.

**Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118

Individual Public Dose		
Reference Dose	1.00E+01	µSv/yr
Dose from External Exposure	1.47E-03	µSv/yr
Dose from Ingestion of Seafood	0.00E+00	µSv/yr
Dose from Ingestion of Beach Sediment	2.29E-07	µSv/yr
Dose from Inhalatio of Beach Sediment	4.57E-11	µSv/yr
Dose from Inhalation of Sea Spray	3.10E-08	µSv/yr
Total Individual Dose	1.47E-03	µSv/yr

Collective Public Dose		
Reference Dose	1.00E+00	man-Sv/year
Collective Dose from Exposure on shore	1.84E-05	man-Sv/year
Collefctive Dose from Seafood Consumption	0.00E+00	man-Sv/year
Total Collective Dose	1.84E-05	man-Sv/year

Individual Dose to the Public				
Concentration Factors				
The activity concentration of a radionuclide in the box depends on the rate of input of the radionuclide to the box, its radioactive decay and its dispersion. The rate constant due to dispersion, λ_{dis}, (in 1/a) is the reciprocal of the mean residence time in the coastal region and is obtained from the equation:				
λ_{dis} = F / V		3.64E-03		
The annual average input of activity of radionuclide j, Q(j) (in Bq), is obtained from the equation:				
Q = M x C		2.96E+10		
The equilibrium concentration of Ir-192 in the box volume is given by				
$C_{box} = Q/(V*(\lambda_{rad}+\lambda_{dis}))$		5.46E-04		
The concentration C_{BOX}(j) in the box includes radioactivity in the dissolved phase of seawater and radioactivity associated with the suspended sediment particles and the sediment boundary layer. The concentration by volume of radionuclide j in the dissolved phase of seawater, C_{DW}(j) (in Bq/m3), is given by:				
$C_{DW} = C_{box}/(1+K_d(S+(L_B*p_B/D))$		2.05E-04		
The concentration, by mass, in the suspended particles, CP obtained from the equation:				
$C_p = K_d*C_{dw}$		2.05E-02		
The total concentration in seawater, C_W, (in Bq/m3), is given by:				
$C_w = (1+K_d*S)*C_{DW}$		2.66E-04		
Activity concentration of radionuclide j in marine biota				
$C_B = CR*(C_{DW}/p_w)$				
$C_B = CR*(C_{DW}/p_w)$ (fish)		3.91E-06		
$C_B = CR*(C_{DW}/p_w)$ (shellfish)		1.96E-05		
Transfer of radioactivity to edible marine biota is calculated from the concentration of dissolved radioactivity in the water using element dependent concentration factors for biological material. Radionuclide concentrations in edible parts of the marine biota k are obtained from the concentrations in the dissolved phase in seawater, CDW(j), multiplied by the appropriate concentration factors (CFs):				
$C_{EB} = C_F*C_{DW}$				
C_{EB} = CF(fish)*C_{DW}		4.09E-06		
C_{EB} = CF(crab)*C_{DW}		2.05E-05		
C_{EB} = CF(oyster)*C_{DW}		2.05E-05		
For the calculation of the external exposure from contaminated beach sediments the radionuclide concentration in coastal sediment is assumed to be a factor of 10 lower than that in suspended particles in the water column [16]. The surface contamination in the coastal sediment of radionuclide j, C_S(j) (in Bq/m2), is obtained from the equation (25):				
$C_s = (C_p*p_s*d_s)/10$		3.07E-01		
Dose Calculation				
Dose from External Exposure				
$E_{ext, public} = t_{public}*C_s*DC_{gr}$		1.47E-09	1.47E-04	mrem/yr
Dose from Ingestion of Seafood				
$E_{ing, food, public} = H_B*C_{EB}*DC_{ing}$				
$E_{ing, food, public} = H_B*C_{EB}*DC_{ing}$ - fish		2.87E-13	2.87E-08	mrem/yr
$E_{ing, food, public} = H_B*C_{EB}*$DCing - shell fish		4.30E-13	4.30E-08	mrem/yr
Dose from ingestion of Beach Sediment				
$E_{ing shore, public} = t_{public}*H_{shore}*((C_s/(p_s*L_B)*DC_{ing})$		2.29E-13	2.29E-08	mrem/yr
Dose from inhalation of Beach Sediment				
$E_{inh shore, public} = t_{public}*R_{inh, public}*D_{lshore}*C_p*DC_{inh}$		4.57E-17	4.57E-12	mrem/yr
Dose from Inhalation of Sea Spray				
$E_{inh, spray, public} = t_{public}*R_{inh,public}*(C_{spray}/p_w)*Cw*DC_{inh}$		3.10E-14	3.10E-09	mrem/yr
Total Individual Dose to Members of the Public				
$E_{ind, public} = E_{food}+E_{ing,shore}+E_{ihn,shore}+E_{inh,spray}$		1.47E-09	1.47E-04	mrem/year
Reference Dose, if cell D58 ≤ 10 uSv acceptable, if >10 uSv not acceptable; If cell F58 ≤ 1 mrem acceptable, if > 1 mrem not acceptable.		10	1	mrem/year

Collective Public Dose

The collective dose to members of the public is the combination of collective doses from exposures on the shore and the consumption of seafood.					
Collective Dose from Exposure on Shore					
$E_{coll,\ shore,\ public} = (E_{ext,\ public} + E_{inh\ shore,\ public} + E_{inh\ spray,\ public}) * ((O_{coll,\ public} * L_{shore} * N_{sites})/t_{public})$		1.84E-05	man-Sv/year		
Collective Dose from Seafood Consumption					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DC_{ing}$					
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (fish)		5.48E-08	man-Sv/year		
$E_{coll\ ing,\ public} = N_{sites}*f_B*N_B*C_B*DCing$ (shellfish)		9.59E-08	man-Sv/year		
Total Collective Dose					
$E_{coll,public} = E_{coll\ shore,\ pubic} + E_{coll\ ing,\ public}$		1.86E-05	man-Sv/year	1.86E-03	man-rem/year
Reference Dose, if cell D19 ≤ D21 acceptable, if D19 > D21 not acceptable; If cell F19 ≤ F21 acceptable, if > F21 not acceptable.		1	man-Sv/year	100	man-rem/year

Specific Parameters			
Depth of Water Column	D	1.10E+03	meters
Volume of Seawater in Box	V	1.10E+13	m^3
Annual mass of material disposed	M	5.18E+05	kg
Avg concentration of Ir-192	C	5.72E+04	Bq/kg
Number of dump sites	N_{sites}	4.00E+01	sites
Density of seawater	ρ_w	1.05E+03	kg/m3

Generic Parameters			
Flux of water through region	F	4.00E+10	m^3/year
Radioactive decay constant Ir-192	λ_{rad}	4.93E+00	$year^{-1}$
Thickness of boundary sediment layer in box	L_B	1.00E-02	m
Effective sediment thickness	d_s	1.00E-01	m
Bulk sediment and waste density	ρ_s, ρ_B	1.50E+03	kg/m3
Suspended sediment concentration	S	3.00E-03	kg/m3
Sediment Distribution Factor	K_d	1.00E+02	m3/kg
Dust loading on shore (kg/m3)	DL_{shore}	2.30E-10	kg/m3
Seaspray concentration in air (kg/m3)	C_{spray}	1.20E-02	kg/m3
Density of seawater (Kg/m^3)	ρ_w	1.05E+03	kg/m3
Annual collective shore occupancy per unit length	$O_{coll, shore}$	5.00E+01	man-h/yr/m
Coastline length for one site	L_{shore}	1.00E+04	m
Annual fish catch in the area of a single site	N_B(fish)	5.00E+05	kg/year
Annual shellfish catch in the area of a single site	N_B(shellfish)	2.50E+05	kg/year
Fraction of fish utilized for human consumption	f_B(fish)	5.00E-01	
Fraction of shellfish utilized for human consumption	f_B(shellfish)	3.50E-01	

Element	Concentration Factor			Concentration Ratio		
	(m3/kg)			(Bq/Kg per Bq/Kg)		
	CF			CR		
	Fish	Crustacean	Mollusc	Flatfish	Shellfish	Seaweed
Iridium	2.00E-02	1.00E-01	1.00E-01	2.00E+01	1.00E+02	1.00E+03

External dose coefficients		Internal dose coefficients			
(Sv/h per Bq/kg)		(Sv/Bq)			
DC_{gr}	DC_{ship}	DC_{ing}		DC_{inh}	
		Infants	Adults	Infants	Adults
3.00E-12	8.30E-12	8.70E-09	1.40E-09	2.20E-09	6.60E-09

Public				
Annual time spent on sediments on shore	t_{public}	1.60E+03	1.00E+03	hours
Public breathing rate	$R_{inh, public}$	9.20E-01	2.20E-01	m3/hour
Annual ingestion of fish	H_B(fish)	5.00E+01	2.50E+01	Kg
Annual ingestion of shellfish	H_B(shellfish)	1.50E+01	0.00E+00	Kg
Ingestion rate of sediment on beach	H_{shore}	5.00E-06	3.00E-05	Kg/hour

Conversions	
mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

Average Summary Frac Jobs YTD Jan-Sep 2nd (20 Wells)

Est. Jobs/Year # 40

Tracers			SI Units	
Sc-46 1st Tracing (Avg)				
Proppant Traced Sc-46	34,260	lbs	1.54E+04	kg
Sc-46 Total Injected	17.000	mCi	6.29E+08	Bq
Conc. Sc-46 mCi	0.496	mCi/k lbs proppant		
Sc-46 pCi	1,093.947	pCi/gm		
Ir-192 2nd Tracing (Avg)				
Proppant Traced Ir-192	90,378	lbs	4.07E+04	kg
Ir-192 Total Injected	63.000	mCi	2.33E+09	Bq
Conc. Ir-192 mCi	0.697	mCi/k lbs proppant		
Ir-192 pCi	1,536.783	pCi/gm		
Total Proppant Traced (Avg)	124,638	lbs	5.61E+04	kg
Total Ir-192 & Sc-46	80.000	mCi	2.96E+09	Bq
Material Returned to Surface (Avg)				
Proppant Reversed-out	28,766	lbs	1.29E+04	kg
Reverse-out Ir-192	8.566	mCi	3.17E+08	Bq
Flush Pumped	489.00	bbl		
Concentrations (Avg)				
Reverse-out Ir-192	8.57E+00	mCi	3.17E+08	Bq
Reverse-out Ir-192	8.57E+03	µCi	3.17E+08	Bq
Reverse-out Ir-192	1.10E-04	µCi/ml		
Well & Job Data (Avg)				
Well Depth	3619.6	ft	1.09E+03	m
Well Depth	1099.11	meters	1.10E+03	m
Distance to Shore	101	miles	1.63E+02	km
Pumping Time Minutes	784.43	min		
Pumping Time Hours	13.07	hr		

****Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118**

Tracers			SI Units	
Sc-46 1st Tracing (Total)				
Proppant Traced Sc-46	1,370,400	lbs	6.17E+05	kg
Sc-46 Total Injected	680	mCi	2.52E+10	Bq
Conc. Sc-46 mCi	0.496	mCi/k lbs proppant		
Sc-46 pCi	1,094	pCi/gm		
Ir-192 2nd Tracing (Total)				
Proppant Traced Ir-192	3,615,120	lbs.	1.63E+06	kg
Ir-192 Total Injected	2,520	mCi	9.32E+10	Bq
Conc. Ir-192 mCi	0.697	mCi/k lbs proppant	5.72E+04	Bq/kg
Ir-192 pCi	1,536.783	pCi/gm		
Total Proppant Traced (Avg)	4,985,520	lbs	2.24E+06	kg
Total Ir-192 & Sc-46	80.000			
Material Returned to Surface (Total)				
Proppant Reversed-out	1,150,640	lbs	5.18E+05	kg
Reverse-out Ir-192	343	mCi	1.27E+10	Bq
Flush Pumped	19,560	bbl		
Well & Job Data (Total)				
Well Depth	144784	ft		
Well Depth	43964	meters		
Distance to Shore	4040	miles		
Pumping Time Minutes	31377	min		
Pumping Time Hours	523	hr		

Conversions

mCi to Bq conversions	
2.70E-08	mCi/Bq
3.70E+07	Bq/mCi
lbs to Kg conversion	
4.50E-01	Kg/lb
Sv to mrem	
1.00E+05	mrem/Sv
meters per foot	
0.3	m/ft
km per mile	
1.61	km/mile

Last 10-20-30 Jobs conducted from Broussard, LA - worst case

	Date	API #	Depth (ft)	Depth (m)	Pumping Time (min)	Pumping Time (Hours)	Surface Latitude	Surface Longitude	Miles to Shore**	Amount Traced Sc-46	Sc-46 (mCi)	Conc. Sc-46 (mCi/k)	Sc-46 Picocuries/gram	Amount Traced Ir-192	Ir-192 (mCi)	Conc. Ir-192 (mCi/k)	Ir-192 Picocuries/gram	Total Picocuries/gram	Total Proppant	Reverse-out Pounds	Reverse-out Ir-192 (mCi) *	Flush pumped bbl.	Flush Pumped ml	µCi	µCi/ml
1	1/1/2022	608114067901	3604	1098.5	564.57	9.41	27.56045503	-90.10466997	101	36,269	18	0.496	1094.137	89071	53	0.595	1311.820	1248.830	125,340	8,314	4.95E+00	533	8.47E+07	4.95E+03	5.84E-05
2	1/7/2022	608164029901	1290	393.192	295.5	4.93	28.97308168	-88.62599537	74	26,700	13	0.487	1073.413	105600	63	0.597	1315.259	1266.451	132,300	13,879	8.28E+00	170	2.70E+07	8.28E+03	3.06E-04
3	3/5/2022	608114068801	3603	1098.19	815.58	13.59	27.56045859	-90.10493052	101	33,604	17	0.506	1115.302	110973	67	0.604	1331.043	1280.898	144,577	8,694	5.25E+00	578	9.19E+07	5.25E+03	5.71E-05
4	3/7/2022	608164035601	1290	393.192	226.39	3.77	28.97302946	-88.62599143	74	24,662	12	0.487	1072.723	100529	60	0.597	1315.814	1267.926	125,191	21,064	1.26E+01	176	2.80E+07	1.26E+04	4.49E-04
5	3/10/2022	608114008703	760	231.648	341.41	5.69	27.94369889	-91.0291754	95	36,827	18	0.489	1077.558	167676	101	0.602	1327.960	1282.868	204,503	24,772	1.49E+01	174	2.77E+07	1.49E+04	5.39E-04
6	3/29/2022	608104016400	1570	478.536	374.9	6.25	28.07837889	-89.98232167	69	31,875	16	0.502	1106.635	70054	42	0.600	1321.755	1254.483	101,929	31,608	1.90E+01	182	2.89E+07	1.90E+04	6.55E-04
7	4/1/2022	608114071200	4958	1511.2	322.71	5.38	27.15409583	-90.30964083	126	93,605	47	0.502	1106.964	139951	84	0.600	1323.238	1236.559	233,556	89,075	5.35E+01	539	8.57E+07	5.35E+04	6.24E-04
8	4/11/2022	608114071200	4958	1511.2	181.32	3.02	27.15409583	-90.30964083	126	42,375	21	0.496	1092.557	57750	35	0.606	1336.136	1233.048	100,125	33,145	2.01E+01	530	8.43E+07	2.01E+04	2.38E-04
9	4/19/2022	608114074802	3606	1099.11	784.43	13.07	27.56100318	-90.10413894	101	34,260	17	0.496	1093.947	90378	63	0.697	1536.783	1415.058	124,638	12,289	8.57E+00	489	7.77E+07	8.57E+03	1.10E-04
10	4/19/2022	608174142901	3223	982.37	265.1	4.42	28.47060823	-88.9400004	72	80,992	40	0.494	1088.811	123511	74	0.599	1320.872	1228.966	204,503	42,258	2.53E+01	421	6.69E+07	2.53E+04	3.78E-04
11	4/25/2022	608114074802	3606	1099.11	754.13	12.57	27.56100318	-90.10413894	101	22,000	11	0.500	1102.312	66743	40	0.599	1321.262	1266.983	88,743	4,656	2.79E+00	498	7.92E+07	2.79E+03	3.52E-05
12	5/7/2022	608114065800	4979	1517.6	311.55	5.19	27.14571806	-90.319515	126	46,724	23	0.492	1085.232	122335	73	0.597	1315.548	1251.894	169,059	26,077	1.56E+01	603	9.59E+07	1.56E+04	1.62E-04
13	5/23/2022	608114071900	4987	1520.04	311.55	5.19	27.14567167	-90.31935528	126	42,375	21	0.496	1092.557	62322	37	0.594	1308.865	1221.317	104,697	26,697	1.58E+01	595	9.46E+07	1.58E+04	1.68E-04
14	6/4/2022	608114068000	3788	1154.58	1207.42	20.12	27.49509917	-90.06402528	104	33,000	17	0.515	1135.716	57033	34	0.596	1314.278	1248.829	90,033	30,381	1.81E+01	621	9.87E+07	1.81E+04	1.83E-04
15	6/6/2022	60812400680	5190	1581.91	969.75	16.16	26.93265556	-90.520285	141	67,301	34	0.505	1113.761	55322	33	0.597	1315.075	1204.585	122,623	4,457	2.66E+00	571	9.08E+07	2.66E+03	2.93E-05
16	6/11/2022	608114068000	3788	1154.58	924.1	15.40	27.49509917	-90.06402528	104	45,151	23	0.509	1123.040	121582	73	0.600	1323.696	1269.358	166,733	4,416	2.65E+00	547	8.70E+07	2.65E+03	3.05E-05
17	7/16/2022	608174120900	3036	925.373	1109.54	18.49	28.15991111	-89.23903278	76	23,326	12	0.514	1134.163	142095	85	0.598	1318.787	1292.753	165,421	95,629	5.72E+01	99	1.57E+07	5.72E+04	3.63E-03
18	7/18/2022	608114068901	3760	1146.05	1522.16	25.37	27.49786711	-90.06045106	104	52,657	26	0.494	1088.559	123505	74	0.599	1320.936	1251.476	176,162	14,776	8.85E+00	529	8.41E+07	8.85E+03	1.05E-04
19	8/15/2022	608174108401	6946	2117.14	1857.18	30.95	28.30785016	-88.20155808	110	106,000	46	0.434	956.724	93500	56	0.599	1320.417	1127.176	199,500	80,914	4.85E+01	135	2.15E+07	4.85E+04	2.26E-03
20	9/2/2022	608114074701	3450	1051.56	994.05	16.57	27.53643558	-90.16512122	102	26,360	13	0.493	1087.258	51768	31	0.599	1320.185	1241.597	78,128	2,219	1.33E+00	640	1.02E+08	1.33E+03	1.31E-05
21																									
22																									
23																									
24																									
25																									
26																									
27																									
	Averages		**3,620**	1103.25	**707**	11.78			**102**	**45,303**	**22**	**0.491**	**1,092**	**97,585**	**59**	**0.604**	**1,331**	**1,255**	**142,888**	**28,766**	**1.74E+01**	**432**	**6.86E+07**	**1.74E+04**	**2.53E-04**

* Ir-192 is always pumped after the Sc-46 and should be the only tracer remaining above the crossover.
**Nautical Miles to Grand Isle, LA 29.2339196776543, -89.9992938991118

		3,606	1099.11	784	13.07			101	34,260	17	0.496	1,094	90,378	63	0.697	1536.783	1415.058	124,638	12,289	8.57E+00	489	7.77E+07	8.57E+03	1.10E-04