CARDINAL SURVEYS COMPANY

Well Sand-Out / Flow-Back Procedures During Tracer Studies

REV. 3/2015

I. OPERATIONAL POLICY

Cardinal's personnel will have control of the events involving their equipment and the radioactive operations. Under the nature of the service being performed, Cardinal's personnel, during the pumping operation, will be operating under instruction from and in cooperation with, the pumping service company. Communication will be established prior to pumping radioactive tracer material with the oil company representative and the service company supervisor to establish job procedures. See Attachment I for applicable State regulations.

If job procedures call for tracer ("tag") through-out the treatment, adequate (un-tagged) flush will be pumped to displace material into the formation. Procedures calling for flush to top of zone, or in any event that call for less than complete displacement of the well-bore, should have tagging stopped early enough to compensate for flush volume. In the event that an approaching screen-out is detected, the tag should be stopped immediately, and an effort should be made to flush material below the surface. A bleed line should be available in the event of a complete screen-out so that it is possible to flush all surface equipment before the pumping service company is released.

II. WELL REVERSAL PROCEDURES

The following procedures will be used in the event radioactive material is to be reversed from the well. These procedures will include the completion of the Sand Out / Flow Back Report (copy located at the end of section).

Discuss with the well operator the procedures that will be followed. If the procedures require additional personnel, equipment, or support which is not available, the operation should be suspended until adequate equipment is made available.

1. A preconstructed pit (either an above-ground container or earthen pit) for flow-back will be used for control of radioactive material.
2. A bleed line will be run from the well head to the pit to minimize contamination.
   a. A well control valve should be installed on the well head to maintain well control.
   b. A suitable check-valve or valve will be provided by the pumping service company to prevent back-flow through pumping service company equipment, if the pumping service company remains connected ("rigged-up") during the flow back operation.
3. A survey of the area around the pit will be conducted to establish back-ground radiation levels. **Do not enter pit**.
4. Flow back well returns into the designated pit.
   a. If returns produce a small volume of contaminated material, where practical, remove and place material in a suitable container for transportation to controlled location for decay, or prepare for on-sight dilution and burial.
   b. If returns produce a large volume of contaminated material take steps to contain within pit.
   c. If the area is unsuitable for burial, due to the well location, place material in suitable containers for transportation to controlled location for decay.
   d. If above-ground containers were utilized to collect the well returns, prepare a burial pit for permanent dilution and disposal, if the location is suitable and burial is required.
5. Monitor flow back for measurable radiation levels in return. Document or use a recording monitor. Note the instrumentation used, location of sensor relative to containers and flow-lines, and back-ground readings.

CAUTION: see warnings below.

6. Record total volume of treating materials pumped by Pumping Service Company to establish amount and concentration of possible return. A treatment schedule should be included.
7. Record radioactive material, type, amount (mCi) and concentration (mCi/volume) pumped.
8. Calculate wellbore volume to determine maximum volume of return expected.

9. Record estimated volume of back-flow to establish possible amounts of radioactive material.
10. Collect samples to establish concentration levels of back-flow.
    a. Use appropriate sample container.
    b. Measure radiation level of sample.
    c. Calculate µCi/gram. Use tabulated proppant densities.
11. Returns can be released for unrestricted use if radiation concentrations are below regulatory guidelines.
    a. Contaminated back-flow fluid can be removed if it is to be disposed in an appropriate disposal system. Transport vehicle must be surveyed and be in compliance with applicable regulations.
    b. Fluid that is to be reused in oil-field applications will be checked before it is released for unrestricted oil-field use. If contaminated, dilute with additional volume and recheck before release.
    c. Contaminated sludge can be removed if it is to be disposed in an appropriate disposal system. Transport vehicle and containers must be surveyed and be in compliance with applicable regulations.
    d. Contaminated sludge can be released for unrestricted use if levels can be reduced by dilution to acceptable limits.
    e. Contaminated sludge that cannot be disposed of by dilution or in an appropriate disposal system may be placed in suitable containers for transportation to controlled location for decay. Transport vehicle and containers must be surveyed and be in compliance with applicable regulations.
    f. Contaminated sludge that can be disposed of by dilution and burial on-sight or at an appropriate site may be buried.
12. Record the volume of contaminated material for disposal by pit burial.
13. Use the calculations or results from sample collection to calculate amount of soil needed to dilute contaminated volume to a level below TAC 289.202 (eee) soil limits.
14. If unable to dilute sufficiently, use the half-life of the material to calculate the time necessary to decay the contamination below TAC 289.202 (eee) soil limits.
15. Cover pit with soil to prevent spread and to reduce levels within the limits. Survey the pit area after pit covering and record highest measured radiation level.
    a. If soil contamination levels have been reduced by dilution, the area can be released for normal surface use. Recommend that pit not be opened for a period of one half-life. If land owner or operator requires opening the pit within this time, the area should be re-surveyed.
    b. If survey levels are less than twice the background, but TAC 289.202 (eee) soil levels after dilution of sludge were exceeded before closure, the pit area should be fenced and posted with Caution signs to prevent disturbance or use of the pit area until after necessary decay time.
    c. If level is more than twice the background but less than 2 mR/hr, the pit should be fenced and posted with Caution Radiation signs. The pit area should not be disturbed or used until after the necessary decay time.
    d. If level is more than 2 mR/hr, the pit should be fenced and posted with Caution Radiation signs and Radiation Area, Authorized Personnel Only signs. Position fence so as to reduce exposure levels; at a minimum the fence should be outside the 2 mR/hr restricted area limit. A level of less than twice the background can be achieved by distance or additional covering. If soil contamination levels or surface reading exceed 2 mR/hr, a report will be submitted to the state agency. The report will consist of a copy of the Sand Out/Flow Back Report, procedures used and a cleanup plan or a surveillance plan. Surveillance will include radiation surveys of the area and condition of containment. The state agency will be notified at final release.
16. Construct a diagram of the site. (Diagram form is page 3 of Sand Out / Flow Back Report)
    a. Indicate the location of the well (use for reference).
    b. Indicate approximate North (orient the diagram).
    c. Indicate pit location in relation to well.
        1. Direction.
        2. Distance.

    d. Indicate approximate size (area of contamination after flow back).
    e. Indicate approximate depth below average surface elevation to contaminated material (feet of fill).
    f. Record radiation readings at ground level before and after soil is added.
    g. Identify any water source in the vicinity and indicate type of source and distance to source.

i. Record legal well location.

17. Instruct well operator that a report will be sent to him and a copy should be placed in the well file. The area should be re-surveyed before it is reused or disturbed.
18. Instruct the well operator that samples may be required to establish environmental levels. Samples will be taken so as to collect a representative grid of the location (as permitted by safe entry to the pit). Sampling of the returns may be required if suitable, safe sampling procedures can be devised.
19. Instruct the well operator that posting and/or fencing of the pit and/or location may be required to prevent unauthorized access of personnel or livestock, depending on ultimate determination of contamination levels.

CAUTION: Flammable, corrosive, and or toxic material may be used in a stimulation job. Toxic vapor will collect in low places.

WARNING: If well is gassing during flow back DO NOT TAKE SAMPLE. Fluid may contain acid gas or Hydrogen Sulfide gas. Stay up wind while monitoring. Wear appropriate safety equipment.

A well head and area survey will be taken before and after the job. This will establish base radiation levels in the event of contamination.

SAND OUT / FLOW BACK REPORT

Initiator of Report _____ Date _____
Company _____ Company Rep. _____
Well Name & Number _____
Pumping Service Company _____
Tot. Fluid Pumped (gal) _____ Type Fluid _____
Total Proppant (lbs) _____ Type Proppant _____
Total Flush (gal) _____ Type Flush _____
Attach treatment schedule as required. Indicate portions of the treatment that were tagged.

Type of R/A Material _____ Amount Pumped (mCi) _____
Concentration (µCi/volume) _____
Total Tagged Volume (lbs) _____
Indicate only the tagged volume. If pumping procedure calls for tagged treatment stages with untagged volumes pumped between stages, or if tag is cut off before end of treatment, do not include the untagged volume in the amount tag volume.

Calculate Wellbore Volume (lbs/gal) _____
Calculate maximum expected return (mCi) _____
Amount of contaminated material returned (lbs) _____
Amount of soil needed for dilution (lbs) _____
Amount of time needed for decay (days) _____
Date of decay (month,day,year) _____

Pit Area Surveys **(EXERCISE CAUTION):**
Survey Meter (make, model, & serial no.) _____

	Position (four sides at ground level)	
Base	1. _____ 2. _____ 3. _____ 4. _____	Max. Reading: _____
Pre-Closure	1. _____ 2. _____ 3. _____ 4. _____	Max. Reading: _____
Post-Closure	1. _____ 2. _____ 3. _____ 4. _____	Max. Reading: _____

If additional positions are required use back of this form, or attachment.

Sample Collection **(EXERCISE CAUTION):**

Container Number	Size grams	Radiation Level mR/hr	Calculated µCi/grams
1			
2			
3			
4			

Mark sample container with date, time, and the number of the sample. If additional samples are required use back of this form, or attachment.

Flow-Back Monitoring **(EXERCISE CAUTION):**
Indicate method used and document any measurable levels. Attach print out if recording monitor is used.
Method used _____ Highest reading _____

SAND OUT / FLOW BACK REPORT

Transportation of contaminated material

If contaminated material is transported to a Licensed Waste Facility, indicate company, location, and volume. If contaminated material is moved to a controlled area on the well operators property (with written agreement), give location of area and indicate method of disposal or storage for decay. If containers are used for storage, containers must be marked with labels as to the Hazardous Material involved in the treating fluids (Radioactive, Flammable, Corrosive, Toxic, etc.)

Company _____ Volume _____
Location _____
Method _____

Transport Vehicle Surveys

If contaminated material is transported, survey vehicle after material is loaded and after it is unloaded. If vehicle move on a public roadway vehicle must be placarded in compliance with applicable regulations.

	Driver Cab	Front of Vehicle	Right Side	Left Side	Rear of Vehicle
Unloaded					
Loaded					

Transport Container Surveys

If contaminated material is transported in containers. Survey each container after material is loaded and after it is unloaded. If material is to be decayed in the container, it must be marked in compliance with applicable regulations.

Type of Container _____ Number of Containers _____

Container I.D. Number	Highest reading at Surface	Highest reading at 3 Feet

List personnel involved in cleanup

_____
_____

Review of report by Radiation Safety Officer

_____
_____

Plan for monitoring radiation levels and conditions of containment

_____
_____

SAND OUT / FLOW BACK REPORT

Use this space for diagram of the well site.

Mark the location of the well on the drawing and use it for the reference point. Indicate approximate North. Draw pit location and indicate distance to well, approximate size of the area of contamination after flow back, and approximate depth to the contaminated material (feet of fill). Indicate positions of readings on surveys listed on page 1. Record readings at ground level before and after soil is added. Identify any water source in the vicinity, type of source and distance to source.

III. EQUIPMENT CONTAMINATION

If measurable radiation levels on well-head equipment are detected following the tracer study, the following steps will be taken.

1. A complete survey of the equipment involved will be taken to establish the location and levels of contamination.
2. Well operator will be notified of contamination and instructed in the procedures of decontamination.
   a. Equipment will be detained until contamination limits are met.
   b. Internal contamination will be removed by pumping additional flush fluid.
   c. External contamination will be removed by washing contaminated area. Washing fluids will be absorbed and removed.
   d. Surveys and washing or flushing will be repeated until radioactive material is removed.
3. A report will be submitted to the well operator.

IV. PERSONNEL CONTAMINATION

If measurable radiation levels on personnel are detected following the tracer study, the following steps will be taken.

1. A complete survey of clothing will be taken to establish contaminated articles.
   a. Contaminated articles will be removed immediately and stored for decay.
2. A complete survey of the body will be taken to establish areas of contamination.
   a. Areas of contamination will be thoroughly washed.
   b. Surveys and washing will be repeated until radioactive material is removed.
3. Bioassay can be performed for internal exposure. Internal exposure can only occur from ingestion of the material.
4. A report will be submitted to the well operator indicating personnel involved and a list of contaminated articles. If bioassays have been performed, the results will be included.

V. CONCLUSION

It is the purpose of this document to assure all parties involved in a tracer study understand where the levels of responsibility lie. Under the regulations and in the event of contamination, Cardinal has the responsibility of performing or supervising the required decontamination procedures of personnel and equipment. The expense of decontamination shall be the responsibility of the company which created the event resulting in the contamination.

Cardinal will not knowingly place radioactive material into or through storage tanks, fracture blending equipment or conventional well-treatment pumps. If the pumping service company allows no back-flow to or through the pumps or blenders, contamination will be contained within the last portion of the treatment line, and can be removed simply with additional flushing. Service company pump failure will result in no contamination to the pumps.

TAC §289.253(d)(2)

(2) No licensee shall perform tracer study operations with a substance tagged with radioactive material in any well or wellbore unless, prior to commencement of the operation, the licensee has a written agreement with the well operator, well owner, drilling contractor or land owner, and the service company to which the licensee's equipment is connected, as applicable, that specifies who will be responsible for ensuring the following requirements are met:

(A) in the event the service company's personnel or equipment are contaminated with radioactive material, they shall be decontaminated in accordance with §289.202(n) or (eee) of this title before release from the job site or release for unrestricted use;

(B) in the event the well head or job site is contaminated with radioactive material, it shall be decontaminated in accordance with §289.202(eee) of this title; and

(C) in the event radioactive material is to be reversed from the well or the well screens out, the licensee shall have established procedures and equipment or facilities to do the following:

*(*i) reverse material into a preconstructed pit that is specifically established in the event of a screen out; or

(ii) reverse material into suitable transport container(s) in the event of a screen out.

(3) The licensee shall maintain, in accordance with subsection (bb)(5) of this section, a copy of the written agreement specified in paragraphs (1) or (2) of this subsection.

TAC §289.202(ggg)(6) Acceptable surface contamination levels.

NUCLIDE [a]	AVERAGE [bcf]	MAXIMUM [bdf]	REMOVABLE [bcef]
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 dpm beta, gamma/100 cm 2	15,000 dpm beta, gamma/100 cm 2	1,000 dpm beta, gamma/100 cm 2

a. Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.

b. As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

c. Measurements of average contamination level should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each object.

d. The maximum contamination level applies to an area of not more than 100 cm 2 .

e. The amount of removable radioactive material per 100 cm 2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

f. The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 centimeter and 1.0 mrad/hr at 1 centimeter, respectively, measured through not more than 7 mg/cm 2 of total absorber.

TAC 289.202 (eee) Limits for contamination of soil, surfaces of facilities and equipment, and vegetation.

(1) No licensee shall possess, receive, use, or transfer radioactive material in such a manner as to cause contamination of surfaces of facilities or equipment in unrestricted areas to the extent that the contamination exceeds the limits specified in subsection (ggg)(6) of this section.

(2) No licensee shall possess, receive, use, or transfer radioactive material in such a manner as to cause contamination of soil in unrestricted areas, to the extent that the contamination exceeds, on a dry weight basis, the concentration limits specified in:

(A) subsection (ggg)(8) of this section; or

(B) the effluent concentrations in Table II, Column 2 of subsection (ggg)(2)(F) of this section, with the units changed from microcuries per milliliter to microcuries per gram, for radionuclides not specified in subsection (ggg)(8) of this section or paragraph (4) of this subsection.

(3) Where combinations of radionuclides are involved, the sum of the ratios between the concentrations present and the limits specified in paragraph (2) of this subsection shall not exceed one.

TAC 289.202(ggg)(2)(F) Concentration in Air and Water above Natural Background

Table II

Element (Atomic No.)	Class	Column 1	Column 2
Antimony-124 (51)	D	1E-9	7E-6
	W	3E-10	
Bromine-82 (35)	D	6E-9	4E-5
	W	5E-9	
Gold-198 (79)	D	5E-9	2E-5
	W	3E-9	
	Y	2E-9	
Iodine-131 (53)	D, all compounds	2E-10	1E-6
Iridium-192 (77)	D	4E-10	1E-5
	W	6E-10	
	Y	3E-10	
Iridium-194 (77)	D	4E-9	1E-5
	W	3E-9	
	Y	3E-9	
Scandium-46 (21)	Y, all compounds	3E-10	1E-5
Silver-110m (47)	D	2E-10	6E-6
	W	3E-10	
	Y	1E-10	