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U.S. FISH & WILDLIFE SERVICE

REGION 6

ENVIRONMENTAL CONTAMINANTS PROGRAM

Migratory Bird Mortality in Oil and Gas Facilities in Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming

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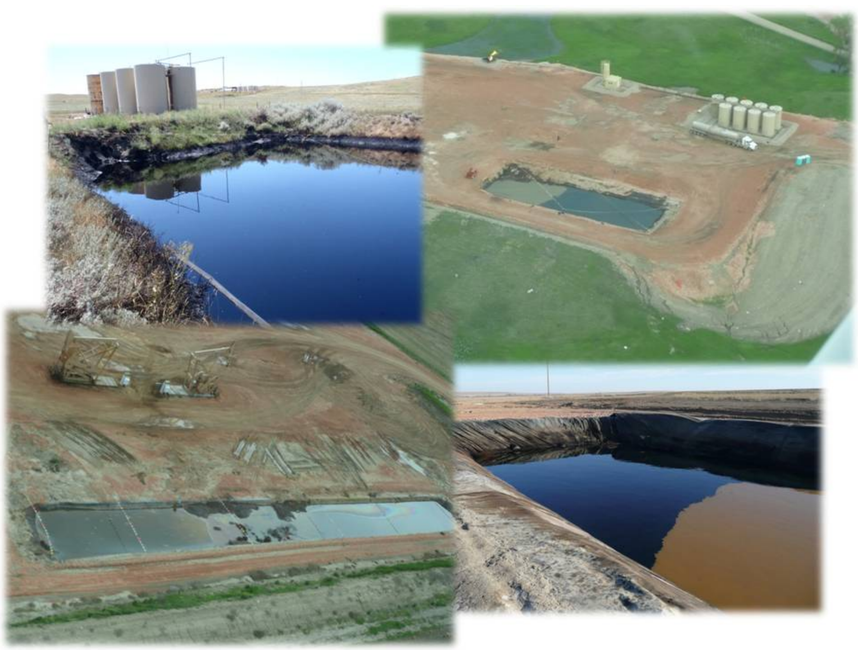

ABSTRACT

U.S. Fish and Wildlife Service (Service) law enforcement special agents and environmental contaminants specialists conducted inspections of oil and gas production facilities and commercial oilfield wastewater disposal facilities from 2007 through 2010 within Colorado, Kansas, Nebraska, Montana, North Dakota, South Dakota, Utah, and Wyoming to document risks and hazards to migratory birds. Service personnel recovered 1,405 bird carcasses from 205 oil and gas facilities during the three-year investigation (*i.e.* on average, 2.3 bird carcasses per facility per year). Approximately half of the bird carcasses (719) were recovered from dehydrator tanks at natural gas production facilities in Wyoming. We attributed the large number of carcass recovery from dehydrator tanks to the ease of detection and recovery of carcasses from these tanks compared to the larger reserve pits and production skim pits similarly inspected. Dehydrator tanks typically ranged from 4 to 6 feet in diameter and 3 to 5 feet in height. Investigators recovered 24 percent (333) of the bird carcasses from reserve pits between 2007 and 2010. An increase in drilling activity in Colorado, North Dakota, Utah, and Wyoming and associated increase in the number of reserve pits may account for the large amount of bird mortality in reserve pits. Reserve pits are not typically covered with netting to exclude birds and other wildlife. Ground-feeding songbirds and aquatic birds were the most common bird carcasses recovered from reserve pits, 76 percent and 69 percent, respectively. Ground-feeding songbirds and aquatic birds were the most frequent victims in oil and gas facilities, excluding dehydration tanks, comprising 48 and 47 percent, respectively, of all bird carcasses recovered from oil and gas facilities. Investigators also documented bird mortality in flare pits, emergency spill catchment pits, and open-topped tanks or small containers containing exposed oil or hydrocarbons. Ongoing wildlife mortality incidents necessitate implementation of best management practices by oil operators to prevent bird mortality and the continued inspections of these facilities by state and federal regulatory agencies to ensure compliance with applicable environmental and wildlife protection laws. Multiple inspections should be conducted throughout the year, especially between the spring and fall, to document most bird mortality in oil and gas facilities. Inspections should not be limited to production skim pits, reserve pits, and open-topped tanks but should include all hazards such as leaking valves, pipes, and wellheads. Detailed field notes by oil and gas facility inspectors should include the specific location and probable cause of the mortality incident (i.e. reserve pit, production skim pit, dehydration tank, open-topped tank, etc.). This data will serve to identify hazards encountered by migratory birds at oil and gas facilities and provide specific solutions and best management practices (BMPs) to minimize those hazards.

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INTRODUCTION

Exposure to oil and other pollution hazards at oil and gas production facilities and oilfield wastewater disposal facilities poses a significant risk to migratory birds and other wildlife (Flickinger 1981, Grover 1983, Lee 1990, Esmoil and Anderson 1995, Ramirez 2005, 2009 and 2010, and Trail 2006). For example, waterfowl can mistake earthen pits in oil and gas facilities for natural bodies of water (Flickinger 1981, Esmoil and Anderson 1995). Exposure to oil either spilled on the ground or contained in pits, open-topped tanks or in smaller, open containers also attracts and entraps insects, which may, in turn attract and entrap birds (Grover 1983). Horvath and Zeil (1996) reported the entrapment of large numbers of insects in oil pools and suggested that the insects may be "attracted by the strong polarization of light reflected from these pools" of oil. Passerine songbirds attempting to feed on the insects stuck in the oil become coated with oil and are unable to fly depending on the severity of the oiling on their feathers. What ensues is escalating rates of wildlife mortality with the oiled, entrapped songbirds attracting other songbirds with their alarm calls or attracting raptors or other predators seeking prey, which, in turn can be subsequently contaminated with oiled. These oiled birds can also be scavenged by raccoons, coyotes or other wildlife that may also become oiled or ingest the oil with their prey. Oil ingested by avian and mammalian wildlife can cause impaired reproduction or make an animal more vulnerable to disease, starvation, and predation by causing a variety of systemic effects such as anemia, immune suppression, and red blood cell damage, (Albers 2003). In 1997, the U.S. Fish and Wildlife Service (Service) estimated that 2 million migratory birds were lost each year to oil pits throughout the United States. Since that time, many oil operators have implemented measures to prevent migratory bird and other wildlife mortality in oilfield waste pits. Almost 10 years later, Trail (2006) updated the mortality rates associated with oilfield production skim pits and commercial and centralized oilfield wastewater disposal facilities (COWDFs) and estimated that 500,000 to 1 million birds are lost annually.

Early documentation of bird mortality in an oil pit was reported by Borell (1936) who found 131 birds (6 raptors and 125 songbirds) entrapped in five pits containing tar and oil used in association with road construction. King (1956) reported bird mortalities found in oilfield production skim pits in Wyoming. Subsequently several oil operators expressed a commitment to "keep all open pits free of oil, burning and covering oil spills" and draining pits or installing bird deterrents such as "tin flashers and spirolenum whirlers" (King 1956). Similar observations were made eight years later in the oilfields of the San Joaquin Valley of California (Bloch 1964) and 13 years later in the plains of northeastern Colorado (Tully and Boulter 1970). Following the Tully and Boulter report of wildlife mortalities in oil pits, the Colorado Oil and Gas Conservation Commission advised oil operators to "prevent additional wildlife losses, prevent future pollution problems and to clean up their field maintenance problems" (Tully 1973). During the 1990's, forty years after the King (1956) report, Service law enforcement agents continued to identify high rates of bird mortality in oilfield sumps and pits (EPA 2003). In 1996, the Service, working with the U.S. Environmental Protection Agency (EPA) Region 8, inspected production skim pits in oil and gas facilities in Colorado, North Dakota, Montana, South Dakota, Utah, and Wyoming. Aerial surveys were also conducted from 1997 through 1999 on approximately 5,600 pits in the six state area (EPA 2003) of which 516 sites were identified as warranting follow up ground inspections. Field inspections of these pits resulted in 428 enforcement actions. The combined efforts of Service and EPA personnel resulted in the documentation of 411 pits with some oil on the surface (80 percent of sites), 181 pits with 100 percent oil coverage (35 percent of sites), and bird mortalities documented at 40 sites (8 percent of sites).

Wildlife mortality in oil and gas facilities is not limited to production skim pits. Mortality also occurs when wildlife is exposed to oil and gas waste fluids in reserve pits, flare pits, emergency spill catchment pits, open-topped dehydrator tanks, and open-topped tanks or small containers (Figure 1). Reserve pits are earthen pits excavated adjacent to drilling rigs used for the disposal of drilling muds and well cuttings. Reserve pits range in size from 85 feet (ft) by 140 ft (26 by 43 meters) to 120 by 200 ft (37 by 61 meters) (Ramirez 2009). Flare pits are excavated below vertical pipes, also known as flare stacks, used to flare or burn off gas that is not feasible to use or transport. The flare pits are designed to contain oil and other liquid hydrocarbons that are released from the flare stack. Emergency spill catchment pits are designed to catch any accidental releases or spills of oil or other hydrocarbons.

Oil production sites typically consist of a well, the well head, and pump jack as well as a heater treater used to separate produced water from crude oil using heat. Produced water is water present in the oil and gas-bearing formations that is produced along with the oil and gas. Heater treaters used to remove produced water from oil can be either horizontal or vertical with a firebox at the bottom (Raymond and Leffler 2006). Demulsified crude oil or natural gas is typically used to fuel the firebox. Exhaust gases from the firebox are vented to the atmosphere through a vertical pipe also referred to as a “vent stack.”

Brine, produced water, and crude oil are typically temporarily stored in tanks. Storage tanks containing oil or other hydrocarbons are usually closed; however, tanks containing brine or produced water can be open-topped. The contents in storage tanks are loaded onto vacuum trucks (tanker trucks) and transported off-site. Brine and produced water are taken to COWDFs or underground injection control (UIC) facilities for disposal. COWDFs typically use one or more evaporation ponds (>1 acre in size) for wastewater disposal. COWDFs also may contain one or more skim pits to separate oil from the wastewater. UIC facilities dispose of wastewater through deep well injection.

Conventional natural gas well production sites contain the well, wellhead that has a series of valves termed a “Christmas tree.” Natural gas from the well and wellhead is directed to a pipeline if the gas is dry. If the gas contains fluids, including water, natural gasoline, and or condensate (a light crude oil), it is piped to a treater or dehydration unit for the removal of water, condensate, and other fluids from the gas prior to collection and transport. Dehydration units may also be used to remove water from the natural gas stream and the waste water will either evaporate or collected in small open-topped tanks (dehydrator tanks). Hydrocarbon liquids are removed from the natural gas and stored in close-topped tanks on site for transportation via tanker trucks to an oil refinery for further processing. Formation water produced with the natural gas is also stored in tanks at the well pad and transported via tanker trucks to COWDFs or UIC facilities for disposal. Organic chemicals such as glycols and amines are typically used in the dehydrators to remove water from the natural gas stream.

Many of the COWDFs have been in operation for 20 years; consequently, years of evaporative concentration of the produced water has concentrated salts in the ponds at these facilities. Sodium concentrations in some of these evaporation ponds exceed the thresholds for sodium toxicity in waterfowl (Ramirez 2010).

Figure 1. Hazards to birds in oil and gas production facilities.

Sodium toxicity is suspected as a cause of eared grebe (*Podiceps nigricollis*) and waterfowl mortality in these facilities (Ramirez 2010). Accelerated natural gas development may result in the construction of additional COWDFs in the region with a concomitant increase in exposure to migratory bird populations. For example, three COWDFs have been permitted and constructed in Wyoming to dispose of produced water from the Jonah, Pinedale Anticline and Wamsutter natural gas fields within the last 3 years. Operators of oil and gas production facilities have made progress in implementing proactive measures such as netting to prevent migratory bird and other wildlife mortality in production skim pits as well as in COWDFs. However, the degree of bird mortality at production skim pits had not been updated to evaluate the current use of protective measures and bird mortality rates at oil and gas production facilities to that found from 1997 to 1999 and reported by EPA (2003). Therefore, we initiated this study to update this information.

Given the accelerated development of oil and gas in the Service's Mountain-Prairie Region, Service law enforcement agents and environmental contaminants specialists conducted inspections of oil and gas production facilities from 2007 to 2010 to document the number of oil/gas production skim pits, reserve pits, and commercial oilfield wastewater disposal facilities in non-compliance as well as those within compliance within the mountain/prairie region; to compare non-compliance data with environmental compliance data from 1997 to 1999 as reported by EPA (2003); and to develop an estimate for regional impacts on various categories of migratory birds.

METHODS

Aerial surveys of oil and gas production facilities in Colorado, Kansas, Nebraska, Montana, North Dakota, South Dakota, Utah, and Wyoming were conducted from 2007 through 2010 to identify reserve pits, and production skim pits with significant amounts of oil or other hydrocarbons that could pose a risk to migratory birds. Service law enforcement agents and environmental contaminants specialists made follow up ground inspections of sites that had been identified in the aerial surveys as posing potential risks to migratory birds. The number of oil and gas facilities inspected by Service law enforcement agents varied by state and by year with a minimum of 384 sites and a maximum of 505 sites inspected in the eight state area during the study period. Follow up inspections were typically made during the spring, summer, and early fall. Weather conditions precluded the need for surveys during the winter when most pits were frozen. Sites were generally visited only once unless circumstances dictated the necessity of follow up inspections. Data collected included physical locations of oil and gas pits mapped using Global Positioning Satellite (GPS) technology; compliance status of the oil pits; the number and type of migratory bird carcasses found in pits or elsewhere in the oil and gas facilities (e.g. flare pits, heater treaters, natural gas dehydration unit tanks, spill containment devices); and any other pertinent information such as other impacted wildlife, obvious breeches, spills, condition of the site, operator, lease number, well name or number, and legal location. During the follow up inspections, Service law enforcement agents typically walked the perimeter of reserve and production skim pits. Bird carcasses observed on the surface or edges of pits or ponds were collected by hand and placed in plastic bags. Bird carcasses on the surface of pits that could not be reached by hand were retrieved using an aluminum extension pole fitted with a hook, trowel or large spoon at one end. Disposable nitrile or latex gloves were used in handling the bird carcasses. All bird carcasses collected were labeled with evidence tags and later stored in freezers. Where necessary for enforcement actions, carcasses were submitted to the National Fish and Wildlife Service Forensic Laboratory in Ashland, Oregon, for identification purposes following evidence chain-of-custody procedures. Identification of bird carcasses to species was generally not done in bird mortality cases in which the oil operators did not contest the citations issued under the Migratory Bird Treaty Act by Service law enforcement agents (Roy Brown, US Fish and Wildlife Service, personal communications, Jan 16, 2013). In Wyoming, one oil company discovered and voluntarily reported bird mortality incidents in dehydrator tanks to the Service in 2009. Personnel from the oil company subsequently inspected 4,255 of their natural gas production sites with dehydrator tanks and forwarded bird carcasses recovered from the tanks to a Service law enforcement agent.

Wastewater samples were collected from some COWDFs in Wyoming by Service environmental contaminants specialists as part of ongoing annual multiple inspections of COWDFs in Wyoming with EPA and the Wyoming Department of Environmental Quality (WDEQ) (Ramirez 2010). The wastewater samples were collected in 1-liter chemically-clean polyethylene bottles with teflon-lined lids. The pH in the water samples collected for trace element analyses was lowered to approximately 2.0 with laboratory grade nitric acid. Water samples for the other analytes were kept chilled in an ice-filled cooler and then transferred to a refrigerator. Samples were submitted to designated laboratories under contract with the Service's Analytical Control Facility (ACF) at Shepherdstown, West Virginia, for analysis of trace elements, total alkalinity, total dissolved solids, sulfates, chlorides, bicarbonates, calcium, total cations and total anions. Trace element analysis included scans for arsenic, mercury, and selenium using atomic absorption spectroscopy. Inductively Coupled Plasma Emission Spectroscopy was used to scan for a variety of elements including boron, barium, chromium, copper, lead, selenium, vanadium, and zinc. The ACF provided quality assurance and quality control.

RESULTS

During this three-year inspection period, 1,755 bird carcasses were recovered from 205 oil and gas facilities in Colorado, Kansas, Nebraska, Montana, North Dakota, South Dakota, Utah, and Wyoming (Table 1). In addition to documenting bird mortality in production skim pits and reserve pits, Service law enforcement agents and environmental contaminants specialists documented migratory bird mortality in heater treaters, in dehydrator tanks, and in trays or tanks placed underneath well chemical tanks to contain spills (SPCC trays).

In 2009, the discovery of bird carcasses in dehydrator tanks in southwestern Wyoming resulted in inspections by oil company personnel of an additional 4,255 sites, 123 of which were subsequently closed by the operator. A total of 517 bird carcasses were retrieved from dehydrator tanks in Wyoming in 2009. Most, if not all, the bird carcasses found in dehydrator tanks were songbirds (Order Passeriformes). Subsequently, oil operators retrofitted the openings of dehydrator tanks with netting or wire mesh to exclude birds. Half of the bird carcasses (719) recovered during this investigation were found in dehydrator tanks in Wyoming between 2009 and 2010 (Figure 2).

Reserve pits accounted for 24 percent (333) of the bird carcasses recovered between 2007 and 2010. From 3 to 5 percent of the bird carcasses were recovered from production skim pits, COWDFs, and trays or tanks placed underneath well chemical tanks to contain spills (SPCC trays) (Figure 2). Detailed information on the site or cause of bird mortality was not specified by Service law enforcement agents in 11 percent of the oil and gas facilities with documented bird mortality.

Table 1. Numbers of sites with bird mortality and bird carcasses recovered.

State		Year				
		2007	2008	2009	2010	Total
CO	# Sites # Birds	10 (16)	1 (1)	ND*	ND	11 (17)
KS	# Sites # Birds	1 (2)	ND	ND	4 (5)	5 (7)
MT	# Sites # Birds	16 (59)	ND	1 (2)	ND	17 (61)
ND	# Sites # Birds	14 (25)	14 (22)	7 (8)	5 (6)	40 (61)
NE	# Sites # Birds	3 (4)	1 (1)	ND	ND	4 (5)
UT	# Sites # Birds	ND	ND	4 (47)	ND	4 (47)
WY	# Sites # Birds	10 (43)	11 (135)	108 (1014)	8 (52)	137 (1244)
Total	# Sites # Birds	47 (149)	25 (159)	116 (1071)	17 (63)	205 (1442)

*ND = No Data reported

Service law enforcement agents documented bird mortality in SPCC trays primarily in North Dakota and Wyoming: in 2007 (1 vesper sparrow (*Pooecetes gramineus*)), 2009 (6 birds in one SPCC tray), and 2010 (31 birds in several SPCC trays). Bird mortality in SPCC trays was not common as typically the spill containment trays or tanks are empty and do not contain oil or chemicals. Between 2007 and 2008, Service law enforcement agents inspected heater treaters in 60 sites in Kansas and recovered 6 bird carcasses from three heater/treaters.

Of the 1,755 bird carcasses recovered between 2007 and 2010, approximately 74 percent (1,043) were not taxonomically identified to order, family, or species. Most of the unidentified bird carcasses were recovered from dehydrator tanks (51% of total carcasses recovered). Songbirds (Order Passeriformes) were the primary bird mortality victims in dehydrator tanks. Assuming that all of the bird carcasses retrieved from dehydrator tanks were passerine songbirds, passerine birds (Order Passeriformes) comprised 87 percent of all bird carcasses recovered. Waterfowl (Order Anseriformes) made up 12 percent of all bird carcasses recovered (Figure 3). Waterfowl (Order Anseriformes) and passerine songbirds (Order Passeriformes) made up the majority of bird carcasses, 46 and 49 percent, respectively, recovered from pits (reserve, production skim, and flare pits), open-topped tanks, SPCC trays, and spilled oil in oil and gas facilities.

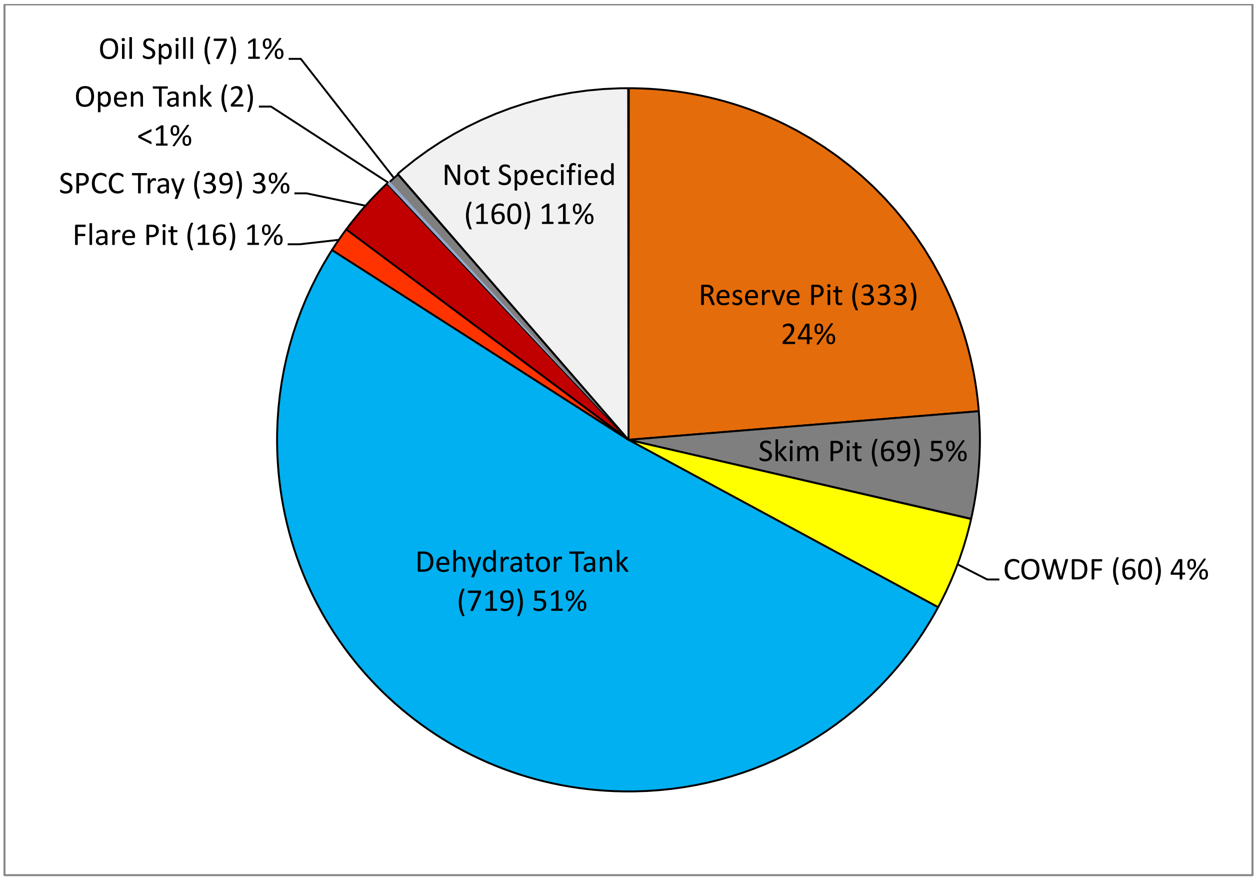

Figure 2. Number of bird carcasses recovered from oil and gas facilities, 2007 to 2010 (number of bird carcasses shown in parenthesis).

Bird carcasses recovered from oil and gas facilities were grouped into the following ecological categories as defined by Trail (2006):

Waterbirds = Podicipediformes + Anseriformes
Wading Birds = Charadriiformes + Gruiformes
Birds of Prey = Falconiformes + Strigiformes
Ground Feeders = Columbiformes + Corvidae + Mimidae + Emberizidae + Icteridae (except *Icterus*) + Fringillidae
Aerial Feeders = Tyrannidae + Hirundinidae

Ground feeders and waterbirds accounted for 48 and 47 percent of all bird carcasses recovered from oil and gas facilities, excluding dehydration tanks (Figure 5). Reserve pits accounted for 76 percent of the mortality of ground feeders and 69 percent of waterbirds (Figures 6 and 7). Water quality results are shown in Tables 3 and 4. Water samples from four COWDFs had high total dissolved solids (TDS) and are classified as hypersaline, salinity higher than (>35,000

TDS). Although salinity classifications for water salinity vary in the literature, most geoscientific literature uses the following terminology: freshwater <3,000 ppm TDS); saline 3 – 35,000 ppm; and hypersaline > 35,000 ppm (Last and Ginn 2005). High concentrations of boron, barium, selenium, and strontium were found in water samples collected from several COWDFs in Wyoming.

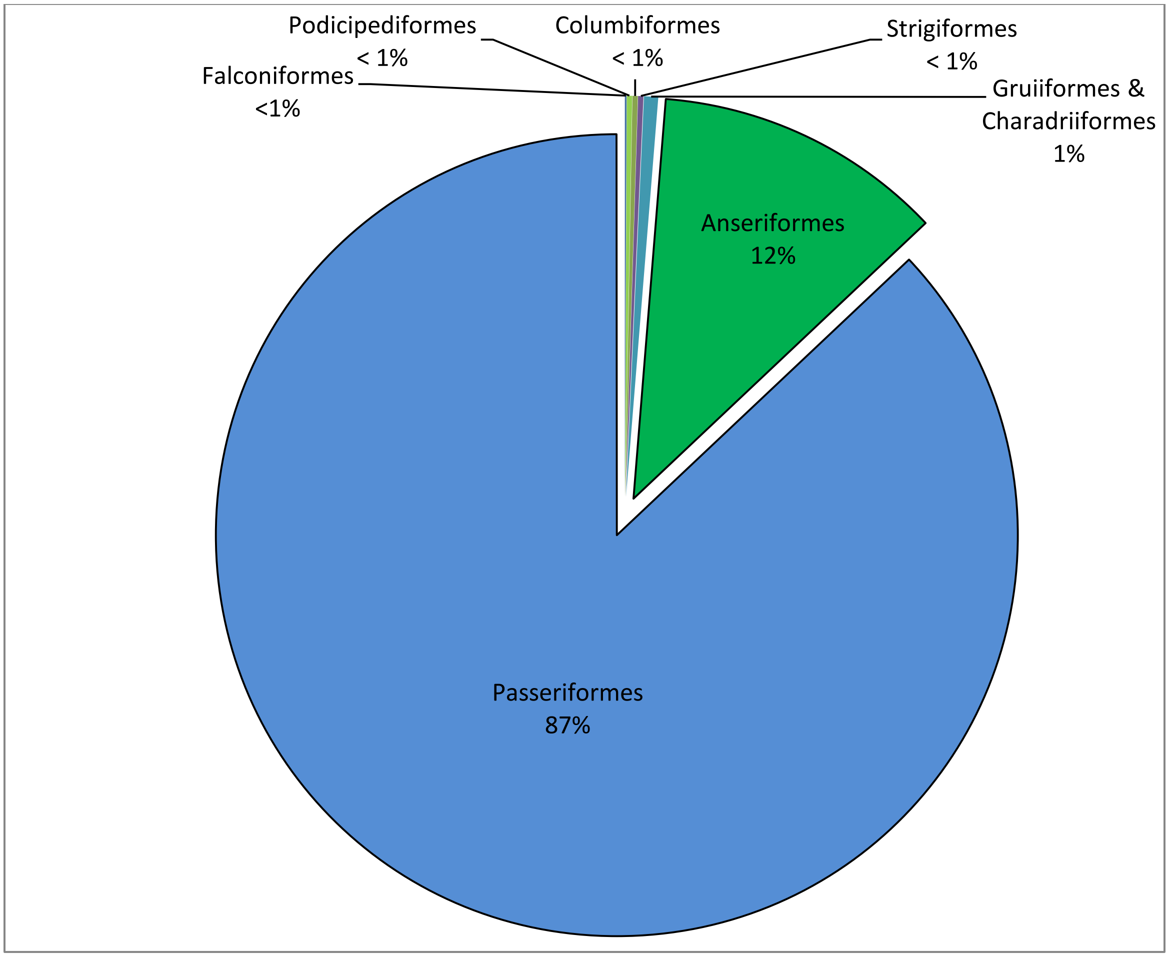

Figure 3. Bird carcasses recovered from oil and gas facilities, including dehydration tanks, summarized by avian order.

Table 2. Bird carcasses recovered from oil and gas sites in Colorado, Kansas, Montana, North Dakota, Nebraska, South Dakota, Utah, and Wyoming between 2007 and 2010.

Order Family Species	**Reserve Pit**	**Skim Pit**	**COWDF**	**Dehy Tank**	**Flare Pit**	**SPCC Tray**	**Open Tank**	**Oil Spill**	**Not Specified**	**Totals**
Waterbirds										
Podicipediformes / Podicipedidae										
Unidentified grebe	1		2							3
Anseriformes / Anatidae										
Blue-winged teal (*Anas discors*)	6		3							9
Green-winged teal (*Anas crecca*)	1								1	2
Unspecified teal (*A. discors* or *A. crecca*)	11	1								12
Gadwall (*Anas strepera*)	4									4
Common goldeneye (*Bucephala clangula*)	1									1
Mallard (*Anas platyrhynchos*)	5	1							4	10
Northern shoveler (*Anas clypeata*)	7									7
Hooded merganser (*Lophodytes cucullatus*)	1									1
Ruddy duck (*Oxyura jamaicensis*)			1							1
Unidentified duck (Anatidae)	79	3	35							117
Wading Birds										
Gruiformes / Rallidae										
American coot (*Fulica americana*)			2							2
Charadriiformes										
Charadriidae										
Killdeer (*Charadrius vociferus*)	1									1
Scolopacidae										
Red-necked phalarope (*Phalaropus lobatus*)	1									1
Common snipe (*Gallinago gallinago*)	1									1
Unspecified shorebird (*Scolopacidae*)	2									2
Laridae										
Unspecified gull (*Larus* species)	1									1
Falconiformes / Falconidae										
American kestrel (*Falco sparverius*)					1					1
Strigiformes / Strigidae										
Great-horned owl (*Bubo virginianus*)	1	1								2
Unspecified owl (Strigidae)	1									1

Order Family Species	Reserve Pit	Skim Pit	COWDF	Dehy Tank	Flare Pit	SPCC Tray	Open Tank	Oil Spill	Not Specified	Totals
Ground Feeders										
Columbiformes / Columbidae										
Mourning dove (*Zenaida macroura*)	1								2	3
Passeriformes										
Corvidae										
Raven (*Corvus corax*)	1									1
Mimidae										
Gray catbird (*Dumetella carolinensis*)					1					1
Emberizidae										
Vesper sparrow (*Pooecetes gramineus*)	1				1	1				3
Lark sparrow (*Chondestes grammacus*)	1								1	2
Lark bunting (*Calamospiza melanocorys*)		1								1
Song sparrow (*Melospiza melodia*)	1									1
Unspecified sparrow (Emberizidae)		1							1	2
Icteridae										
Red-winged blackbird (*Agelaius phoeniceus*)								1		1
Unspecified meadowlark (*Sturnella* species)									2	2
Unspecified blackbird (*Agelaius* species)					2					2
Brewer's blackbird (*Euphagus cyanocephalus*)					2					2
Common grackle (*Quiscalus quiscula*)					2					2
Brown-headed cowbird (*Molothrus ater*)					1					1
Fringillidae										
Gray-crowned rosy finch (*Leucosticte arctoa*)	116									116
Unspecified passerine (Passeriformes)	11	19			2				2	34
Aerial Feeders										
Tyrannidae										
Eastern kingbird (*Tyrannus tyrannus*)					1					1
Western kingbird (*Tyrannus verticalis*)	1									1
Unspecified kingbird (*Tyrannus species*)								2	1	3
Unspecified flycatcher (Tyrannidae)					1					1
Hirundinidae										
Barn swallow (*Hirundo rustica*)								1		1
Unidentified birds	76	42	15	719	2	38	2	3	146	1,043
Totals	333	69	58	719	16	39	2	7	160	1,403

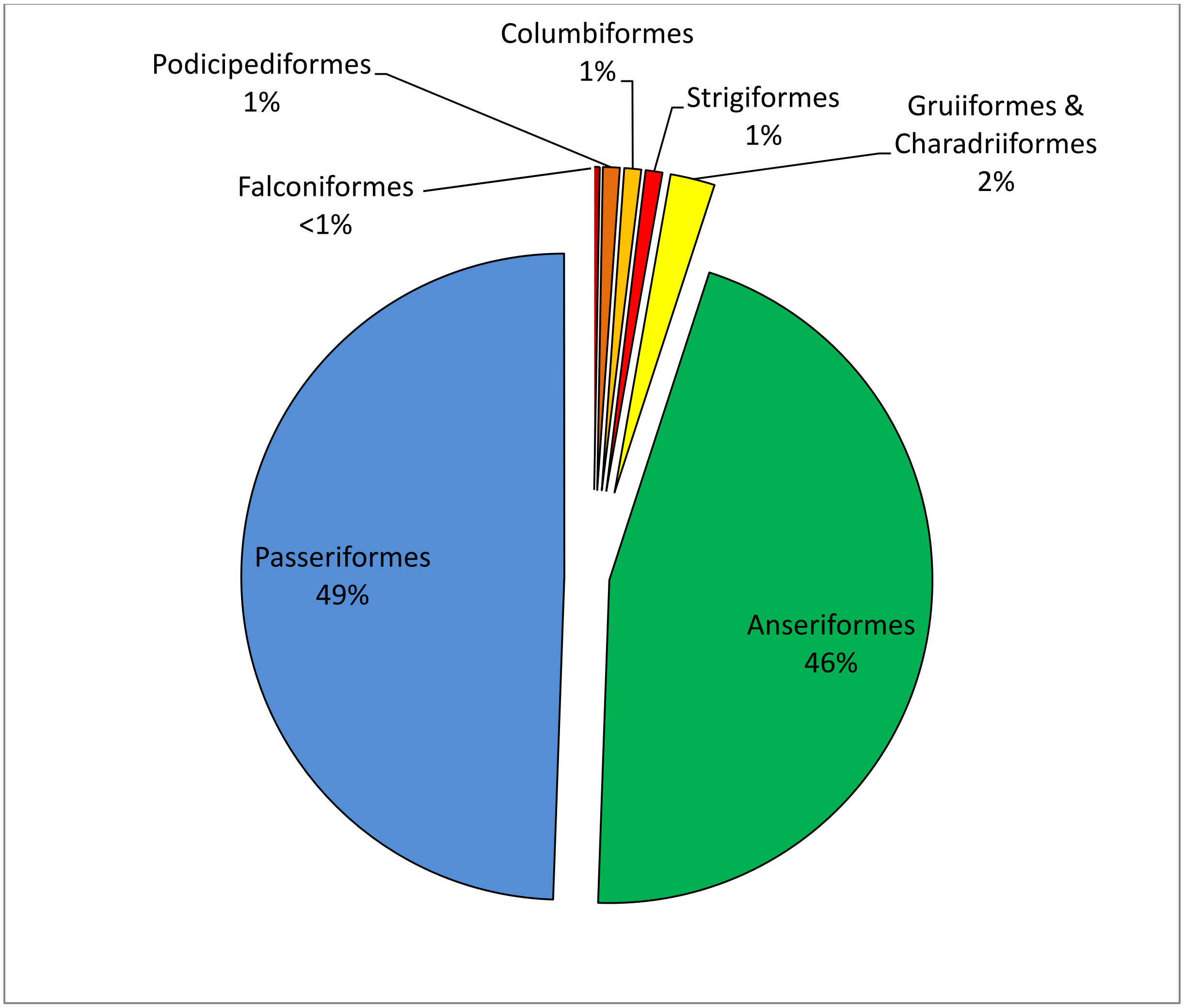

Figure 4. Bird carcasses recovered from oil and gas facilities, excluding dehydration tanks, summarized by avian order.

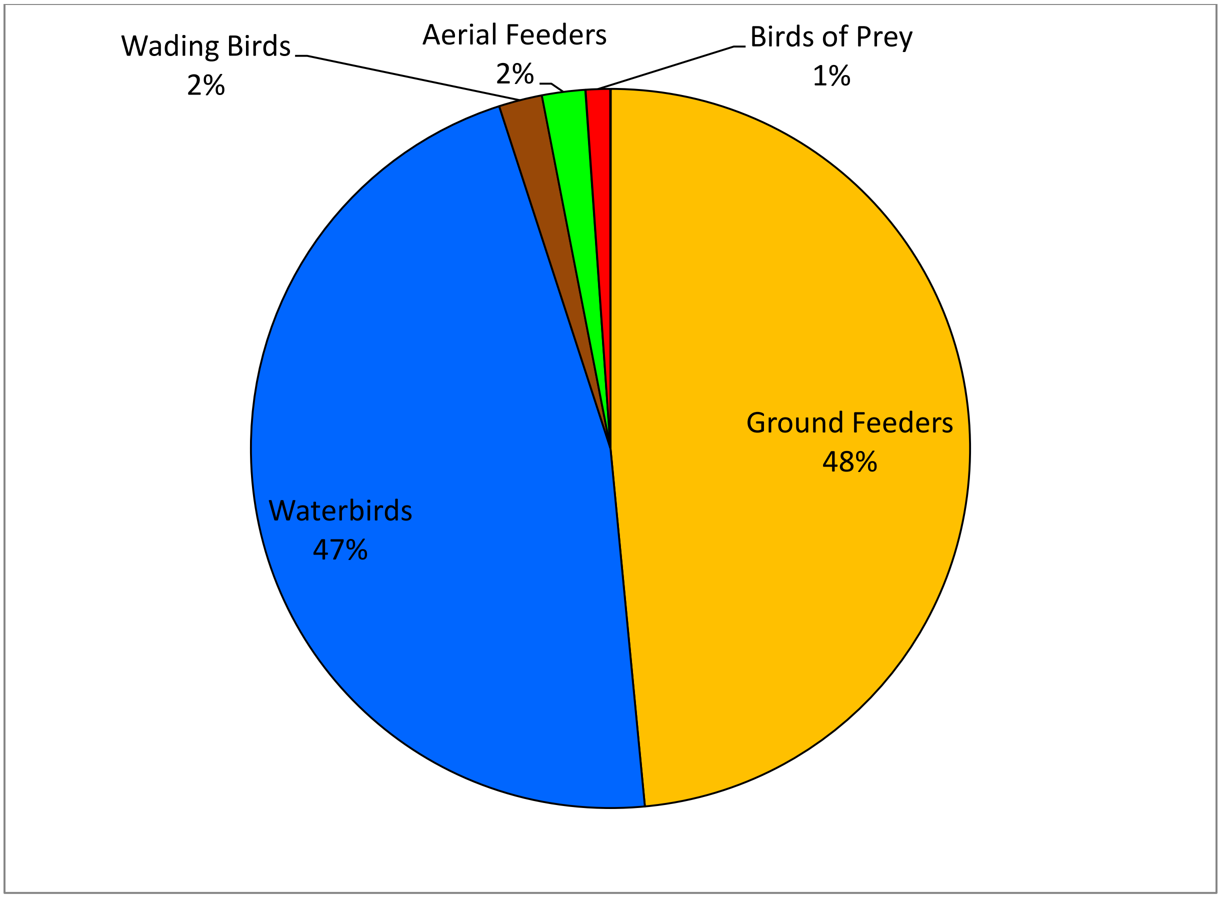

Figure 5. Bird mortality in oil and gas facilities by ecological category, excluding dehydration tanks.

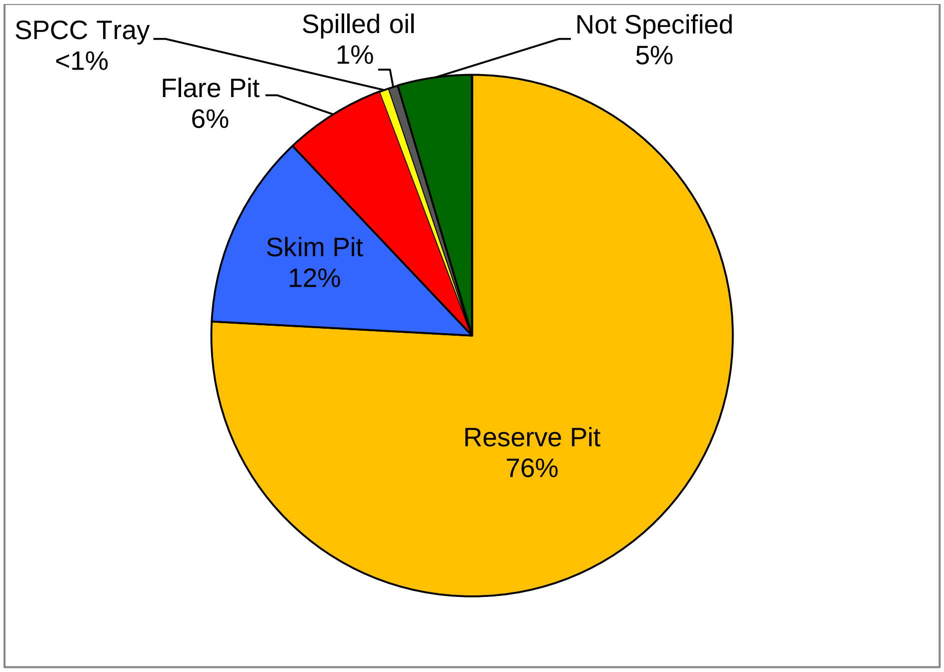

Figure 6. Mortality of Ground Feeding birds by oil and gas site type, excluding dehydration tanks.

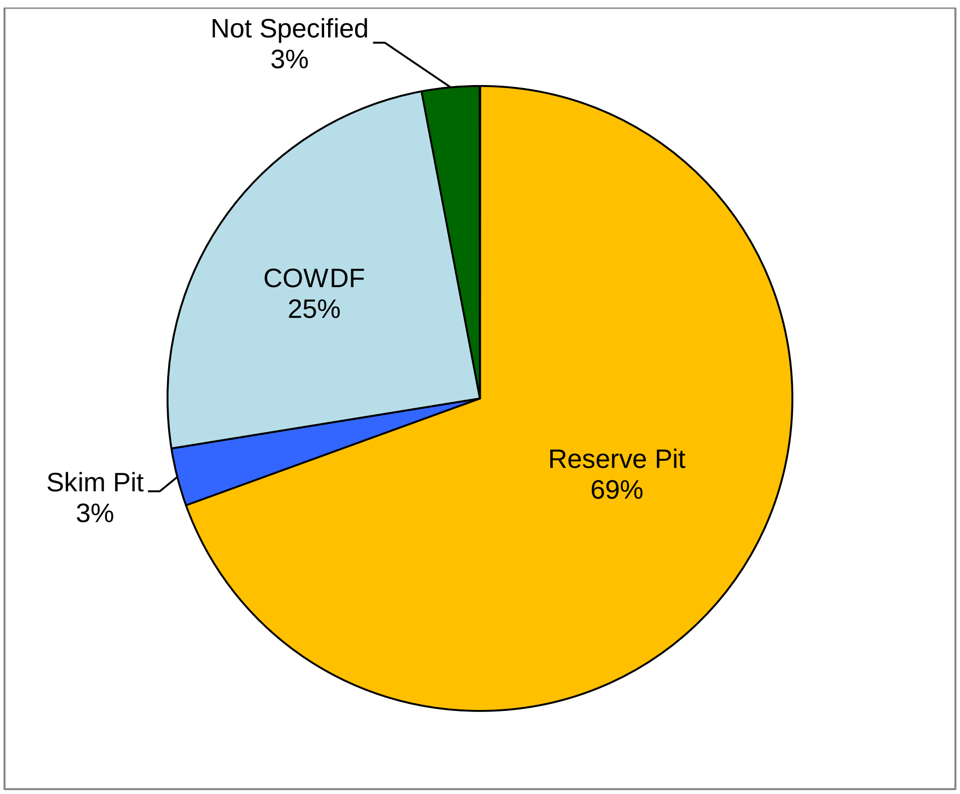

Figure 7. Mortality of Waterbirds by oil and gas site type.

Table 3. Trace element concentrations (in ug/L) in wastewater from oilfield wastewater disposal facilities in Wyoming.

COWDF #	CAM 1	CON 1	CON 2	CON 2	JOH 1	SWE 1	SWE 1	SWE 2	SWE 3	WAS 1	UIN 1
Sample ID	JWSMB1	JWS CANNON01	JWSW1	JWS WERNER01	HPR01	SWH COWDF1	SWH COWDF01	BPW COWDF01	RGSC COWDF01	ODS COWDF01	DB COWDF1
Date Collected	13-Apr-09	26-May-11	14-Apr-09	26-May-11	13-May-09	8-Jun-09	6-May-11	6-May-11	5-May-11	16-May-11	8-Jun-09
Al	< 2,500	<1000	< 2,500	<1000	< 2,500	< 2,500	<1000	<1000	<1000	<1000	< 2,500
As	168	36.9	0.168	107	< 0.0250	0.0404	75.4	95.4	80.9	162	0.0301
B	50,600	25,500	50.6	35,400	5.76	28.7	53,700	87,400	33,900	56,300	30.9
Ba	6,470	18,600	6.47	33,000	0.857	30.1	31,100	<10	<10	<10	< 25
Be	< 25	<10	< 25	<10	< 25	< 25	<10	29,100	674,000	133,000	
Cd	< 25	<5	< 25	<5	< 25	< 25	5.6	<5	<5	<5	< 25
Cr	<50	<20	<50	<20	<50	<50	29	22	43	67	<50
Cu	0.497	138	0.497	249	< 0.0500	0.143	232	486	185	89	0.067
Fe	< 2,500	9,920	< 2,500	15,400	8.56	3.58	2,210	<0.25	0.32	<0.25	<0.05
Hg	<0.05	<0.25	<0.05	<0.25	<0.05	<0.05	<0.25	362,000	1,380,000	1,490,000	575,000
Mg	179,000	45,600	179,000	292,000	17,900	67,400	176,000	71,100	67,000	111,000	23,300
Mn	63.9	420	63.9	1,370	736	2,370	56	15.4	28.3	31.6	0.0475
Mo	< 25	18,300	< 25	<10	< 25	< 25	<10	27,800,000	10,800,000	5,570,000	3,880,000
Ni	25.9	23.9	25.9	91.5	< 25	36.4	53.2	178	45.2	35.3	25.7
Pb	<50	<20	<50	<20	<50	<50	<20	<20	<20	<20	<50
Se	411	487	411	492	<250	<250	330	701	440	<100	<250
Sr	12,800	21,800	12,800	61,300	7,020	19,700	20,300	7,590	31,500	5,980	13,800
V	94	<100	94	<100	<50	<50	<100	<100	<100	<100	<50
Zn	<500	<200	<500	<200	<500	<500	<200	<200	201	<200	<500

Table 4. Ion concentrations (in mg/L) in wastewater from oilfield wastewater disposal facilities in Wyoming.

COWDF Site #	Sample Id	Date Collected	Calcium Ca	Chlorides Cl(-)	Sodium Na	Sulfates SO4(-2)	Total Dissolved Solids TDS
UIN 1	DBCOWDF2	8-Jun-09	267	6,800	3,580	86	12,000
JOH 1	HPR01	13-May-09	364	5,400	3,190	< 50.0	9,900
CON 1	JWSCANNON01	28-May-11	122	8,479	8,920	18	31,497
CAM 1	JWSMB2	13-Apr-09	54	43,000	26,900	210	73,000
CON 2	JWSW2	14-Apr-09	4,960	34,000	12,000	< 50.0	58,000
CON 2	JWSWERNER01	28-May-11	1,829	21,250	12,820	422	47,035
WAS 1	ODSCOWDF01	16-May-11	53	842	4,350	621	19,841
SWE 2	RGSCCOWDF01	5-May-11	276	2,506	10,800	102	36,842
SWE 3	SWHCOWDF2	8-Jun-09	397	17,000	10,600	< 50.0	35,000

DISCUSSION

Service law enforcement agents and Environmental Contaminants Specialists documented bird mortality in a variety of sites at oil and gas facilities: COWDF evaporation ponds and skim pits, reserve pits, production skim pits, flare pits, and open-topped tanks as well as in oil spilled in oil production facilities. These are the same type of sites where previous investigators have documented bird mortality (EPA 2003, Flickinger 1981, Grover 1983, Lee 1990, Esmoil and Anderson 1995, Ramirez 2005, Trail 2006, and Ramirez 2010). In addition to the above sites, bird mortality was also documented in dehydrator tanks and SPCC trays during this investigation. Bird mortality in dehydrator tanks was initially documented by Service law enforcement agents in Wyoming in 2009. Half of all bird carcasses (719) recovered in this multi-state investigation were recovered from dehydrator tanks in Wyoming. The large number of carcasses found in dehydrator tanks can probably be attributed to the ease of detection and recovery of carcasses from these tanks compared to the larger reserve pits and production skim pits. The dehydrator tanks typically range from 4 to 6 feet in diameter and 3 to 5 feet in height with a partially covered top (Figure 8).

Figure 8. Dehydrator tank with a partially-covered top.

The large number of bird carcasses (719) recovered from dehydrator tanks compared to pits and open-topped tanks is in large part due to the small size of the dehydrator tanks, and the containment of the carcasses. Birds entering and dying in the dehydrator tanks quickly succumb to oiling and are unable to climb or fly out. Scavengers are unable to access the carcasses and remove them from the dehydrator tanks. Birds entering the dehydrator tanks are probably attracted to these vessels by insects entrapped in the fluid. Horvath and Zeil (1996) suggest that insects are attracted to oil surfaces because light reflected off the oil "closely mimics the polarization and reflectivity characteristics of water." The scale of bird mortality in dehydrator tanks may be indicative of higher bird mortality that goes undetected in production skim pits, reserve pits, and COWDF evaporation ponds where the pit and pond surface areas are much larger and bird carcasses can go unobserved due to their removal by scavengers, or people. Birds that do manage to escape typically seek a place to hide, such as under vegetation, where they eventually die. Additionally, bird carcasses in pits or COWDF evaporation ponds can sink into the pit or pond fluids within a very short time frame (Flickinger and Bunck 1987).

Reserve pits accounted for 24 percent of the bird carcasses recovered at oil and gas facilities. Most of the bird mortality in reserve pits occurs after well completion when the drilling rig and associated equipment have been removed from the well pad. Colorado, Kansas, Nebraska, Montana, North Dakota, South Dakota, Utah, and Wyoming allow oil operators one year after well completion to close reserve pits (Ramirez 2009). If the reserve pit contains condensates, oil or other hydrocarbons or harmful well stimulation chemicals, the risk of mortality to birds landing in the pits is high. Reserve pits accounted for 24 percent (333) of the bird carcasses recovered between 2007 and 2010. An increase in drilling activity in Colorado, North Dakota, Utah, and Wyoming and the associated increase in the number of reserve pits may account for the large amount of bird mortality in reserve pits. Reserve pits are not typically covered with netting to exclude birds and other wildlife probably due to the expense and logistics of installing netting and having to remove it just prior to the closure of the pit up to a year after well completion. Reserve pits accounted for 76 percent of the mortality of ground-feeding songbirds and 69 percent of aquatic birds.

Ground-feeding songbirds and waterbirds accounted for 48 and 47 percent of all bird carcasses recovered from oil and gas facilities, excluding dehydration tanks. Ground-feeding birds are more susceptible to mortality in pits, SPCC trays, and spilled oil, especially if insects are entrapped in the oil. If ground-feeding birds walking along the edge of pits or entering the SPCC trays come into contact with oil, they may become entrapped in the fluids and die.

Of the states investigated between 2007 and 2010, bird mortality in reserve pits was observed in Colorado, North Dakota, Utah and Wyoming. Three of these states, (Colorado, North Dakota, and Wyoming had the highest amount of drilling activity (Figure 9) and, thus, were expected to have the most number of reserve pits. Colorado experienced the highest drilling activity in 2007 and 2008, while drilling was highest in North Dakota in 2010. Reserve pits comprised the biggest threat to birds at oil and gas facilities in North Dakota. In Utah, reserve pits comprised 77 percent of the sites with bird mortality in 2009. In Wyoming, reserve pits accounted for 13 to 52 percent of the sites with bird mortality during the study period. The North Dakota Oil and Gas Division amended the state oil and gas rules in April 2012 to prohibit the use of reserve pits for wells drilled below a depth of 5,000 ft (1,524 meters). North Dakota promulgated the rule change in response to spring flooding in 2011 which caused several reserve pits to overflow and discharge pit fluids onto adjacent lands and wetlands (McEnroe and Sapa 2011).

COWDFs and production skim pits accounted for four and five percent, respectively, of the bird carcasses recovered at oil and gas facilities. The low numbers may be due to proactive measures facility operators are taking to prevent bird mortality at COWDFs and production skim pits such as netting small pits and keeping large evaporation ponds free of oil. Past inspections of COWDFs in Wyoming conducted by the Service, EPA, and Wyoming Department of Environmental Quality between 1998 and 2008 documented oil in COWDF evaporation ponds in half of 154 inspections conducted over a 10-year period (Ramirez 2010). Between 1997 and 2001 the US EPA, Service and other state and federal regulatory agencies inspected a total of 36 COWDFs in Colorado, Utah, and Wyoming (EPA 2003). In Wyoming, the EPA (2003) documented problems, including oil in evaporation ponds in all (100%) of the COWDFs inspected in 1997 and 1998. The EPA (2003) also documented oil in COWDF evaporation ponds in Colorado. Most of the COWDFs initially inspected in

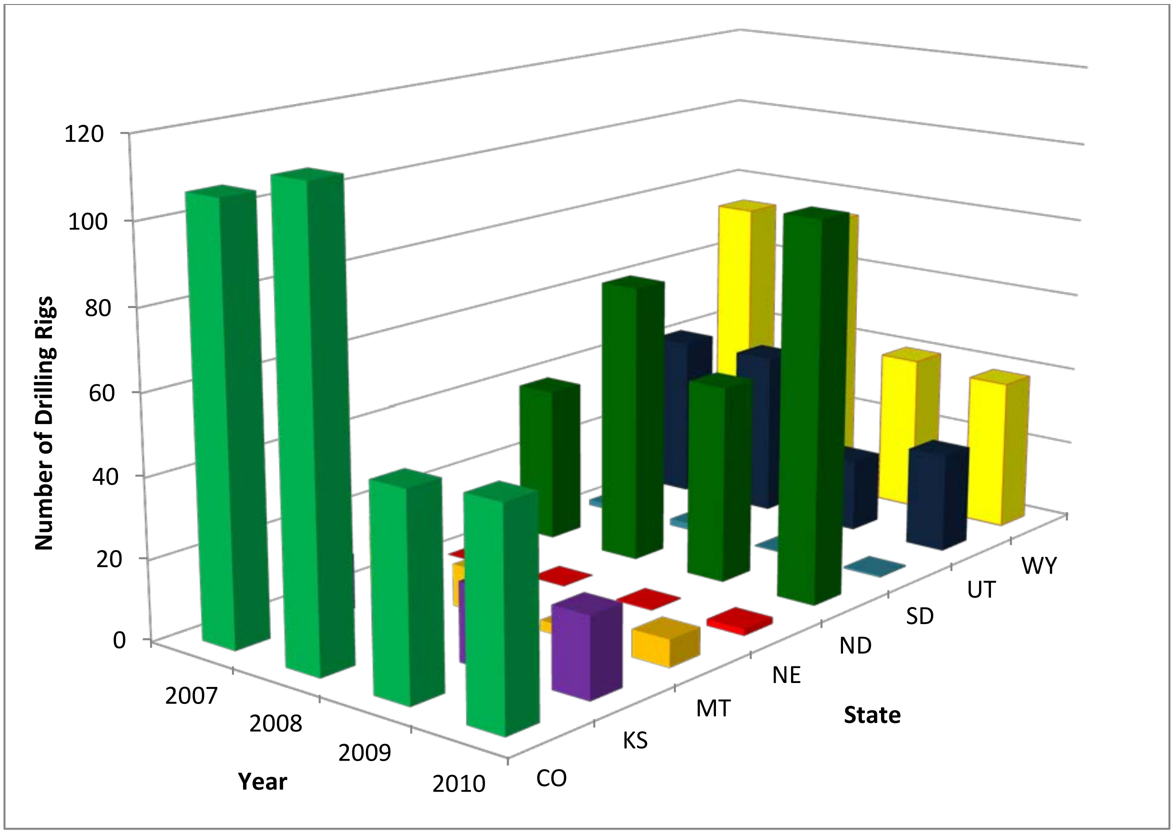

Figure 9. Number of drilling rigs in the study area, 2007- 2010 (Baker Hughes 2012).

Wyoming by the EPA and the Service in 1997 and 1998 were permitted and constructed between 1980 and 1982. Wyoming had a total of 22 COWDFs in 2001. The increase in natural gas drilling and production after 2005 led to a concurrent increase in the permitting and construction of additional COWDFs for the disposal of produced water from natural gas wells.

To accommodate the increase in wastewater disposal from the increase in natural gas drilling and production, the number of COWDFs in Wyoming increased from 22 facilities in 2001 to 26 in 2012. The majority of the new COWDFs were permitted and constructed in Carbon, Converse and Sweetwater Counties to provide disposal facilities for water produced from natural gas fields to the north and south of Wamsutter in Carbon and Sweetwater Counties and oilfields between Douglas and Bill, Wyoming. Oil operators in Wyoming generally have three options for disposal of produced water: surface discharge, deep injection well disposal or disposal in a COWDF. Surface discharge of produced water is an accepted option if the water meets State water quality standards. Formation water produced from conventional natural gas wells is typically 10 times more toxic than produced water from oil wells and cannot be discharged into surface waters (Jacobs et. al. 1992). Oil operators in Wyoming typically opt to dispose of poor quality produced water in COWDFs as deep well injection is more expensive.

Hypersaline conditions result in COWDF ponds from the continual concentration of dissolved solids (salts) due to evaporation. Two of the four COWDFs with hypersaline water have been operational for over 25 years and two for 10 to 15 years. Hypersaline conditions also decrease the evaporation rate of water (Hammer 1986). Over time, the remaining COWDFs are likely to become hypersaline. One of the risks to aquatic birds that land on hypersaline COWDF evaporation ponds is the crystallization of salts from the super-saturated water onto the birds' feathers. Salts crystallizing on feathers disrupt feather morphology and allow water to penetrate through the feathers and onto the skin; thus causing hypothermia and mortality (Sladky et. al. 2004). Bird mortality due to salt crystallization is known to occur in hypersaline industrial wastewater ponds (Meteyer et. al. 1997, Sladky et. al. 2004, Jehl et. al. 2012). Additionally, evaporation concentrates trace elements such as boron, selenium and strontium in the wastewater; however, we expect that there would be low risk of avian exposure to these elements through ingestion because we did not observe aquatic invertebrates or submerged aquatic vegetation at these sites during our inspections and perhaps because salinity concentrations observed at COWDF evaporation ponds are not favorable to aquatic life.

Production skim pits accounted for five percent of the bird carcasses recovered at oil and gas facilities, a decrease from nine percent in the late 1990's. EPA (2003) documented bird mortality in 9 percent of oil and gas sites inspected between 1997 and 1999 in Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. Approximately 51 percent of the pits surveyed by the EPA (2003) in the 1990's had oil on the surface. In general, the threat of production skim pits to wildlife has been reduced in the past decade due to proactive efforts made by the oil industry, including closing production skim pits, removing oil from pits, and or enclosing production skim pits with netting to exclude wildlife. Bird mortality problems currently stem from poorly maintained netting (holes in the netting, and or nets sagging into the pit fluids), and upsets in the oil-water separation resulting in the discharge of oil into uncovered secondary or tertiary production skim pits.

Passerine songbirds (order Passeriformes) comprised most of the bird mortality (87 percent) followed by waterfowl (order Anseriformes) (12 percent). In comparison, Trail (2006) determined that passerine songbirds and waterfowl comprised 62 and 10 percent of all bird remains recovered from oil pits by the Service from 1992 to 2005. Trail (2006) attributed the low number of waterfowl to the reduction in the size of oil pits. Conversely, Grover (1983) reported a mortality pattern comprised of 37 percent songbirds and 33 percent ducks. Ground feeders and waterbirds comprised 48 and 47 percent, respectively, of the carcasses recovered in this study, dehydration tanks excluded. Trail (2006) found that ground feeders and water birds accounted for 63 and 12 percent, respectively, of avian mortality in oil pits. Reserve pits potentially present a greater hazard to waterbirds as these pits are typically not netted to exclude wildlife as are production skim pits. Additionally, reserve pits are generally two to four times larger than production skim pits (Ramirez 2005 and 2009) and may be more attractive to waterbirds than production skim pits. Esmoil and Anderson (1995) found increased mortality with increased pit size and Lokemoen (1973) reported pond size as a significant factor affecting duck use.

Past reports on bird mortality in oil pits showed large numbers of waterfowl mortality in large pits and produced water impoundments located in drainages (Bloch 1964, King 1956, Lee 1990). In the 1960's and 1970's oil operators disposed of produced water and waste oil into natural basins or by creating impoundments in natural drainages (Bloch 1964, Grover 1983, Lee 1990). Bloch (1964) reported 1,000 duck carcasses in a series of three oil pits created by constructing berms in a natural drainage. The three pits ranged in size from 200 by 300 ft (61 to 91 meters) up to 600 x 900 ft (183 to 274 meters). Lee (1990) described an "oil-covered alkali basin" in Texas that killed hundreds of ducks and grebes in 1976. The use of large earthen pits up to six acres (2.4 hectares) in size to store oil and oilfield waste was a common industry practice in the early 1900's (Barrett 2001). The discharge of produced water and waste oil into impoundments in natural drainages was probably a common practice in Wyoming during the early 1900's (Hancock 1921) (Figure 10). This practice has largely been eliminated (Lee 1990); however, in Wyoming, produced water meeting water quality standards and legally discharged into streams can be impounded to benefit livestock and wildlife. The produced water typically flows through a heater treater and production skim pits to remove the oil. Malfunction of the heater treater or the production skim pit can result in oil discharges into streams and downstream impoundments posing a risk to birds and other wildlife. Although the disposal of waste oil into natural basins or large impoundments is no longer an accepted industry practice, large evaporation ponds in COWDFs pose a risk to migrating birds especially if these ponds contain oil or eventually become hypersaline. The risk increases during times of drought when the availability of wetland habitat is limited.

The absence of observed bird mortality may lead oil operators and COWDF operators into complacency; however, bird mortalities in oil and gas facilities appear to be episodic. There may be long periods without incident, but then a large number of birds may be killed during short periods, such as migration. Grover (1983) found that in southeastern New Mexico, wildlife losses in oil pits during the summer consisted of inexperienced, recently fledged or weaned wildlife. During the fall, waterfowl and shorebirds were the primary victims of oil pits. Esmoil found a disproportionate number of loggerhead shrikes (*Lanis ludovicianus*) killed during a two-week period that coincided with fledging (Ramirez 2010).

MANAGEMENT RECOMMENDATIONS

Although the oil industry has taken proactive measures to minimize risks to birds and other wildlife at oil and gas production facilities and COWDFs, oil and COWDF operators should implement the following best management practices (BMPs) to prevent wildlife mortality at oil and gas exploration and production facilities:

- Use closed containment systems to store oil, condensate, or other hydrocarbons at oil and gas exploration and production facilities;
- Eliminate the use of pits to store drilling fluids, produced water, or other wastes;
- If pits or ponds must be used, install effective wildlife exclusionary devices to prevent wildlife access to pits and ponds;
- Buckets, trays, or open-topped vessels used to contain drips or leaks should be covered with wire mesh or netting to prevent entry by bird and other small animals;

- If evaporation ponds are used for water disposal, implement engineering controls to prevent the discharge of wastewater containing oil and surfactants into the evaporation pond; and
- Where possible, use deep well injection of oilfield wastewater to eliminate the need for evaporation ponds and the risk to migratory birds and other wildlife from exposed oil, surfactants and hypersaline conditions.

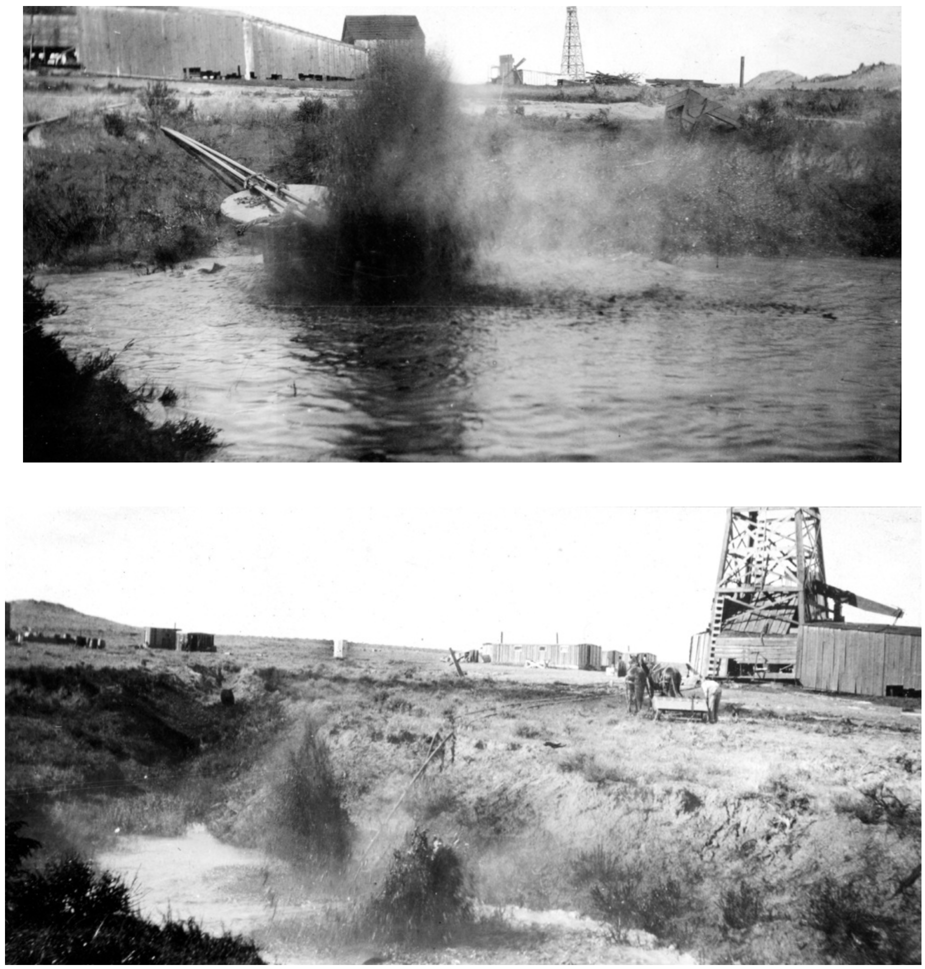

Figure 10. Discharge of oil into a dammed up gulch, Lance Creek field, Niobrara County, Wyoming, 1918 (USGS Historical Photos) (Hancock 1921).

Continued wildlife mortality incidents at oil and gas production facilities and COWDFs necessitate continued inspections of these facilities by regulatory agencies to ensure compliance with applicable environmental and wildlife protection laws. Single inspections reveal only a small fraction of the annual avian mortality in an oil pit or sink and remain undetected within a very short time frame, as few as 4 days in warmer months (Flickinger and Bunck 1987). Carcasses present in or near the edges of pits can be removed by scavengers such as coyotes, raccoons, and raptors or by people. Flickinger and Bunck

(1987) recommended that pits be inspected at least once a week to document all passerine mortality in summer, with inspections at least every three weeks in winter.

Trail (2006) proposed a total of 24 inspections from March through October to document most bird mortality in oil pits. The proposed inspections should consist of two inspections per month in March, April, September, and October; and four inspections per month in May, June, July, and August.

Inspections of oil and gas facilities should not be limited to production skim pits, reserve pits, and open-topped tanks. Puddled oil from leaking valves, pipes, and wellheads will also entrap small mammals, small reptiles such as lizards, and songbirds. Open-topped drip buckets placed under valves to catch oil drips can also entrap small wildlife. Service biologists have documented birds entrapped in small puddles of oil spilled on the ground (Figure 11).

Figure 11. Horned lark entrapped in puddle of oil at an oil production facility in Wyoming.

Detailed field notes should include the specific location and probable cause of the mortality incident (i.e. reserve pit, production skim pit, dehydration tank, open-topped tank, etc.). This data would serve to document specific problem areas or hazards to birds at oil and gas facilities and assist in developing solutions or best management practices (BMPs) to minimize or eliminate those hazards.

Although the cause of most bird mortality incidents at oil and gas exploration and production facilities and COWDFs involves exposure to oil or other hydrocarbons, bird carcasses with no obvious signs of external oiling should be submitted for necropsy to determine if mortality was caused by salt crystallization or exposure to other substances such as surfactants or other chemicals.

Outreach efforts should continue to encourage industry to implement BMPs to eliminate or minimize risks to migratory birds and other wildlife at oil and gas production facilities and COWDFs. Since 75 percent of all bird mortalities were documented in dehydration tanks and reserve pits, outreach efforts should focus on informing the oil industry about these two hazards. Manufacturers of dehydration tanks should design these containers with smaller openings covered with a small meshed screen to prevent entry by birds.

Outreach efforts should encourage drilling contractors and oil operators to use closed loop drilling systems and eliminate the use of reserve pits. Closed loop drilling systems eliminate the risk to birds and also reduce the amount of drilling waste, recycle drilling fluids, and reduce drilling costs (Ramirez 2009). Eliminating the use of reserve pits will also eliminate the risk of soil, groundwater, and surface water contamination (Ramirez 2009).

State and federal agencies should increase the monitoring of COWDFs for surface and groundwater contamination. Air emissions of volatile organic compounds (VOCs) from COWDF evaporation ponds should also be monitored. Most COWDFs use sprayers or evaporators to enhance the evaporation of wastewater (Ramirez 2010). The sprayers can exacerbate the emissions of VOCs from the evaporation ponds as well as cause the aerial drift of hypersaline wastewater outside of the facility boundary thus adversely impacting soils and vegetation. Regulatory agencies should also monitor COWDF evaporation ponds for hypersaline conditions that could cause bird mortality. Surfactants from flowback water disposed of into COWDFs can reduce water surface tension and pose a hazard to birds landing on the evaporation ponds (Ramirez 2010).

Although biologists and wildlife law enforcement agents have conducted numerous investigations of bird mortality in oil pits, research is needed in the following areas to better manage oil and gas exploration and production facilities and COWDFs to prevent bird and other wildlife mortality:

- the persistence of surfactants in hydraulic fracturing flowback water and risks to birds if the flowback water is disposed in COWDFs and reserve pits;
- the impacts of aerial drift from COWDF evaporation-enhancing sprayers to resident wildlife and their habitats;
- the effects of volatile organic compound emissions from COWDFs on resident birds and other wildlife; and
- the efficacy of decoy wetlands used to lure aquatic birds away from COWDF evaporation ponds.

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