



Regulating oil and gas facility stormwater discharge: An assessment of surface impoundments, spills, and permit compliance

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ABSTRACT

Contaminated stormwater runoff from oil and gas (O & G) operations can pose a significant threat to surface waters. The purpose of this study is to examine the extent of this threat and identify more specific permitting requirements to protect surface waters. To better understand the extent of the threat, this paper identified and characterized the use of waste surface impoundments at O & G facilities as well as the threat level from O & G spills in California. To assess the efficacy of the current federal and California state-permitting regime, the paper evaluated stormwater permit compliance in two California counties. It also reviewed selected spill cases and associated Spill Prevention, Control and Countermeasure Plans and Stormwater Pollution Prevention Plans to identify the adequacy of current industry practices.

The analysis showed that contaminated stormwater from O & G facilities can be better regulated. The U.S. Environmental Protection Agency does not require O & G facilities to file for an Industrial Stormwater General Permit even though many O & G industry practices have the potential to contaminate stormwater runoff from the site. When O & G facilities discharge a Reportable Quantity of a hazardous chemical or violate a water quality standard, they are required to enroll in the National Pollutant Discharge Elimination System permit program. Spills, although not a direct indication of stormwater runoff, can highlight polluted runoff discharges that should have been regulated. Medium and large spills that reached waterways were such a risk for which operators did not file for a permit. In California new filing requirements for the oil and gas industry require all facilities that discharge stormwater that has come into contact with any overburden, raw material, or intermediate products located on the site, to file for an Industrial Stormwater General Permit. As this study showed, there has been an increase in enrollment since the enactment of the new requirements. Having all facilities enroll in the general permit program, as done in California, would require minimum monitoring and maintenance that could help prevent spills. A further step to ensure better protocol is to require specific pollution control practices in addition to the current general permit requirements. Such permitting regimes not only can be implemented on the US federal level but also internationally.

1. Introduction

O & G exploration and development is a large global industry, and it is likely to expand in the near future due to technological advances and the increased cost-effectiveness of unconventional oil stimulation techniques. With increased activity, there are a variety of ways in which pollutants can get into our waterways, especially if the activity goes unregulated: stormwater transports debris, chemicals, sediment and other pollutants that may adversely impact wildlife, cause algae blooms and increase flooding. Due to an exemption, stormwater runoff from oil and gas drilling sites is not regulated under the National Pollutant Discharge Elimination System (NPDES).

There are many O & G field operations that can contribute to

contamination of stormwater. They include but are not limited to drilling and production equipment and other machinery, raw materials, waste products and by-products, O & G treatment units, finished products, storage areas, fuels and lubricants, and waste treatment areas (US EPA, 2006). For more details on the activities, pollutant sources, and pollutants that are commonly found at O & G extraction facilities see the supplementary section.

Construction activity is a major source of pollutant discharge, both from sediment and also the equipment and materials used. O & G construction sites have the potential to produce as much sediment as other types of construction sites (McBroom et al., 2012; Williams et al., 2008). Well drilling, well stimulations, and well production are all sources of increased total suspended solids (TSS), total dissolved solids

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(TDS), and pollutants including oil and grease as well as a large variety of hazardous chemicals listed as chemicals requiring reporting under the Clean Water Act (US EPA, 2006).

Vehicles and equipment on site are another source of TSS, TDS, oil and grease, and pH alterations. Oil fields with more wells are greater threats to stormwater pollution. Well density is positively correlated with in-stream turbidity measurements (Entekin et al., 2011) and increased TSS concentrations (Olmstead et al., 2013).

Another source of contamination are surface impoundments that are often used to store a variety of potentially toxic, as well as non-hazardous liquid and solid wastes associated with O & G development. Although no studies have looked at the impact of stormwater runoff from surface impoundments, the chemicals may leach into groundwater; contaminate soils and vegetation; or overflow from the sides of the impoundment—either during a rain event, or due to inadequate storage—and pollute soil and surface waters.

The purpose of this study is to identify the extent that O & G exploration and production operations threaten surface water and identify more specific permitting requirements to eliminate the exposure of O & G operations to stormwater runoff and/or to control pollutants in discharges to protect surface waters. To determine if a significant threat exists—which if it does exist, the US EPA Regional Administrator may designate additional stormwater discharges as requiring NPDES permits—this paper identified and characterized the use of waste surface impoundments at O & G facilities and highlighted risks from spill reports, quantifying the occurrence rate of medium and large sized spills as well as whether they came in contact with waterways.

To identify more specific permitting requirements the paper identified areas of improvement in the current federal and California state regulatory framework for managing direct and indirect discharges from O & G development. To do so the paper reviewed Industrial Stormwater General Permit compliance and current unconventional oil stimulation stormwater permit compliance given the increase in this practice in two California Counties. It also reviewed selected spill cases and associated Stormwater Pollution Prevention Plans (SWPPP) and Spill Prevention, Control and Countermeasure (SPCC) plans to identify adequacy of current industry practices.

1.1. Oil and gas exploration and production stormwater regulations

The Clean Water Act regulates the treatment and discharge of wastewater into surface waters of the United States. It sets national standards for industrial wastewater discharges to surface waters – which is known as direct discharge – and municipal sewage treatment plants (also known as publicly owned treatment works or POTWs) – which is known as indirect discharge – based on the performance of treatment and control technologies.

Direct discharges are subject to the National Pollutant Discharge Elimination System (NPDES) permit program. The permit contains limits on what can be discharged, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or people's health. There are two basic types of NPDES permits issued: an individual permit and a general permit. An individual permit is tailored to an individual facility, and a general permit to a group of similar dischargers. In certain cases there are more sector/industry specific permits/requirements, such as the Washington States boatyard permit (Boatyard General Permit) or California Regional Water Quality Control Board Santa Ana Region's sector-specific general permit for storm water runoff associated with industrial activities from scrap metal recycling facilities (SWRCB, 2012).

Stormwater runoff is a direct discharge. Requirements for the Industrial Stormwater General Permit include development of a written Stormwater Pollution Prevention Plan (SWPPP), implementation of control measures, and submittal of a request for permit coverage, usually referred to as the Notice of Intent or NOI. The SWPPP is a written assessment of potential sources of pollutants in stormwater

runoff and measures that will be implemented at the facility to minimize the discharge of these pollutants in runoff from the site. These measures include site-specific best management practices (BMPs), maintenance plans, inspections, employee training, and reporting. The procedures detailed in the SWPPP must be implemented by the facility and updated as necessary, with a copy of the SWPPP kept on-site. The Industrial Stormwater General Permit also requires collection of visual, analytical, and/or compliance monitoring data to determine the effectiveness of implemented BMPs (US EPA, 2009).

Direct discharges from O & G sites are subject to the NPDES permit program, with the exception of coal bed methane. There can be no discharge of water pollutants from any source associated with production, field exploration, drilling, well completion, or well treatment, except for wastewater that is of good enough quality for use in agricultural and wildlife propagation.

Stormwater runoff at O & G sites, however, is exempted from the NPDES program unless a facility has a discharge of Reportable Quantity (RQ) or contributes to a violation of a water quality standard (40 CFR 122.26(a)(2)). This includes discharges that cause a film or sheen, or a discoloration of the water surface or adjoining shorelines, or causes a sludge or emulsion to be deposited beneath the water surface or upon adjoining shorelines. Reportable Quantity is a determined limit for specific hazardous chemicals pursuant to section 311 of The Clean Water Act.

Proving a discharge of RQ or noting a violation of a water quality standard will not happen if proper monitoring equipment and requirements are not in place. Such monitoring happens when a facility is enrolled in the NPDES program.

The stormwater discharge exemption impedes our ability to prevent contamination of waterways. However there is Residual Designation Authority in the CWA that allows for regulating an activity that may adversely impact surface waters. A delegated state such as California also has this authority. It states that, “the EPA Regional Administrator may designate additional stormwater discharges as requiring NPDES permits where he determines that the discharge, or category of discharges within a geographic area, contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States (40 CFR 122.26).”

Also part of the CWA, the US EPA requires certain oil drilling facilities to prepare and implement Spill Prevention, Control and Countermeasure (SPCC) plans to prevent discharge of oil into navigable waters or adjoining shorelines. Facilities that must prepare and implement SPCC plans include: non-transportation related facilities; facilities that have an aggregate above ground storage capacity over 1320 gallons or a buried storage capacity over 42,000 gallons; and facilities that have a reasonable expectation of discharging into or upon navigable waters or adjoining shorelines (40 CFR 122).

The SPCC plan and the NPDES permit program are intended to capture potential sources of pollutants that may contaminate surface water. However, often the suggested protocol and measures taken are too general for them to be effective for the specific industry. With no industry specific permits there is no guidance as to where and how representative and effective monitoring should take place, what industry specific constituents should be monitored, or which BMPs serve that industry's needs. With no industry specific recommendations, it is left up to operators to implement or not implement measures. If appropriate monitoring is not happening it is not capturing any violations.

The limitations of Federal regulations, summarized above, are counteracted to some extent by CA regulations that require all O & G facilities that discharge stormwater contaminated by contact with, or that has come into contact with any overburden, raw material, intermediate products located on the site of such operations, to file for an Industrial Stormwater General Permit, effective July 2015 (SWRCB, 2014). O & G exploration and production facilities that drain to waterways must now submit an application to be covered by the General Permit or file a No Exposure Certification. A No Exposure Certification

means that the entity identified does not require permit authorization for its stormwater discharges associated with industrial activity due to the existence of a condition of no exposure. In the new order it also states, “when developing the next reissuance of this General Permit, the State Water Board expects to have a better understanding of the feasibility and benefits of sector-specific and watershed based permitting alternatives, which may include technology – or water quality based numeric effluent limitation (SWRCB, 2014).” This means the State Water Board recognizes that sector-specific permitting may be necessary for certain industries, O & G included.

At the national level, only spills that exceed a Reportable Quantity or contribute to a water quality violation require notification to be covered by the general permit for stormwater discharges. In California, all O & G exploration and production facilities that drain to waterways must submit an application to be covered by the Industrial Stormwater General Permit or file for a No Exposure Certification. At issue is the fact that an important industry is either going unmonitored at the federal level or being regulated with very general pollution prevention and control requirements when more specific control measures would be appropriate to reduce the risk of contamination of waterways.

2. Methods

The following sections discuss the methods used to assess the threat from surface impoundments and spills, as well as look at permit compliance.

2.1. Surface impoundments

Surface impoundments, sometimes referred to as ponds, can be a source of contaminated runoff. They are used for temporarily storing drilling fluids for use in drilling operations, settling/skimming of solids and separation of residual oil, storage of produced waters prior to injection or off-site transport, percolation of liquids via drainage or seepage into surrounding soil, and evaporation of produced waters into the atmosphere (Karami et al., 2013).

In California, surface impoundments are permitted by the Regional Water Quality Control Boards. In California, surface impoundments are predominantly unlined and used to dispose of produced water through evaporation and/or percolation. Produced waters account for 96–98% of all O & G wastes (Congress of the U.S., Office of Technology Assessment, 1992). An estimated 1.9 billion barrels of water were produced during oil extraction in the Central Valley in 2013. Approximately 12% (12 billion gallons) was disposed into sumps or recycled (Zinky, 2016).

Section 45 of California Senate Bill 83 requires that the State Water Board report on the regulation of oil field produced water ponds within each region by January 30, 2016, and every six months thereafter. The first report contains information from the Central Coast and Central Valley Water Boards, and includes the total number of ponds in each region, the number of permitted and unpermitted ponds, enforcement actions, and the status of permitting the unpermitted ponds. Enforcement Actions include Informational Orders (13267), Notices of Violations and Cleanup and Abatement Orders. This report was reviewed to understand surface impoundment use and makeup in the State of California. The literature was searched to determine in what capacity surface impoundments are used and what the operation entails.

2.2. Oil and gas exploration and production spill analysis

This study conducted a survey of O & G spills in Kern County and Ventura County, California for the time period of 2010–2016. Reviewing the types and sizes of spills at oil fields and whether they reach waterways can inform us on the potential risk to surface water. O & G facilities that spill chemicals of Reportable Quantity (RQ) or

contribute to a violation of a water quality standard must enroll in the NPDES permit program. The research assessed permit compliance in such cases. Looking at permit compliance is useful in determining if current regulations are capturing entities that should be filing for a permit.

We used data from the California Office of Emergency Services (Cal OES) for hazardous material release information. The data was downloaded in March 2016 from the Cal OES website for the years 2010–2016. The Excel sheets provide spill details including, date, time, location, substance type, amount spilled, and a general description of the cause of the spill. It also provides information on the type of immediate impact, including surface water contamination or fatalities and injuries involved. The responsible party and the agency reported to are also listed.

The data was filtered to include only spills that occurred on oil fields in Kern and Ventura counties. The assumption is that spills entail runoff. The spills were classified by size. There are no standard definitions for small, medium, or large spills. A variation of the United States Coastal Guard (USCG) threshold cutoffs was used. USCG classifies a small spill as less than 24 oil barrels (bbl), a medium spill as less than 240 bbl, and a large spill as greater than or equal to 240 bbl (Anderson et al., 2012). One bbl represents 42 gallons. Ten bbl was used as the lower end of a small spill because according to California's Department of Oil, Gas, and Geothermal Resources (DOGGR) it is considered significant for spill management purposes (Department of Conservation, 1998). The study also identified which spills reached waterways.

Once the information on oil field spills in Kern County and Ventura County was collected, the State Water Resources Control Board's (SWRCB) Stormwater Multiple Application and Report Tracking System (SMARTS) was used to see which facilities filed for an Industrial Stormwater General Permit. SMARTS was developed as an online database for dischargers to electronically file their stormwater permit documents. The database was searched using the Standard Industrial Code (SIC) 13xx; this applies to the O & G industry. The time frame of the study was from 2010 to 2016. Some of the information included in the database is the application type (Industrial, No Exposure Certification, etc.), its status (active or terminated), status date, and the operator/owner name and address.

2.3. Analysis of selected spill cases and associated SPCC and SWPP plans

For the larger spills (those above 10,000 gallons) in Kern and Ventura County corresponding facility SPCC and SWPP plans were reviewed to see if plans were specific enough to prevent such spills. The plans were reviewed to identify and compare the BMPs between SPCC or SWPP plans and see if one plan had more detailed and preventative protocol. Representatives from DOGGR were contacted to obtain the SPCC plans. The SMARTS site was used to find the associated SWPP plans.

2.4. Oil and gas facility industrial stormwater general permit compliance analysis

The analysis was done for Kern County and Ventura County, California. Kern County is the main hub of UOG stimulation techniques in California; much of the county is oil fields. Ventura County has O & G activity but to a lesser extent than Kern County. It is more representative of an area that has residential, commercial, and industrial areas spread out over a county. According to daily updated well information on California's Department of Oil, Gas, and Geothermal Resources website there are about 8300 wells in Ventura County and 143,000 wells in Kern County as of June 2017.

This analysis looked at how many O & G facilities filed for an Industrial Stormwater General Permit pre/post the new Industrial Stormwater General Permit requirements for O & G in California. The

analysis determined how many facilities had a permit prior to and after July 2015 for Kern and Ventura County.

Another area of interest is unconventional oil and gas (UOG) stimulation. The use of UOG stimulation techniques has increased dramatically over the last 5 years. Most of the reporting on UOG stimulation in California has really only begun in the last 3 years. Reporting on UOG stimulation techniques, including HF, acid fracturing, and matrix acidization, began in 2014 in California through the interim Senate Bill 4 (SB4) and is now required through the SB4 bill as of July 2015. New NPDES Industrial Stormwater General Permit requirements for O & G facilities in California went into effect July 2015. This paper documented how permit compliance has changed in relation to UOG exploration. Unless a facility is entirely contained it is likely that all operators would need to be covered by the Industrial Stormwater General Permit post July 2015.

Industrial Stormwater General Permit information was obtained from the California State Water Board's SMARTS system using SIC 13xx to narrow down to O & G industry up until April of 2016. To get information on UOG stimulation facilities, a representative at DOGGR gave a list of all the disclosures submitted to them.

3. Results

3.1. Surface impoundments analysis

In the Central Coast most of the active and inactive ponds were unpermitted, and there were enforcement actions against most of them. In the Central Valley about 40% of the ponds were unpermitted, and almost all the ponds had enforcement actions against them. The use of ponds is very pervasive, especially in the Central Valley where most of the O & G exploration and production takes place. There were over 1100 ponds. Unpermitted ponds and ponds violating code indicate that best protocol to protect surface waters from improper containment practices are not in place (Table 1).

A survey of the literature concluded that there are no current reports on surface impoundments. The EPA produced a few reports in the 70 s and early 80 s but none published recently. There were no articles found on surface impoundments and surface water threats.

3.2. Oil and gas exploration and production spill analysis results

There are fewer spills in Ventura County compared to Kern County. In Ventura County there were a total of 61 reported spills from January 2010 to March 2016. Of those 61 spills, 7 were of medium size (24–240 bbl) and the rest were small spills. For the medium sized spill, only 1 of the 4 entities responsible had an active permit. There were 22 spills that came in contact with waterways, of which only 1 entity of the 6 responsible had an active permit. There were 14 different entities that reported the 61 spills, meaning the same entities had repeated spill instances. The only entity that was covered by the Industrial Stormwater General Permit was California Resources Production Corp. If one assumes that the spills met the reporting requirements, few to no facilities filed for a permit (Table 2).

There were 316 spills in Kern County during the study time frame. Of those 316, 47 were medium sized spills (24–240 bbl) with only one

of the 14 entities responsible for the spills having a Notice of Non-Applicability. A Notice of Non-Applicability would indicate that the site was either enclosed, there was no stormwater discharge/exposure, they were not required to be permitted by federal regulation, they were regulated by another permit, there was a new facility operator or they never operated the facility. There were 10 large spills (> 240 bbl) and only one of the 5 entities responsible had a Notice of Non-applicability. Of the 34 spills that reached waterways, only one of 20 entities responsible had a Notice of Non-applicability. There were a total of 70 entities responsible for the 316 spills, but only 3 filed in the NPDES program; Inergy had an Industrial Stormwater General Permit; Schlumberger and Chevron submitted a Notice of Non-Applicability, Chevron being responsible for one of the large, medium, and contact with waterway spills. In Kern County as well only a very small percentage filed for a permit.

For the medium/large spills and/or those that reached waterways, the responsible entity most likely would have needed to notify the Water board and have been enrolled in the NPDES program. However, there is very little overlap between who the polluters were and who is covered by the NPDES permit.

3.3. Analysis of selected spill cases and associated SPCC and SWPP plans

After sorting through the Ventura and Kern County oil field spills, the 3 largest spills were chosen in each county as case studies. Information about the spills is taken directly from the Cal OES site and is in the tables below (Table 3).

The largest spills in Ventura County were of medium size. The 3 case studies involved spills of 60–100 bbls of produced water and/or crude oil. Produced water contains many chemicals either from the injected fluid or formation waters (CCST, 2014), and it accounts for 96–98% of all O & G wastes (Congress of the U.S., Office of Technology Assessment, 1992). These medium sized spills were either caused by a faulty pipe/hose, or build up of pressure; in two of the releases, waterways were reached. California Resources Production Corp was the only entity covered by the NPDES general industrial permit.

3.3.1. Ventura county facility SPCC and SWPP plans

There were no SPCC plans obtained for these three sites. California Resources Production Corp. was the only one with a SWPP plan on file (See Supplemental Section). The SWPP plan had specific best management practices listed. Of particular interest were the general BMPs. These included: containing all stored non-solid industrial materials or wastes that can be transported or dispersed by the wind or contact with stormwater during handling; and covering industrial waste disposal containers and industrial material storage containers that contain industrial materials when not in use. The advanced BMP used was berming/containment around tank batteries and well pads. Tank batteries are constructed with secondary means of containment with the volume capacity of the containment designed to exceed the contents of the largest tank within the facility and with sufficient freeboard to contain precipitation. Well pads are constructed of earthen berms and/or well cellars to contain liquids on location. There are open drains within the site, which collect miscellaneous fluids from the containment areas. These drains are piped and transported to a central sump from

Table 1
SWRCB Oil Field Produced Water Ponds Report as of January 30, 2016.

Regional Water Board	Active Ponds		Inactive Ponds		Total Ponds		Enforcement Actions
	Permitted	Un-permitted	Permitted	Un-permitted	Permitted	Un-permitted	
Central Coast	3	41	0	8	3	49	52
Central Valley	530	162	101	269	631	431	1062
Total	533	203	101	277	634	480	1114

Table 2
Oil Field Spill Analysis for Ventura and Kern County, California (January 2010–March 2016).

	Ventura County	Kern County
# of spills	61	316
# of medium spills (24–240 bbl)	7	47
# of large spills (≥ 240 bbl)	0	10
# in contact w/waterways	22	34
# of different facilities/entities reporting spills	14	70
Which facility/entity was covered by NPDES permit	California Resources Production Corp (Industrial)	Inergy (Industrial) Schlumberger (Notice of non-applicability) Chevron (Notice of non-applicability)

which they are pumped for proper disposal. Containment structures are inspected regularly for deficiencies and repairs are made as necessary (Table 4).

The largest spills in Kern County were 500–700 bbl of produced water; the largest of these spills occurring after a rain event. This is just one case that shows that rain events can cause stormwater pollution issues from O & G facilities. Preventing overflows from rain events is possible if the facility is entirely covered or contained. The remaining two spills were caused by faulty pipes lines. Only one operator, Chevron USA Inc. had a Notice of Non-Applicability, the others had no permits.

3.3.2. Kern county facility SPCC and SWPP plans

There were two associated SPCC plans obtained: one for the Plains All American Pipeline site and the other for Chevron site. The first SPCC plan had an annual pipeline inspection plan and monthly facility maintenance plan for primarily checking equipment integrity. In addition there was a general spill protocol outlined. There was no discussion of any secondary containment. The SPCC plan was not very specific in its prevention protocol. Chevron's SPCC plan had similar spill and maintenance protocol, but the site was designed with containment berms and had a valve shut-off protocol. Because the facility was entirely contained Chevron appropriately filed for a Notice of Non-Applicability. In this case the site was contained and the spill did not cause a threat to surface waters. As for SWPP plans there were none found for the spill sites of concern.

There were not enough reports to make any clear conclusion about the efficacy of SWPP plans versus SPCC plans. On a theoretical level SWPP plans should provide a more detailed assessment of potential sources of pollutants in stormwater runoff as well as measures to minimize the discharge of these pollutants. The Industrial Stormwater General Permit also requires collection of visual, analytical, and/or compliance monitoring data to determine the effectiveness of implemented BMPs.

Ideally, there needs to be specific guidance and requirements for O & G facilities to prevent spill and overflow. Currently there are no industry specific requirements. EPA has a list of BMPs for potential pollutant sources at oil and gas extraction facilities (US EPA, 2006), as well as more specific guidance for oil and gas construction sites provided by the Independent Petroleum Association of America (IPAA, 2004).

Table 3
Ventura County Medium Sized Spills.

Entity	Permit Status	Spill Size	Spill Description
California Resources Production Corp.	Active Industrial Stormwater General Permit	100 bbl produced water	A hole in a 4" pipe caused a spill onto a private road on the leased property (oil production lease); some release entered a nearby metal culvert and then into a soil ravine.
Vintage Productions California	Terminated Permit	65 bbl crude oil	During hydrotesting of a line, built up pressure caused a spray of oil and water onto trees over a dry creek bed.
Vintage Production LLC	Terminated Permit	60 bbl produced water/crude oil	A broken hose caused this release.

3.4. Oil and gas exploration and production industrial stormwater general permit compliance analysis

This study also looked at Ventura and Kern County's active O & G facilities to see how many filed for an Industrial Stormwater General Permit pre/post the new requirements. This covered until March of 2016. In Ventura County there were 36 Active permits, 10 of those filed post July 2015. This is a substantial percentage (28%) that enrolled in a short time frame of 8 months (July 2015–March 2016) after the new permit requirements. In Kern County there were 45 Active NPDES permits; 27 of those were post the new requirements. In Kern County 60% enrolled after the new order. The new Industrial Stormwater General Permit requirements had a large proportion of operators enroll in the program in a short time span. Surprisingly, facilities where spills occurred did not file for permits (Table 5).

There were 9 different UOG stimulation facilities filing for well stimulation permits with DOGGR prior to the new Industrial Stormwater General Permit requirements and only one applied for a Notice of Non-applicability. About 10% of operators filed for a permit. After the new requirements, there were five different entities filing for well stimulation permits with DOGGR; two filed for an Industrial Stormwater General Permit, and one filed a Notice of Non-applicability. Post new requirements, 60% of the UOG facilities filed for a permit (Table 6).

4. Discussion and recommendations

The results on surface ponds, spills, and permit compliance show some specific ways that regulations can be improved.

Surface impoundments at O & G facilities can be a serious threat to waterways. In California there are thousands of these impoundments, currently most are unlined and many are unpermitted. Almost all are in some sort of violation. Proper oversight and development of surface impoundments is needed. Many states have banned the use of surface impoundments for the many problems associated with them, overflows being one of them.

Spills, although not a direct indication of stormwater runoff, can give some idea of potential polluted runoff that should be regulated. If we assume the medium and large spills in this study that reached waterways violated a water quality standard then those facilities must have an active permit on file. However, what we see is that most of

Table 4
Kern County Large Sized Spills.

Entity	Permit Status	Spill Size	Spill Description
Berry Petroleum	No Permit	700 bbl Water – Produced type used for well kill	A rain event occurred over the area and filled a concrete cellar that a well sits in and floated residual oil to the surface, resulting in the release of crude oil on a dry, unknown creek bed.
Plains All American Pipeline	No Permit	600 bbl Produced Water	Produced water line failure caused the release of approximately 5 gallons of crude oil into a dry waterway; the rest of the release went to land only, impacting no waterway.
Chevron USA Inc.	Notice of Non-Applicability	500 bbl Produced Water	Corrosion on a 3" flow line caused a release to a blue line (stream).

Table 5
O & G Facilities Filing for NPDES Permit Pre/Post New NPDES Permit Order.

County	# of NPDES Permit	# of NPDES Permits After July 2015
Ventura	36	10
Kern	45	27

Table 6
UOG Facilities Filing for NPDES Permit Pre/Post New NPDES Order.

	Before July 2015	After July 2015
# DOGGR UOG facilities	9	5
# DOGGR UOG facilities w/NPDES permit	1	3
% UOG facilities obtaining NPDES permit	10%	60%

This analysis shows an increase in enrollment that coincides with the new regulations; the new regulations may be providing an incentive to enroll. However increased enrollment does not mean better regulatory control or pollution reduction. There needs be specific best management practices for O & G as well as specific requirements for known polluters. Nonetheless having all O & G at least.

those facilities are not filing for a permit. Filing for a permit would not necessarily prevent a spill but would require better monitoring, maintenance and preventative measures to be in place. In California new filing requirements for oil and gas industry require all facilities that discharge stormwater contaminated by contact with, or that has come into contact with any overburden, raw material, intermediate products located on the site of such operations, to file for an Industrial Stormwater General Permit. The new requirements coincide with a larger pool of facilities enrolling in the program. More research would have to be done to determine causation, but getting facilities enrolled is a good start. On the federal level requiring similar permitting of all O & G facilities may help increase the number of enrolled facilities.

The permit however is still general in nature and may not provide the industry with the more specific requirements that it needs. In certain cases there are more sector/industry specific permits/requirements, such as the Washington States boatyard permit () or California Regional Water Quality Control Board Santa Ana Region's sector-specific general permit for storm water runoff associated with industrial activities from scrap metal recycling facilities (SWRCB, 2014) that have provided more specific guidance. Such guidance may help polluters implement the necessarily changes to their sites.

There are a few guidance documents with more specific recommendations for O & G facilities. Two were developed by the US EPA, one looking at BMPs for potential pollutant source (US EPA, 2010) and the other providing voluntary practices for oil and gas wastes (US EPA, 2014). Although many of the recommendations are general there is specific guidance that could be used in the permitting process. Another document by the Independent Petroleum Association of America identifies practices for stabilization of O & G construction sites (IPAA, 2004). These documents could be sources to establish requirements for a more industry specific stormwater permit. Currently most of the BMPs recommended in these documents don't have defined performance standards.

For the Ventura County and Kern County medium and large sized spill case studies, there were only two associated SPCC plans and one SWPP plan that were obtained. One site's SPCC plans show that measures in place are very general; they may be able to detect faulty equipment but do not address containment issues. The other SPCC plan was for an enclosed facility whose spill did not reach waterways. The SWPP plan provides more specific recommendations for sites that are in contact with waterways. However with such a limited number of reports no conclusive difference can be made.

Permit compliance is an issue. Currently with the federal framework it is left up to facilities to identify when a violation has occurred and then file for a permit. Cases in California show that when large spills were occurring that reach waterways, facilities were still not filing for a permit. Having all facilities that are a potential source of contaminated stormwater file for a permit is a preventative measure that would at least require basic monitoring and maintenance. The authors recommend a tiered permitting approach nationally. The tiers should relate to spills as well as toxicity of chemicals used. All O & G facilities should file for the Industrial Stormwater General Permit for potential stormwater discharges as the first tier. The next tier of facilities would be regulated more strictly in cases of spills or use of toxic chemicals. If there is a medium sized spill (24–240 bbls) or hazardous chemicals are used that appear on the Reportable Quantity list or have a toxicity grade of an F, as reported for acidization chemicals in Abdullah et al. (2016), the operator must file for a sector specific permit as the second tier, which calls for more specific protocols for the O & G sector. The BMPs in the guidance documents mentioned can be incorporated in such a permit. If there is a large sized spill (> 240 bbls) or hazardous chemicals (identified in the second tier of reporting) are used in quantities above identified thresholds the operator must file for a site-specific individual permit under the third tier. This allows for more scrutiny and oversight. A tiered approach gives operators an incentive to prevent spills, use safer chemicals, and employ BMPs. Companies will want to avoid industry specific or site-specific permits and thus make sure proper measures are in place for spills or use of toxic chemicals.

At the California State level all O & G are required to file for an NPDES permit. To ensure that this happens it can be a requirement for all facilities obtaining a drilling permit to file for a permit with the Water Board. There can be a drilling permit block stating that no O & G stimulation will be permitted until an NPDES permit has been filed for. Such inter-agency dependency can enhance the effectiveness of rules and better protect the public and environment.

5. Conclusions

Evidence presented herein shows there is value in increasing regulatory protocols. In California there are too many spills that are not being contained, and even after spills have occurred, facilities are not complying with regulations that require greater scrutiny over their actions. There is a need to both understand the potential threat from O & G activities to surface waters from contaminated stormwater as well as have the regulations in place to prevent any contamination. It is hoped that this paper shed light on the threat and the need for appropriate regulations concerning O & G stormwater management.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.envsci.2017.06.016>.

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