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Effectiveness of self-identified and self-reported environmental regulations for industry: The case of stormwater runoff in the US

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- This paper looks at compliance with NOI for regulated facilities as indicator of overall success of stormwater general permit program.
- Makes similar point to Cross and Duke paper about need to think about facilities that actually produce pollution versus those that are in a regulated class but actually don't impact stormwater much.
- Good review of history of CWA/SW regulations and rise of "self-regulation" under Reagan and Bush Sr. Also discusses difference between command and control and self-regulation as applied to point and NPS.
- Discusses how EPA structured (with 1997 amendments) MS4 permits to have oversight of industrial stormwater general permits. In reality, based on research by Cross and Duke (2006) this hasn't really been done by MS4s or, at least, is super highly variable. Generally they see themselves as educators not as enforcers but because each does things differently, there is not uniform approach or effectiveness in education (who they reach out to, etc.)
- Agues that few studies have tried to assess regulatory success for industry. Only limited efforts to do so. Argues very little state verification and inspection to gauge effectiveness.
---> Three options to gage success/effectiveness of program: NOI, quality of effluent, or SWPPP tracking. Makes point about difficulty of tracking effluent quality because nature of monitoring (few samples at each site, highly variable values) (from Duke 2001). That's why went for NOI as indicator of success. Suggests indicator of success could also be SWPPP implementation.
- suggests future research might look at outreach programs, resources in state agency SW programs, etc. as related to success/ lack thereof.

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Effectiveness of Self-Identified and Self-Reported Environmental Regulations for Industry: The Case of Stormwater Runoff in the US

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ABSTRACT *US environmental controls for industry include numerous regulations that rely on the regulated community to self-identify, monitor, report, or complete other requirements on their own recognizance. These include state- and federal-issued general permits for stormwater discharges associated with industrial activities, effective in 1992, with known incomplete compliance by 2004. Results demonstrate highly incomplete compliance with variation in effectiveness among studied states and urbanized regions. Texas and Oklahoma, administered by US EPA during the research period, have attained higher compliance rates than California, administered by a state agency, or Florida, also administered by US EPA. Specific program designs and implementation strategies employed by states are evaluated for impacts on states' compliance effectiveness.*

Introduction

Many regulations for environmental protection from industrial emissions in the US contain a substantial component of responsibility of the regulated community to self-identify, self-monitor and self-report. The effectiveness of those regulations depends on effective action by the regulated community, and in many cases there is inadequate oversight or evaluation by the responsible agencies or by third parties to determine whether the intended environmental protection is in fact achieved. This paper evaluates one such set of regulations; the requirements for industrial facilities to prevent pollutants in stormwater discharges, and in so doing investigates the success of the self-implementation concept for environmental regulations.

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US Environmental Regulations Relying on the Regulated Community for Implementation

Centralized, federal regulation protections for the environment in the US largely began in the 1970s, when the US Environmental Protection Agency (US EPA) was formed and a number of sweeping policies were enacted for protection of dwindling species, air quality, water quality, hazardous substances and others. Within the myriad regulations written to implement those policies, evolving over the three decades since that time, it is possible to trace a trend toward increasing reliance on self-identification and self-implementation of the regulations, especially regulations for business and industry. The concept of partnership and active participation by the regulated community exists from the earliest of these regulations, and indeed can be seen as a necessary ingredient. Freeman (2000) cites environmental regulations as examples of how government relies significantly on the participation of the regulated community: "Agencies across a variety of regulatory contexts need regulated entities and independent expert organizations to assist them with implementation" (p. 544). The foundation of the concept is that the regulated community will in fact implement the requirements, under the assumption that penalties and enforcement to which non-compliers are subject is sufficient to compel the reporting and compliance. However, the degree to which the regulated community is expected to be responsive and to implement the requirements with little oversight or verification can be seen as expanding over time.

Regulations implementing the Water Pollution Control Act of 1972 (known as the Clean Water Act) and the Clean Air Act of 1974 were constructed to specify numeric limits for the amount of pollutants allowed in wastewater discharges and air emissions (Rosenbaum, 2005). Both rely on routine self-monitoring requirement for regulated facilities, commonly on a daily basis. Both also include substantial requirements for agencies to inspect facilities, verify that process activities and treatment equipment were functioning as reported, and collect samples of discharges that could readily detect any deviation from the specified standards. Those regulations thus support their self-implementation aspects with quite active verification by agency personnel. That part of the Clean Water Act addressing stormwater discharges from industrial facilities, enacted later during the Reagan administration in 1987, is discussed at length below. These incorporate much less agency oversight and verification, and are among the US regulations that rely most completely on self-implementation by the regulated community.

Hazardous waste regulations of the Resource Conservation and Recovery Act (RCRA) of 1976 were structured with an increased reliance on self-implementation by the regulated community. Generators of hazardous waste are required to identify themselves and then enter the detailed system of controls for transport and disposal of specified wastes. Those who generate wastes, defined by detailed specifications to be within the 'hazardous' category, face substantial penalties for disposal outside the regulatory system (Rosenbaum, 2005). However, the origin of such wastes is far easier to mask than a major wastewater source (a pipe or physical discharge structure) or air emission (a large stack or extensive process activities readily evident to industrial inspectors). A barrel or container of hazardous waste may be indistinguishable from a container of solid waste with no hazardous characteristics.

Verification in any meaningful way would require an agency to monitor or inspect every shipment of solid waste leaving every business that uses potentially hazardous substances, a much more resource-intensive proposition than periodic sampling of wastewater or air emissions. As a result it has been widely recognized that a substantial portion of wastes are not accurately identified as hazardous, and disposed illegally outside the hazardous waste system (Hammitt & Reuter, 1989). This is recognized as a particular problem in the category of sources known as 'small quantity generators' (Schwartz *et al.*, 1989; Silverman & Kubasek, 1989) in particular because small quantities are easy to disguise but, in contrast to small quantities of conventional water or air pollutants, have the capacity for substantial harm to human health or the environment by the nature of the wastes. Agencies and researchers (e.g. Mazmanian & Morell 1988; Hahn & Males, 1990) have long recognized the self-identification aspect of RCRA has led to substantial problems in verifying compliance and in assessing the real proportion of non-compliance.

Regulations under the Superfund Amendment and Reauthorization Act of 1986 also address hazardous substances, specifying that industrial facilities make quantitative estimates of releases to all compartments of more than 400 different substances and report the estimates for publicization under the Toxic Release Inventory system (Lyon & Maxwell, 2001). Industrial facilities' operators determine whether they exceed the reporting threshold, and if so they compute and submit their own quantitative estimates. Oversight by US EPA has been largely limited to checking the submittal dates on reports to determine if they have passed the deadline, verifying that facilities continue to submit reports each year once they have initially identified themselves, and some rudimentary calculation for consistency of units and aggregated totals (Bloch, 1996). Evaluation of that program suggests the reporting is commonly highly approximate, not based on measurements, and not a realistic reflection of either the total mass of hazardous substances entering the facility or the ultimate release points of those substances (Bloch, 1996).

The increasing reliance on self-implementation coincides roughly with the administrations of Presidents Ronald Reagan in the 1980s and George W. Bush in the 2000s, and might be attributed in part to the political agendas of those two leaders (with, arguably, a pause for the administrations of George H. W. Bush and Bill Clinton). Both Reagan and G. W. Bush were elected on platforms that explicitly included alleviation of regulatory burdens on industry, and both sharply reduced the amount of government resources brought to bear on environmental regulation, compliance and enforcement (Kraft & Vig, 2006). An increasing reliance on business to recognize its own best solutions, and an increasing faith in business to effectively implement regulations under reduced oversight, are consistent with those political positions.

In each of these cases, compliance with the regulations is not considered voluntary: the entity that releases each form of waste is required to comply with specified requirements, and is subject to a variety of penalties if apprehended discharging without a permit. However, the self-identification and self-implementation aspects have proven difficult to assess. Few studies have evaluated the success of the self-implementation aspects of environmental regulations for industry.

Water Quality Regulations in the US: Industrial Discharges and Stormwater Runoff

Water quality protection regulations in the US derive from the federal-level Clean Water Act, first passed in 1972, along with a number of analogous policies adopted by the various states. State-level regulations vary to some extent but are required to be at least as stringent as those at the federal level. The Clean Water Act articulated a goal that all waters of the US should be of sufficiently high quality to support human contact recreation and human consumption of species found in the waters, the so-called 'fishable and swimmable' goal (Rosenbaum, 2005).

The Clean Water Act, or CWA, directed the federal oversight agency, US EPA, to develop regulations for control of pollutant discharges, which it did with the National Pollutant Discharge Elimination System, or NPDES. NPDES specified that no wastewater could be discharged without a permit, and specified a series of numeric targets (Duke, 2005). The NPDES wastewater permitting is conceptually structured using a command-and-control approach (Rosenbaum, 2005). That is, the regulations command dischargers to meet the uniform standards, and include routine inspections by agency personnel to verify the standards are met and control the dischargers' actions if they are not.

In the CWA's first 15 years, stormwater discharges were identified as 'non-point sources' and therefore exempt from the point-source NPDES regulations. The non-point sources were at first considered intractable because of the difficulty quantifying discharges, and at the same time considered of secondary importance because point sources represented clear and evident environmental degradation. The CWA's 1987 reauthorization specified that stormwater discharges be included in the NPDES regulations. That change was prompted by findings that pollutants were present in substantial amounts in urban runoff (Athayde *et al*., 1983), along with a lawsuit from a public interest group. In an odd definitional twist, in response to the lawsuit, the US Supreme Court ruled that stormwater discharges from industrial facilities and urban drainage systems are to be considered as point sources, and therefore are required to be subject to NPDES rules. NPDES regulations for stormwater discharges associated with industrial activities, Section 402(p) of the CWA, were effective in 1992. The regulated community for these rules consists of entities that operate ''facilities discharging stormwater associated with industrial activities'', which are called 'industrial facilities' throughout this paper.

In the same 1987 CWA reauthorization, US EPA enacted an NPDES water quality permit requirement for municipal stormwater discharges. Operators of municipal separate storm sewer systems, known as MS4s, under these rules were subject to regulation for water quality protection, a substantial addition to their longstanding mission of providing drainage to protect urban areas from flooding. The rules specify operators of MS4s are required to implement their own management practices to reduce stormwater pollutants from their activities. Further, the MS4 operator agencies have become important to the implementation and evaluation of the regulations for industrial facilities, as a result of a widespread practice adopted by US EPA in the NPDES water quality permits it writes for the MS4 discharges. That practice is to specify that the MS4 operators, as part of their own pollution prevention requirements, conduct inspections of a selected subset of

industrial facilities in their jurisdictions. In particular, the MS4 agencies' permits from US EPA typically require the agencies to identify and inspect facilities they judge to be at 'high risk' of contributing substantial loads of pollutants into the urban drainage system, which are then passed through into the environment. Those permit requirements are intended to encourage urban drainage agencies to operate in tandem with statewide agencies' enforcement of the stormwater general permits for industry. The intentional redundancy not only provides additional mechanisms to enhance compliance, but also provides for certain selected facilities the kind of agency oversight and verification that has been lacking in the statewide implementation.

The US EPA chose not to structure the stormwater discharge rules along the numeric standards and command-and-control approach used for wastewater permitting. Instead, the stormwater discharge regulations both for industry and for municipal drainage take a pollution prevention approach. Rather than numeric limitations on the quantity of pollutants that may be discharged, the standards are specified in narrative terms ("shall not cause problems in receiving waters..."). Facility operators are intended to reduce their pollutants by selecting and implementing Best Management Practices well suited to their own facilities, with the requirement to reduce pollutants to the 'maximum extent practicable' rather than to some specified numeric limit.

Two aspects of the stormwater regulations for industry enhance the self-implementation aspects of this particular set of regulations. The first is the decision to structure the regulations on the model of pollution prevention rather than command-and-control. Much has been written about the relative merits of the pollution prevention approach (e.g. Burnett, 1998; Duke, 2001). It has important conceptual advantages, including the opportunity to reduce pollutant loadings further than a given numeric standard; and the economic efficiency of pollution reduction plans tailored to each facility's unique operations. At the same time, an inescapable practical problem is the intense degree of assessment of each facility required to design an effective program to reduce pollutants, compared to relatively straightforward implementation of command-and-control requirements using numeric standards measured at the point of release. Agencies responsible for industrial storm runoff regulation in the US have accommodated the need for those resources by passing the requirements to the regulated community, so that the regulations have been self-implemented to an extremely large extent.

The second feature that magnifies self-implementation of these regulations is the general permit structure. Facilities are not issued with site-specific permits but instead notified that they are required to comply with a generic set of rules that allow them to be considered as holding the appropriate NPDES permit. US EPA identifies this approach as "a cost-effective option for agencies because of the large number of facilities that can be covered under a single permit" (US EPA, 1996, p. 22). Beyond doubt this approach is much less resource-intensive than preparing individual permits for the extraordinarily large number of facilities that were subject to the NPDES permitting system for the first time with the 1992 regulations. As documented below, the number of facilities now complying include nearly 20 000 in Texas and more than 10 000 in California, with comparable numbers roughly proportional to population in other states. The general permit approach is enshrined in US EPA's approach (US EPA, 1992), and is expected of states that attain

approval for implementation of the stormwater program at the state level. In practice the states have attempted to carry forward the sharply reduced resources of permit writing to the implementation and enforcement activities. The statewide general-permit approach to stormwater regulation for industry therefore relies heavily on the facility operators for implementation, with little routine agency oversight.

Assessing Compliance with Stormwater Regulations for Industry

A typology presented in Duke & Beswick (1997) characterizes the compliance requirements as consisting of three stages. In the first stage, facilities subject to the rules are required to be identified, not by agency personnel but by the operators of the facilities themselves. The facility operator needs to understand the regulations sufficiently to determine whether the facility is subject to regulations and file a Notice of Intent (NOI) that signifies the facility's operators have recognized their duty to comply. This determination is complicated for a number of reasons, summarized in Duke *et al.* (1999a). The second stage of compliance is monitoring and reporting. Facility operators are required to sample their runoff and have the samples analyzed for chemical composition. For most facilities the samples need to be collected only twice per year, much less often than expected of wastewater discharges. The monitoring results are submitted in annual reports that also address other aspects of the facility's operation. Facilities monitor storms they select, sampling at locations they select, without supplemental verification monitoring by agencies except in specialized circumstances. The third stage of compliance requires facility operators to design and implement a site-specific Stormwater Pollution Prevention Plan. That plan is held on-site, not submitted for approval to any agency, but is required to be available for agency inspection upon request.

Compliance with all three stages is self-implemented at its core. The self-implementation could be supplemented by agency oversight, as in the wastewater inspection programs or air emission. However, in practice, evidence suggests agencies implementing the stormwater general permits conduct little verification of any kind. That is only one reason for which evaluation of the success of the stormwater regulations is extraordinarily complicated, even compared to other regulations in the environmental field where the concept of 'success' may be open to debate.

Clearly, only success with the third stage of compliance actually contributes to protecting the environment. Legitimate evaluation of that stage would require assessment of individual Pollution Prevention Plans, including their suitability for the facility's specific activities. Because very few on-site inspections have been implemented by any state agencies of which we are aware, no direct information on third-stage actions is available from the implementing agencies. Evaluation by third party researchers to date has been limited to small numbers of facilities in limited areas and of particular industry types (e.g. Duke & Beswick, 1997; Duke & Bauersachs, 1998; Chang, 2001). In principle the success of the pollution prevention might be evaluated using monitoring results from the second stage, but in practice the high variability of stormwater constituent concentrations and the small number of samples collected at a given facility have been shown to miss or obscure any trends in the runoff water quality (Duke, 2001).

Further, evaluation of those stages might be construed as premature if compliance with the first stage is unknown. First-stage compliance is crucial to the success of the regulations, because if a large proportion of facilities subject to the regulations fail to participate in the program in any way, then compliance by the remainder with reporting and planning requirements will have at best a limited effect on environmental protection. Earlier results demonstrate there are many facilities that do not participate. Experience of the states (e.g. CSWRCB, 1992) and previous research in limited local areas (e.g. Duke & Shaver, 1999; Duke *et al*., 2000) have suggested that a large proportion of facilities in the regulated community have failed to identify themselves, raising questions about the effectiveness of the self-implementation aspects of this regulation. Therefore, this research evaluates first-stage compliance in a systematic way, across a number of states and over the course of a decade in which the regulations have been in effect.

Objectives of this Research

The overall objective of the present research was to assess the degree to which industrial businesses in the US participate in the mandated, self-implemented regulatory system for stormwater discharges. In so doing the research investigates whether this form of self-implementation can be an effective form of regulation to address environmental impacts from various societal activities. The research evaluates the first-stage compliance behavior of industrial facilities subject to regulations for stormwater runoff. The analysis uses empirical data on first-stage compliance for four target states, focusing on 14 selected industry sectors. The research identifies differences in compliance rates among the target states, and to some extent investigates the relative success of a few programmatic approaches and compliance strategies implemented by those states. The research also identifies institutional factors and data limitations that introduce uncertainty in assessing compliance of even the relatively simple first-stage requirements of the stormwater regulations for industry.

Methods

This research evaluated compliance by industrial facilities with federal and state regulations, in particular the difference in compliance among different parts of the US. The research assessed compliance with statewide requirements for stormwater discharges associated with industrial activities, evaluating the behavior of aggregated numbers of industrial facilities in four states.

Data Sources: Facilities Completing First-Stage Compliance in Four States

The states targeted for this research were California, Florida, Oklahoma and Texas. These were selected because of the large number of industrial facilities in these states (including three of the nation's four most populous), and the availability of data about first-stage compliance in these states. Data on first-stage compliance with stormwater regulations were obtained from several sources.

A US EPA database (US EPA, 2000) contains industrial facilities that have identified themselves as subject to the statewide regulations for states where US EPA

held NPDES regulatory authority for stormwater. That includes Texas and Florida, both for the period 1992 through 2000; and Oklahoma, for the period 1992 through 1997. Data contributed to the federal database by Oklahoma, Texas, and Florida were sharply reduced or eliminated, after those dates because those are the years when they began implementing stormwater regulations at the state level.

California agencies did not provide self-identification information to the US EPA database, because California held state-level authority from the time when the stormwater regulations for industry initially took effect in 1992. The data on first-stage compliance by California facilities were acquired from a state-level database maintained by the California State Water Resources Control Board (CSWRCB, 2000).

In Florida, for purposes of this research, personnel at the Florida Department of Environmental Protection provided facility self-identification data for selected counties for the period 2000–04. That effort allowed this research to compare compliance data for the periods before and after the 2000 changeover for those counties, a unique set of data that allows observation of the effects on compliance of the change from Federal to state primacy. The data were not tabulated for Florida statewide, so this evaluation was possible only for three Florida metropolitan areas.

All three databases included information on the facility's county and city, its industrial sector, and the date of the facility's initial self-identification as subject to the statewide general permits. Those data were sufficient for this research's analysis on the number of facilities completing first-stage compliance by industry sector, facility location, and date of filing. The results of this research rely heavily on categorizing facilities into the industry sectors that describe their activities. For this purpose, to avoid double-counting, the research accepted as 'primary' activity the sector listed first on the self-identification form by the facility operator. That is an imperfect approximation, for reasons described below.

Industry Sectors Targeted for Analysis

The industrial stormwater regulations, developed in 1987 and effective in 1992, defined the facilities included in the regulations to include the categories shown in Table 1 (US EPA, 1992). The categories use the Standard Industrial Classification (SIC) system, developed by the Department of Commerce and other federal agencies to classify businesses by the kind of product or service they generate. This classification enables statistical summaries of economic activity by sector that are valuable in planning and evaluation of the nation's economy, wherein businesses are often grouped by their 'primary' industrial category, judged by the on-site activity that produces the largest portion of revenue.

However, the federal and statewide general permit regulations were written in a way that recognizes facilities' main financial activities may not be their key characteristic regarding stormwater runoff pollutants. Modern industrial facilities commonly conduct multiple types of activities, and facilities that, for example, generate their revenue by selling lumber products—a retail activity in the Department of Commerce definitions, and exempt from stormwater regulations—may also as a subsidiary activity cut and shape lumber, perhaps outdoors, generating potential pollutants in runoff in a way the NPDES rules seek to regulate.

Table 1. Industrial categories subject to US stormwater regulations

SIC(s)	Description
Mandatory Compliance Manufacturing	
24 except 2434	Lumber and timber products
26 except 265, 267	Paper, allied products
28 except 283, 285	Chemicals, allied products
29	Petroluem and coal products
32 except 323	Stone, clay, glass, concrete
33	Primary metal manufacturing
373	Ship and boat building, repairing
311	Leather tanning and finishing
3441	Fabricated structural metal
Transportation	
40	Railroads
41	Passenger transport
42 except 4221–25	Trucking, other freight handling
43	Mail
44	Water transportation
45	Air transportation
Other Mandatory Compliance Industries	
10, 12, 13, 14	Metal mining, coal mining, oil/gas extraction, other minerals
495	Waste treatment, disposal; landfills
5015	Used motor vehicle parts
5093	Scrap, recycling facilities materials
4911	Steam electric generating stations
'Conditional Compliance' Manufacturing	
20, 21, 22, 23, 2434, 25, 265, 267, 27, 283, 285, 30, 31, 323, 34, 35, 36, 37, 38, 39 except 311, 3441, 373	All manufacturing not designated 'mandatory compliance'
4221–4225	Warehousing and storage

Source: Duke *et al.*, 1999b.

The NPDES regulations for stormwater specify a facility's operator must identify itself to regulatory agencies, and complete the further permit requirements, in a more inclusive way than the SIC system's industrial classifications. The stormwater regulations apply if the facility conducts industrial activities 'typical of' a selected set of industry sectors, regardless of whether that activity is the facility's primary purpose or accounts for the largest portion of revenue from the facility. Those sectors selected by US EPA for coverage under the stormwater regulations are shown in Table 1. The distinction is logical from the viewpoint of efficient regulatory design: in concept it includes all facilities, and only those facilities, that conduct on-site activities that are judged likely to generate stormwater pollutants, regardless of what activities those facilities use to generate their revenue. However, the structure has been the root of substantial complexity and uncertainty in assessing the effectiveness of the regulations, for reasons that become clear throughout this research.

In the same way, NPDES regulations for industrial process wastewater are not specific to the facility's overall or primary activities, but use a coding system specific for the process that generates the wastewater. Implementation of those regulations is based on regulators' first-hand inspections of those activities, which were identified as sources to particular hard piped outfalls to receiving waters or sewage collection systems, so the database of the regulated community was constructed using first-hand, facility-by-facility observations of agency personnel. The stormwater regulated community has had no such agency site-by-site evaluation, perhaps influenced by the regulations' use of the SIC system rather than an independently constructed code, so the size and character of the regulated community are widely assumed to be represented by the poorly-matched single-code SIC under which the facilities report to the Department of Commerce.

The 1992 US federal-level general permit for industrial stormwater, and the various state-level permits approved by US EPA, specify two categories of industry groups, which can be termed 'mandatory' and 'conditional' compliance categories. In the 'mandatory' or 'heavy industry' category, all facilities conducting those activities must self-identify and comply with the regulations, on the assumption that by their nature those industrial activities will generate pollutants that appear in storm runoff. Sectors defined as 'light industry' categories need to identify themselves only if the industrial activities listed are exposed to stormwater, under that assumption that their operations will not necessarily affect storm runoff unless they are directly or indirectly exposed. The two categories, and the requirements that treat the two groups separately, have been modified in subsequent regulations, but were in effect for the greater portion of the target period for this research, so they are retained here, mostly for purposes of grouping the sectors selected as targets for this research.

This research focuses on 14 selected target industry categories, described using their designated SIC codes. The targeted categories were selected as follows. First, the research emphasizes manufacturing types of facilities, defined under the SIC system with codes from 2000 to 3999. Those are selected because they are the facilities where industrial-type activities are found more uniformly (at nearly all facilities) than in other types of industry. Second, the research emphasizes categories identified as 'mandatory' in the stormwater regulations, because in concept those facilities are not subject to the confounding feature (specified for 'conditional' categories) that facilities need not comply if all their industrial activities are conducted in a way that is not exposed to stormwater. Third, the research emphasizes categories where large numbers of facilities are present in the target states. Combining those criteria, the selected categories include: (a) all nine 'mandatory' categories that are in the manufacturing sectors; (b) three other 'mandatory' categories, not within the manufacturing sectors, where a large number of facilities are present in one or more of the four target states; and (c) two non-manufacturing, non-'mandatory' categories where a large number of facilities are present in the target states. Together, the 14 selected categories encompass the five most-common sectors for all four target states: that is they include, for each state, each of the sectors that contains the first through the fifth largest number of facilities in the first-stage compliance lists. The selected categories are listed in Table 3, in the Results section below.

Data Source: Facilities Failing to Complete First-Stage Compliance

Estimating the proportion of compliance with the statewide permits' first-stage requirements is much less direct, and estimates are much less precise, than data on the number complying. The regulation define the regulated community based on on-site activities at each facility, rather than according to the facility's main category of business. This is reasonable in that it limits the regulations to facilities that need to be concerned with pollutants in stormwater discharges. However, it also serves to mask the true proportion of compliance, because the size of the regulated community cannot be reliably estimated using any database of which we are aware. It may require site-by-site determination for every possible facility, and no agencies have completed such a painstaking assessment of businesses in any sizable geographic area. Extensive evaluations have demonstrated that no databases, public documents, or reports to government agencies reliably correlate facility names with the kinds of activities defined in the general-permit regulations (Duke & Shaver, 1999; Duke *et al*., 1999b).

Therefore the proportion of covered facilities completing first-stage compliance is impossible to assess with accuracy. As a surrogate measure, this research instead uses a term we call NOI/Census ratio. The ratio expresses the proportion of facilities that have identified themselves (by filing NOIs, or Notices of Intent) as a fraction of the number of facilities active in that SIC and region as listed by the US Census of Manufactures. The Census latest year for which complete data were available at the time of this research was 1992 (USBC, 1997), so the calculation assumes that the number and category distribution of facilities did not change substantially from 1992 to the end of the project period. The NOI/Census ratio is calculated separately for each industry sector, because for a variety of reasons we can expect the ratios to be different in different industry sectors. It is also calculated separately for each state, as a means to assess the relative success of various states at attaining compliance.

The Census of Manufactures is a reliable and consistent estimator of the number of facilities conducting business in a given area of the US, and it disaggregates business activity using the same SIC categorization as the 1992 NPDES regulations. However, for purposes of this research the Census information suffers the same limitation of any other known database, in that it assigns to each facility a single 'primary' SIC, while a facility may be required to comply with stormwater regulations if it conducts any activities (beyond the primary financial activity) that are 'typical of' any other SIC included in the stormwater regulations' definition. Therefore the Census data fail to categorize a large number of facilities within the SICs under which those facilities are required to identify themselves and comply with the statewide regulations. Often the business's main activity does not adequately describe a given facility's on-site operations, and often the operations at a given facility include a relatively minor business activity that causes it to be subject to stormwater regulations.

The result is likely to be a consistent indicator for the separate target states within a given SIC, but it should be emphasized that the compliance ratio cannot be compared among different industrial categories, and also that no single compliance ratio for 'all industry' is meaningful. That is because, in different industry types, the Census methods experience to a greater or lesser degree the various limitations in

identifying facilities subject to stormwater regulations. For example, it is possible that nearly all facilities listed in Census data as primary metal manufacturing (metal foundries and similar facilities) do actually conduct those industrial activities on–site; and since they are categorized as mandatory-compliance industries, then nearly all those facilities listed in Census data may need to comply with the regulations. By contrast, many businesses whose primary activity is lumber and timber products manufacture include not only wood-products factories, which are required to comply; they also include lumber-products distributors or sales outlets, with site-specific activities limited to loading/unloading, storage, or retail sales. Those categories constitute a large number of facilities in most regions that have been evaluated, and those facilities are not required to comply with the stormwater regulations for industry. Therefore, the NOI/census ratio will be much smaller even if every facility required to identify itself did so. It might be postulated that every industry sector has some 'full-compliance ratio', or proportion of Census-listed facilities that should comply with the regulations based on their on-site activities. It is not possible to quantitatively estimate this full-compliance ratio for any given SIC with any information currently available.

Thus the Census data are not a valid estimator of the number of facilities in the regulated community, but are a reliable and valid estimator of the number conducting business in a given SIC. The population of facilities counted in the Census data should be considered facilities similar to those required to identify themselves and comply with the regulations. Therefore, Census data may be considered a reasonable estimator of the relative number of facilities for comparison across jurisdictions within a given SIC. The data are expected to be approximately uniform across all the jurisdictions evaluated here, because they are administered by the US Bureau of the Census using identical methods across all parts of the US. The NOI/Census ratio is a means to normalize the number of facilities completing first-stage compliance to the industrial and economic activity within each industry sector for each of the targeted states.

Institutional Settings and Program Design Choices by Target States

States attained approval for state-level industry stormwater permits at different times, as shown in Table 2. The majority of states received US EPA approval to administer NPDES general permits prior to 1992, when the stormwater industrial regulations took effect. Those states issued state-level industry stormwater permits either at the outset of the regulations' taking effect, or soon after. California, one of the target states for this research, is among those states.

Some states gained approval within a few years after 1992, so that US EPA administered the stormwater regulations for a short time until state-level agencies assumed responsibility by issuing their own state-level stormwater permits for industrial facilities. A few further states remained under US EPA's jurisdiction for five years or more, and issued their own state general permits for industry (or otherwise assumed responsibility) in 1997 or later. Those states include the other three targeted for this research: Oklahoma, approved in 1996, issued its state-level industry stormwater permit in 1998; Florida, approved in 1995, assumed state responsibility in 2000 (but as of 2005, still uses the US EPA's general permit); and

Table 2. State-level institutions for implementation of stormwater NPDES regulations

	State stormwater general permit issued	General Permit Program approved by US EPA	Agency with stormwater NPDES responsibility
Targeted states			
California	1992	1989	California State Water Resources Control Board, Division of Water Quality, Stormwater Permits Section
Florida	2000[a]	1995	Florida Department of Environmental Protection, NPDES Stormwater Section
Oklahoma	1998	1996	Oklahoma Department of Environmental Quality, Water Quality Division
Texas	2000	1998	Texas Natural Resources Conservation Commission, restructured as Texas Commission on Environmental Quality
Other states and locations			
AL, AR, CA, CO, GA, HI, IL, IN, KY, MD, MN, MS, MO, MT, NE, NJ, NC, ND, OR, PA, RI, TN, UT, VA, WA, WV, WI, WY		1991 or before	Various state agencies
CT, DE, FL, IA, KS, LA, MI, NV, NY, OH, SC, SD, VT		1992 – 1996	Various state agencies
AZ, ME[b], OK, TX		1997 or after	Various state agencies
AK, ID, MA, NH, NM, DC, PR, VI, most tribal lands, various Pacific islands		State programs not approved	Federal multi-sector general permit applies as of June 2005

[a]Florida assumed responsibility for industrial activities stormwater permitting in 2000 but did not issue state-specific general permits, instead using US EPA's multi-sector general permit.
[b]Maine is subject to Federal multi-sector general permit as of June 2005, until Maine issues a general permit for industrial activities.
Source: US EPA (2005)

Texas, approved in 1998, issued its state-level industry stormwater permit in 2000. A few states and other jurisdictions remain under US EPA administration, as shown in Table 2.

In Florida, investigations dating from the late 1970s determined stormwater to be the primary source of pollutant loading to state surface waters, and as a result it became the first state in the country to establish a statewide program requiring the treatment of stormwater from new developments (State of Florida, 2000). Surface waters of concern are predominantly the myriad lakes across the Florida

landscape, and nutrients that can cause algal blooms are the pollutants of concern in most cases, so the focus of Florida's stormwater program is runoff of organic materials, as reflected in the rules to treat new development runoff. Accumulation of metals, synthetic chemicals and other substances characteristic of industrial activities has not been an environmental problem in Florida's aquatic systems, so industrial NPDES stormwater compliance has not been a leading priority. The Florida Department of Environmental Protection (FDEP) serves as the administering agency of the stormwater management program. FDEP delegated the runoff treatment permitting program to the five regional Water Management Districts (WMDs) to allow for design criteria to better reflect regional hydrology, but has retained the administration of the industrial NPDES stormwater permits at the FDEP level. Florida received general permitting approval from US EPA in 1995, but the stormwater general industrial permits were administered by US EPA Region IV until 2000, when FDEP assumed administration. Permits for discharges by municipal stormwater agencies were initially issued by US EPA in the period 1996–97. These were issued for Florida's urban areas with population greater than 100 000.

In California, NPDES permits are issued through the State Water Resources Control Board (SWRCB), a division of the California Environmental Protection Agency. Nine Regional Water Quality Control Boards (RWQCBs) are responsible for issuing the permits to municipal stormwater agencies, and for implementing the statewide stormwater permit for industries (that is issued by SWRCB). This watershed-based implementation approach might be expected to encourage enforcement by placing responsibility in a more local region rather than originating from the state capital, and is not used in the other three target states. In California the authority for implementing NPDES stormwater regulations was held at the state level from the outset. General permitting authority was in place from the 1970s and the state-level permit for industrial facilities was issued in 1992. The state and regional agencies were active in publicizing industrial facilities' duties to comply from before the time those regulations were issued, including outreach workshops in San Jose and Fresno and published guidelines for compliance (Santa Clara Valley, 1992). Similarly, state regulators had issued municipal stormwater permits to the largest urban regions by 1992.

Oklahoma received general permit authority in 1996. The Oklahoma Department of Environmental Quality (ODEQ) administers a statewide permit for industrial storm runoff. The state-level permit has been in effect since 1998, after several years of administration by US EPA Region 6.

The Texas stormwater program is managed by a division of the state environmental agency. NPDES authority at the state level was approved in 1998. A statewide general permit was issued in 2000 by the Texas Natural Resource Conservation Commission (TNRCC), since restructured as the Texas Commission on Environmental Quality (TCEQ). TCEQ views itself as the most comprehensive state environmental agency in the country, with 3000 employees and 16 offices across the state (State of Texas, 2000). As in Oklahoma and Florida, the statewide permit is administered by a statewide agency with broad responsibilities rather than a water-focused agency as in California, but with multiple local points of administration similar to the watershed-based California RWQCBs.

Assessing Compliance: Facilities Completing First-Stage Compliance as Proportion of Approximate Size of Regulated Community

This analysis assesses the degree to which the regulated community has succeeded in complying with the requirements for self-identification. Table 3a summarizes the total number of facilities completing first-stage compliance in each of the 14 target industry sectors for the four target states. Figure 1 disaggregates these same data by industry sector as a percentage of the total number of facilities completing first-stage compliance in each of the four target states. The auto salvage/recycling category was the single largest category of complying facilities in California and Texas. Auto salvage was a notably smaller category in Florida and Oklahoma, the third largest in each of those states, with 5.6% and 4.8% respectively of the total number of complying facilities. Oil and gas extraction (SICs 1300 through 1399) was by far the largest category of facilities in Oklahoma, with 890 facilities representing about 26% of all facilities in the state that completed first-stage compliance. No other state or region showed such a predominance of facilities in any one industry sector. The same SIC was the third-largest category in Texas, with 1334 facilities comprising about 6.9% of the first-stage complying facilities there. Large numbers of oil and gas extraction facilities operate in those two states, with more than 6000 businesses in Texas and more than 2000 in Oklahoma according to 2000 Census data.

Table 3b displays the NOI/Census ratio that expresses first-stage compliance as a proportion of all facilities identified in Census data for each state. Figure 2 displays those same NOI/Census ratios by state, for the 10 SICs that account for more than 1% of self-identifying facilities in any state. Perhaps the most salient feature of both Table 3b and Figure 2 is that the NOI/Census ratio equals or exceeds 100% in seven of the cases evaluated. Four of those are in separate industrial categories in Texas; two are in Oklahoma; and one is in Florida. The fact that categories can exceed 100% is a product of the regulatory definition and the Census standard procedures, because Census data categorize facilities by their financially predominant activity while the first listed SIC on the self-identification forms typically indicate the activity that leads the facility to be subject to stormwater regulations, often not the financially predominant activity at that site. Exceeding 100% does not imply an error in the data, and does not necessarily mean that the sector has attained full compliance in that state, because it is possible that the full compliance figure is even greater.

Texas has attained a more complete compliance in several categories than any other state in several industry sectors. In primary metals manufacturing the Texas figure of 100% is much higher than that of California (55%). The proportions are less meaningful because of small samples for Oklahoma (89%, comprising only 72 self-identifying facilities) and Florida (29% comprising only 40 facilities). Texas attained a far higher statewide ratio than any other target state in the stone/clay/glass/concrete category with 191%, while Florida and Oklahoma were just over 60% and California just under 50%. In the auto salvage category, Texas' compliance ratio of nearly 200% greatly exceeds any of the other states: California's ratio was 90%; Oklahoma's ratio was 60%; and Florida's ratio was 39%. Texas also attained a higher ratio in the chemicals and allied products category, with 87% compared to 68% for Oklahoma (of only 62 self-identifying facilities statewide), 35% for California, and 34% for Florida.

Table 3. First stage compliance in selected industrial categories in target states

(a) Number of facilities completing first stage compliance as of 2000

	Heavy industry manufacturing (mandatory compliance)									Other selected heavy industry (mandatory compliance)			Selected conditional compliance categories		Total, all NOIs
	Lumber & timber	Paper & allied products	Chemicals & allied products	Petroleum & coal products	Stone, clay, glass, concrete	Primary metal mfg.	Ship & boat building & repair	Leather tanning & finishing	Fabricated structural metal	Recycling & auto salvage	Oil & gas extraction	Passenger & freight transport	Fabricated metal products	Electronic products mfg.	All industries
SIC:	24xx, not 2434	26xx, not 265/267	28xx, not 283/285	29xx	32xx, not 323	33xx	373x	311x	3441	5015, 5093	13xx	42XX, not 4221–25	34xx	36xx	All SICs
California	236	16	493	158	634	356	85	2	45	1596	83	1335	746	440	10 147
Texas	437	15	892	541	2104	338	97	11	116	2286	1334	1690	1088	335	19 331
Florida	169	16	185	212	513	40	302	3	13	321	8	706	135	78	5695
Oklahoma[a]	32	6	62	135	177	72	0	0	14	166	890	239	295	40	3472
(b) NOI/Census ratio: facilities completing first stage compliance as of 2000 as a proportion of facilities identified in Census data															
California	0.10	0.02	0.35	0.77	0.47	0.55	0.29	n/a	0.18	0.90	0.15	0.12	0.16	0.12	
Texas	0.28	0.04	0.87	2.80	1.91	1.00	0.43	0.52	0.53	1.96	0.21	0.18	0.41	0.34	
Florida	0.13	0.08	0.34	4.33	0.65	0.29	0.45	n/a	0.11	0.39	n/a	0.12	0.09	0.10	
Oklahoma[a]	0.16	n/a	0.68	3.00	0.61	0.89	n/a	n/a	n/a	0.60	0.40	0.13	0.49	0.28	

n/a: Not applicable because of a small number of facilities; fewer than 20 facilities in Census data and/or fewer than 5 NOI filers in this sector.
[a]Oklahoma data are through 1997 only.

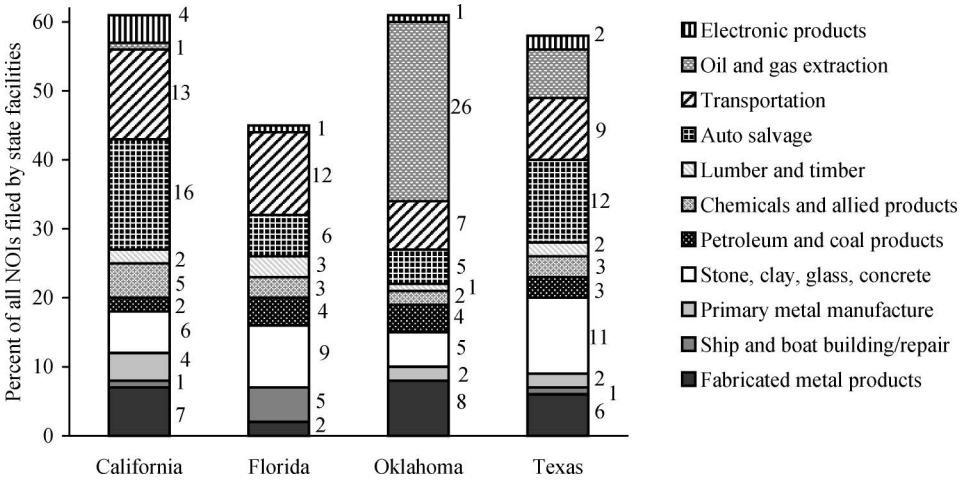


Figure 1. Percentage of NOI filers in each leading industry sector, by state, 2000 data.

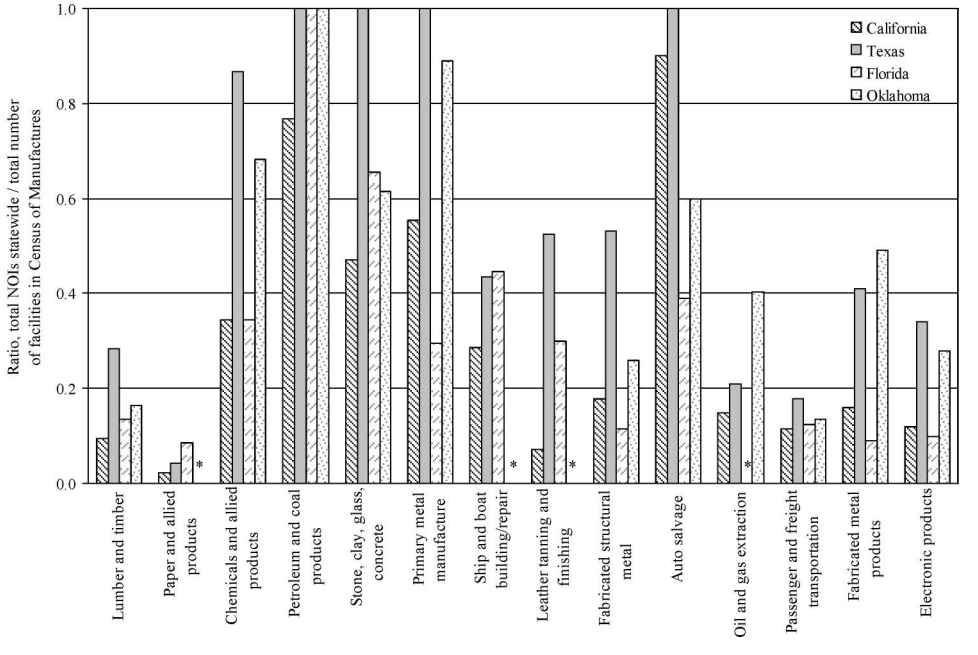


Figure 2. NOI/Census ratios for target industry sectors, by state, 2000 data.

In Oklahoma, the NOI/Census ratio in the oil and gas extraction category was 40%, giving Oklahoma one category where that state excelled. The ratio was nearly twice that of Texas (at 21%), while California's ratio was 15% and Florida's ratio was 14% (of a small number of facilities, only 80 statewide). The oil and gas extraction sector was by far the largest category of NOI filers in Oklahoma, with 890 facilities

representing about 26% of all the first-stage complying facilities in the state. In no other state does one sector dominate the first-stage compliance to this extent. This suggests a particular focus by Oklahoma regulators on this industry, a major one for the state: Census data for Oklahoma show more than 2000 businesses reporting under a primary SIC in this category. The data also show more than 6000 such businesses in Texas, but the diversified industrial base in Texas and the diversified sector focus of the compliance agencies make this same SIC the third-largest category in Texas, with 1334 facilities comprising about 6.9% of self-identifying facilities there. California also had a large number of facilities in this sector, with 83 NOIs filed of 559 statewide listed in Census data, attaining a low ratio of only 15%.

California had no sectors where it was the best-achieving state, and only in the auto salvage area was the ratio second highest among the four states, with a ratio of 90% compared to about 60% in Oklahoma and 40% in Florida. Florida had no category (with enough facilities to be statistically meaningful) where its ratio approached the best among the four states, but in several categories Florida's compliance ratio was similar to or better than California's.

The transportation category accounted for among the largest number of first-stage complying facilities in each of the target states even though compliance proportions are lower than most other categories in every state, at 12% in California and Florida, 13% in Oklahoma and 18% in Texas. This category is a diverse one under the regulations, and the characteristics that require a facility to identify itself are not always well-understood by the regulated community: the definitions of actions that require compliance are somewhat complex; many of the actions that require compliance are not easily detected by anyone other than facility operators themselves; and regulatory definitions are not easy to grasp for the typical businessperson operating a transportation facility. The regulations apply to facilities that maintain, store, or provide vehicles used to carry passengers or freight for hire (thus excluding vehicle fleets maintained by the owners of the freight or transporting employees of the firm). Facilities excluded may have very similar operations to included facilities. The full-compliance proportion may be much smaller than the proportion in other sectors, so the low NOI/Census ratios displayed here might not be far from full compliance in this sector.

Among the stone-products facilities of SIC 32, Texas attained by far the best compliance with nearly 200% of Census listings. Florida and Oklahoma each attained greater than 60% compliance, while California was the least effective, with fewer than 50% of Census-listed facilities completing first-stage compliance.

Among the metal-fabricating facilities of SIC 34, all the states attained relatively low compliance ratios. It is reasonable to expect the full-compliance ratio to be much lower because this is a 'conditional' category, so that a fraction of facilities fabricating metal parts where no industrial activities are exposed to stormwater are not required to comply. Differences between states may in this case be especially subject to differences in industrial composition among regions. Facilities that fabricate industrial machinery, for example, can be expected to be clustered in regions with many manufacturing facilities, such as Los Angeles or Tulsa; and are less numerous in all parts of Florida, where facilities of this general category are more likely to be those that conduct minor repair or re-fabrication services on a less intensive daily basis. The NOI/Census ratio shows some clear differences among the

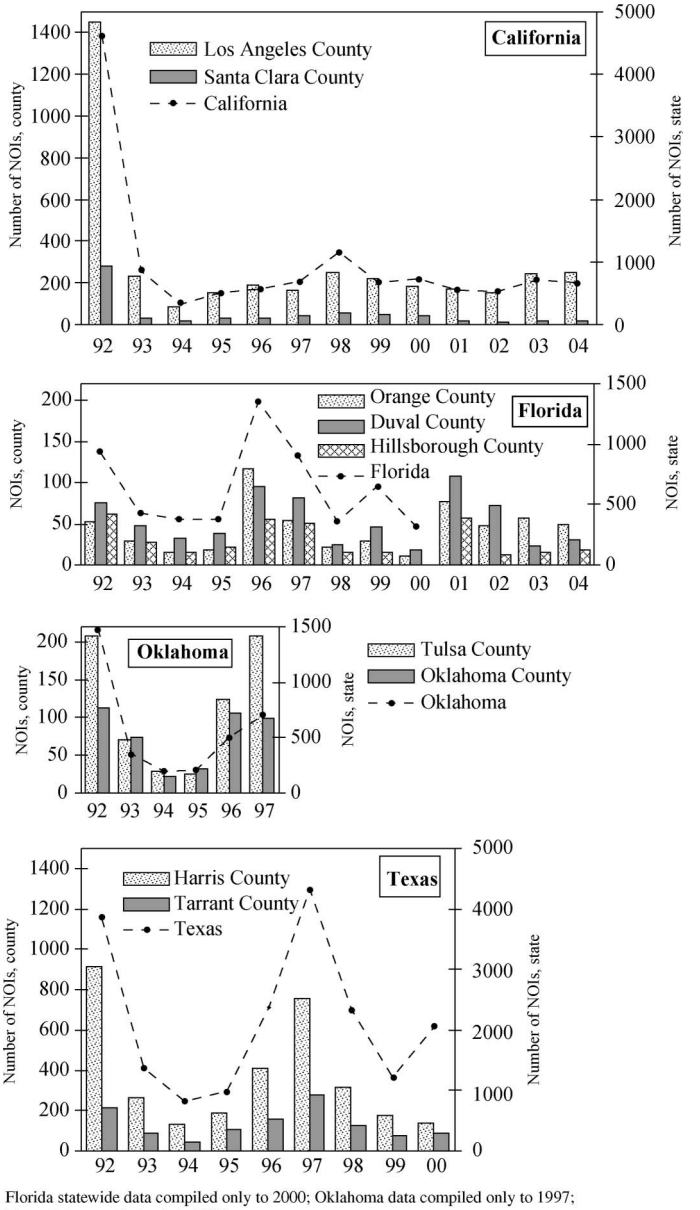
states. The compliance proportions were greater than 40% statewide in both Texas and Oklahoma. The compliance rate in California was surprisingly low, at 16% statewide. The much lower compliance ratio in California suggests that California is under-performing in attaining compliance in the metal-products sector.

Time Trends in First-Stage Compliance for Four Target States

Figure 3 displays the number of facilities in each target state, and selected urban regions, by the year in which they filed NOIs and thus initiated compliance with the statewide stormwater regulations for industry.

In California, by far the largest number of new complying facilities did so in 1992, the initial year of the regulations. This pattern might be consistent with one of reasonably complete compliance, where most facilities subject to the regulations recognized their duty at the outset and in subsequent years the new enrollers consisted of a few facilities that were initially unaware of their obligations and new facilities commencing business in that year. However, some additional observations suggest otherwise. There is a noticeable upswing in 1998, when the total of 1165 facilities identifying themselves statewide is an increase of about 75% to 100% over the totals of 500 to 700 from 1995 through 1997. That change coincides with a statewide mailing and telephone outreach program by the State Water Resources Control Board to reach non-filers and inform them of their duty to comply (Duke *et al*., 1999b), suggesting a substantial impact of the outreach effort. Another reasonably strong upswing in the number of newly self-identifying facilities to the range of 600 to 700 per year occurred in 2003–04, coinciding with a general statewide effort by the Regional Water Quality Control Boards to publicize the issue of non-compliance. The two outreach programs' substantial success indicates a large pool of non-complying facilities remained during each of those two periods, which were encouraged to comply through implementation efforts as simple as notification of their duties to comply. The pattern indicates a substantial refractory portion of the regulated community, consisting of facility operators who continue to be unaware of their duty to comply and/or who choose not to comply in the face of penalties under the Clean Water Act.

Another feature of California's implementation strategy is a special enforcement effort for automobile salvage facilities. As noted above, the NOI/Census ratio in this industry sector was 90% in California, the only sector where the ratio exceeded those in either Oklahoma or Florida. The sector is the target of an implementation agreement between CSWRCB and the California Department of Motor Vehicles (DMV). The latter agency issues licenses to dismantling businesses, which are required of any facility that dismantles automobiles in California. Since the mid-1990s, DMV has specified that no dismantling license be issued or renewed unless the applying facility states it also has complied with the first stage of stormwater regulations and identified itself to the California state agency (Swamikannu, 1999). California has attained a 90% statewide compliance ratio among auto salvage facilities. However, the approach is not ironclad assurance that each licensed facility has in fact completed an NOI: it relies on each applicant to so state, and without enforcement follow-up it is possible that applicants misunderstand or mis-state their compliance status. Compliance in Texas in the auto salvage sector is much more



Florida statewide data compiled only to 2000; Oklahoma data compiled only to 1997; Texas data compiled only to 2000.

Figure 3. New NOIs filed by year, selected states and urban counties, 1992–2004.

complete, with a NOI/Census ratio of nearly 200%. Unless there is some substantial difference in industry composition between California and Texas among facilities listed in Census with SICs 5015 and 5093, the substantially higher Texas NOI/Census ratio suggests the California institutional arrangement between DMV and SWRCB fails to reach a large portion of auto salvage facilities that should identify themselves and comply with stormwater regulations.

The time pattern of compliance in Florida was different. The initial year of enrollment, in 1992, does not have the predominant number of newly-complying facilities. Instead, the number of new self-identifications was higher in several years than in the initial year, and was similar in several other years. The initial year's implementation in Florida appears to have been much less energetic than in California. This may have occurred because there was no statewide NPDES authority for stormwater in Florida during its initial years, when the program was administered from the US EPA Region 4 office in Atlanta. The much lower compliance proportion in Florida than in other states, such as Texas and California, appears to reflect the lower level of statewide involvement at the outset, which is further demonstrated by the strong increase in compliance as municipal and state-level agencies in Florida assumed authority for various aspects of stormwater regulation.

A peak in the number of facilities completing first-stage compliance in Florida occurred in the period 1996–97. During that same period US EPA issued the first water quality permits for municipal stormwater drainage agencies in many Florida urban regions, including the three tabulated here. The years 1996 and 1997 each experienced more facilities complying for the first time with first-stage requirements than the initial year of the industrial permit, in 1992.

The statewide data for Florida end in 2000, the year in which Florida gained primacy for implementing NPDES stormwater regulations, but it is possible to observe the regulated community's behavior using the county-level data plotted in Figure 3. The data for the three target counties prior to 2000 show a pattern that tracked the statewide compliance patterns reasonably well, so it is a reasonable inference that statewide compliance behavior after 2000 can be read from the county-level data for that period. It should be noted that the number of new first-stage complying facilities recorded for the year 2000 is unusually low compared to other years for all three counties, including zero new NOIs in Hillsborough County. This is likely to be a recording error, arising from a failure by state personnel to update the federal database during its final year when it was clear that a new state-level database would soon supersede it. The extremely high number of new first-stage complying facilities in 2001 should properly be allocated to the two-year period 2000–01.

Accounting for the recording errors, a marked increase in first-time compliance with first-stage requirements can be observed in approximately 2000 and 2001 data for the three target counties. That period coincides with the onset of state-level primacy for the industrial stormwater regulations. The number of newly-complying facilities increased to about 60 per year in Duval County, 40 per year in Orange County, and 25 per year in Hillsborough County. Each of these is in the range of 50% to 100% more new facilities per year than in the preceding years, and even greater than in the following years. The number sharply declined in the years after 2001. It appears the transition to state primacy could be responsible for this effect, perhaps owing to the one-time increase on emphasis of agency personnel, and the publicity in general associated with the transition. The high first-time compliance at two dates well after the 1992 initiation of the regulations is further evidence that compliance was lower from the outset in Florida, a state initially regulated by US federal agencies, than in California where a state-level agency held authority from the outset or in Texas where the federal agency attained high compliance initially that was later enhanced by state agencies.

The time pattern in Texas combines some of the same patterns observed separately in Florida and California. An initial peak appears in 1992, tracked by the two counties with the greatest number of new first-stage compliance, though the peak is far less pronounced than in California. A second peak of greater magnitude appears in 1997, coincident with the time the municipal agency stormwater-quality permits were issued for Texas' large-population urban areas. That peak is not as predominant as Florida's peak in the same period, suggesting a greater initial enrollment in Texas than in Florida. A third statewide peak appears in 2000, coinciding with the issuance of the statewide general permit requirements. The institutional factors associated with the initiation of a regulatory program, including initiation of the same requirements at a new level of government, appear to have affected first-stage compliance in Texas. As noted in the previous section, Texas attained the highest NOI/Census compliance ratios, for reasons that are not fully apparent within the scope of this research. Among those reasons, it appeared that Texas succeeded in capitalizing on both the impetus of the initial federal regulation to attain an initial peak in the fashion of California (a feature absent in Florida), and also used succeeding years to continue adding facilities to the first-stage compliance lists. The Texas compliance may be boosted in part by transitional factors that account for most of the compliance in Florida, a feature absent from California where state- and local-level regulations were initiated at the outset in 1992.

Discussion

The research identified strong disparities among states, for which the reasons are not clear. Of the four states, Texas appears to have been the most successful overall at encouraging compliance with first-stage requirements of the industrial stormwater regulations, while Florida and California appear to have been the least successful. The true compliance rate cannot be estimated with available information, because of the way the regulated community is defined. However, the fact that compliance proportions are so sharply disparate is in itself evidence that compliance must be highly incomplete, in at least some states. That observation supports earlier research showing compliance in specific geographic areas to be in the 10% to 20% range in the late 1990s (Duke *et al.*, 2000). The result is also consistent with Federal government findings that states have implemented CWA regulations with varying degrees of resources and results (US GAO, 1996, 1999).

It is possible to identify a few programmatic and institutional factors that appear to have influenced compliance behavior in the target states. One specific outreach activity, via the California Department of Motor Vehicles, had a measurable effect in increasing the number of industrial facilities completing first-stage compliance within a particular target industry category, apparently sustained over time. Another outreach activity, also in California, addressed a broader range of industries for a limited time, and appears to have produced a measurable upturn in first-time compliance among industrial facilities statewide during that period. In Florida, substantial upturns in compliance occurred at two particular times, coinciding with the separate dates on which municipal- and state- level regulations were initiated in that state.

To more fully understand the variations in success, it would be necessary to investigate the implementation methods and program characteristics employed by each state. That was beyond the scope of the present research. Future research might investigate the financial and personnel resources made available to each state's stormwater program. In addition, future research might investigate the impact of states' efforts to publicize the program and directly or indirectly inform the regulated community of its duty to comply. That could support or refute the considerations raised in the present research that publicity associated with initiation of the regulations enhances compliance. It would also be instructive to compare the propensity of state agencies to levy fines for violation of the first-stage requirements and to publicize those fines; anecdotal evidence has suggested immediate short-term upturns after periods when state agencies have identified and punished violators, and made those punishments public knowledge (Swamikannu, 1999). Other possible contributors include institutional factors such as the strength of industry trade associations, their ability to reach their memberships with information about regulations, and their willingness to put their weight behind efforts to improve protection of the environment.

The results presented here suggest another future research need is to better understand the interaction of the statewide general permit implementation with the water quality permits for local urban drainage agencies. The statewide general permits require facilities to self-identify and self-comply directly with a set of fairly remote regulations, and these regulations extend in principle to all facilities of the type identified as "industrial" in the cumbersome definitions of the regulations. Using local storm drainage agencies as an intermediary to identify and inspect facilities considered to be of sufficiently high concern adds a feature of prioritization comparable to wastewater and air emission regulations that is not present in the current stormwater general permits. Local agencies could be expected to bring an understanding of their own communities to this prioritization, and to identify facilities in their regions more effectively than any state-level outreach or enforcement activities. The analysis should also recognize the limitation that reliance on local agencies to set their own priorities likely will lead to a wide variation in diligence and resources allocated among jurisdictions, and ultimately variation in effectiveness of water quality protection.

The most pressing need to improve the regulations is a means to replace the cumbersome SIC system for determining the need to comply. Results of this research demonstrate how severely that system masks evaluation of effectiveness of the regulations because even the proportion of compliance is obscured. Perhaps more importantly, the system hinders the ability of the regulated community to make their required self-identification, and further hinders the ability of responsible agencies to identify non-complying facilities to bring enforcement actions and increase compliance. Under the current federal-approved, state-level general permits, the regulated community is defined based on whether a facility conducts activities 'typical of' some highly detailed definition of an industry type. That approach is successful for regulating wastewater pollutants, where the type and amount of pollutants are reasonably well determined by the type of products at a given facility and the processes used in their production. Borrowing that approach for stormwater has been counterproductive, because product type is unrelated to the characteristics

or magnitude of pollutants that appear in runoff. The regulated community should instead be defined by some factor such as exposure of industrial activities to stormwater. That factor is included in current federal guidelines to allow facilities to be excluded from the general permits if their industry category is included in the definitions but if no industrial activities are exposed to stormwater. The factor could be used to extend the regulations to facilities not among the listed industry sectors, but where industrial activities are in fact conducted and exposed to stormwater, a feature of the current local-level permits for urban drainage agencies. The definition can then be extended to consider some measure of the relative intensity of industrial activities exposed to stormwater, a consideration that would support the current local regulations' feature of prioritization and would allow state-level regulations to de-emphasize not only no-exposure but low-intensity facilities that could reasonably be expected to have minimal effect on water quality. Compliance efforts could then focus on facilities where higher intensity of industrial activities exposed to stormwater indicates higher likelihood of discharging pollutants of concern in significant amounts. This could increase compliance among those facilities at the expense of continued low compliance among facilities of lesser concern.

Conclusions

Compliance with stormwater pollution control regulations for industry in the US appears to be far from complete. It is clear that, more than a decade after the regulations took effect in 1992, a large number of facility operators have failed to make the required notification either by failing to understand the requirements or in the largely correct assumption that they will face no legal consequences if they fail to self-identify. This extensive failure to comply, and the apparent impunity with which members of the regulated community fail to comply, raises questions about the effectiveness of the entire structure of US regulations for environmental regulation that require self-identification and self-implementation but do not include reliable verification by public agencies.

The best available information allows only highly imprecise estimates of the number of industrial facilities required to comply with the regulations, and the ratios used in this research should not be considered such estimates. However, the results do support the premise that at least three of the four target states have highly incomplete compliance, judging from the fact that one state (Texas) attained substantially greater proportions of compliance than the other states for many industry sectors.

The four states evaluated here displayed substantial differences in compliance ratios within the target industry sectors. Differences in institutional settings and implementation strategies among the target states appear to have influenced their relative success. In most of the industrial sectors investigated, Texas had the highest proportion of compliance, with Oklahoma second in most sectors (and first in one, oil and gas extraction). Among the four states, California and Florida had similar proportions, with compliance ratios in most of the targeted industry sectors substantially lower than Texas and similar to or below Oklahoma. The exception was one sector in California, the auto salvage industry, where California's special

implementation approach attained a compliance rate about half that of Texas and substantially greater than either Florida or Oklahoma.

The fact that several programmatic changes and compliance improvement strategies each demonstrated a measurable increase in compliance, some of them quite substantial, is evidence that a substantial pool of non-complying facilities remained, at a time five to 10 years after the regulations took effect. The analysis further demonstrates that compliance with the self-identification requirements of these regulations has been far from complete.

Acknowledgements

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