Comparison of Two International Approaches to Controlling Risk from Produced Water Discharges

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Topics for Discussion

- What is produced water?
- What is in produced water?
- Approaches to minimize risk
  - U.S. approach
  - North Sea approach
- Why are there differences?

What is Produced Water?

- Water that comes to the surface with oil and gas
- Contains many chemical constituents
  - Salt content (salinity, total dissolved solids [TDS], electrical conductivity)
  - Oil and grease
    - *Composite of many hydrocarbons and other organic materials*
  - Toxicity from various natural inorganic and organic compounds or chemical additives
  - NORM

Produced Water Volume

- Largest volume waste stream from oil and gas production
  - Worldwide estimate – 77 billion bbl/year (2003 SPE paper)
  - U.S. - 15-20 billion bbl/year
    - *~ 1 billion bbl/year offshore Gulf of Mexico*
- Ratio of water-to-oil
  - World-wide estimate – 2:1 to 3:1
  - U.S. estimate – 7:1
  - Many older U.S. wells have ratios > 50:1

Number of U.S. Producing Wells

Type of Well	Total
Onshore (low production)	718,976 (2006)
Onshore (high production)	217,214 (2004)
Offshore	7,961 (2004)
Total	944,151

Source: U.S. Department of Energy, Energy Information Administration and Interstate Oil and Gas Compact Commission

Approaches to Minimizing Risk from Produced Water Discharges to the Ocean

- U.S. approach
  - Gulf of Mexico
  - California
  - Alaska

- North Sea regional approach
  - Norwegian approach

U.S. Approach to Minimizing Produced Water Risk

- Emphasizes combined or holistic effect of the effluent when it is discharged
- Follows U.S. legal/regulatory framework
- Specific requirements vary between regions, but all:
  - Start with national oil and grease limits
  - Add effluent toxicity testing requirements for several species
  - Add other monitoring, studies, or operational controls to meet regional needs and interests

EPA Oil and Gas National Discharge Standards Effluent Limitations Guidelines [40 CFR 435]

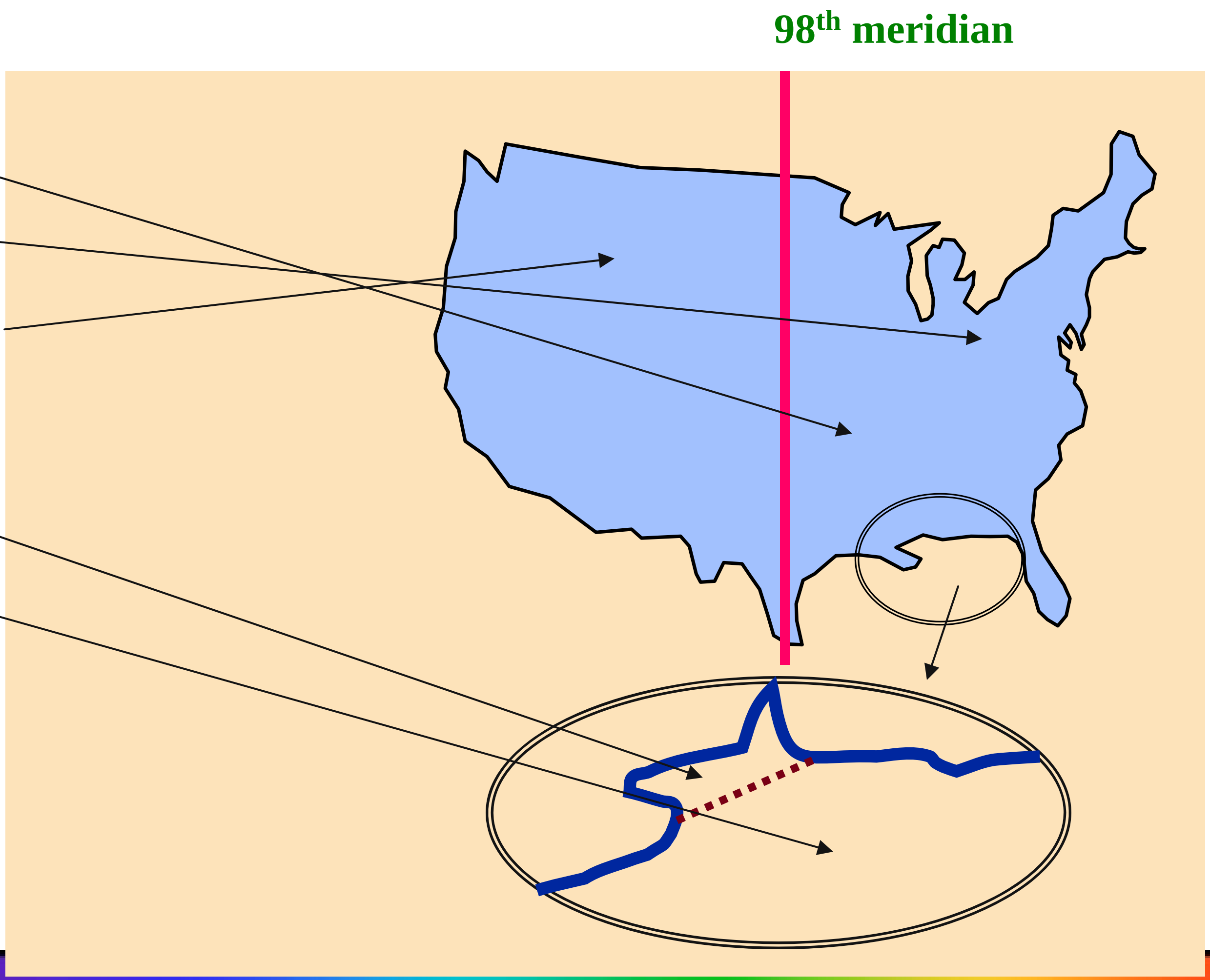
Onshore

Stripper (<10bbl/day)

Agricultural and wildlife use

Coastal

Offshore



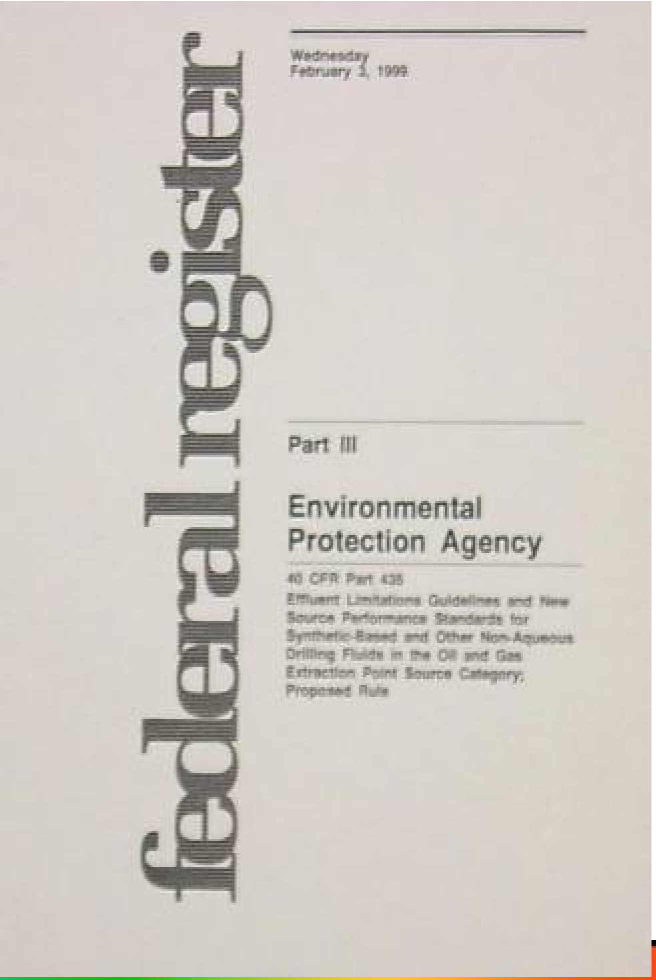
National Produced Water Discharge Standards for Wells Located Onshore

- Onshore subcategory
  - Zero discharge
- Stripper subcategory
  - No national requirements
  - Jurisdiction left to state or EPA region
- Agricultural and Wildlife Use subcategory
  - Produced water must have a use
    - *Water must be of good enough quality for wildlife, livestock, or other agricultural use*
    - *Produced water must actually be put to that use*
  - Oil and grease limit of 35 mg/l maximum
- EPA is currently evaluating the need for a new subcategory for coal bed methane

National Discharge Standards for Produced Water Discharges to Offshore and Coastal Waters

- Coastal wells
  - Zero discharge except in Cook Inlet, Alaska
  - Offshore limits required there

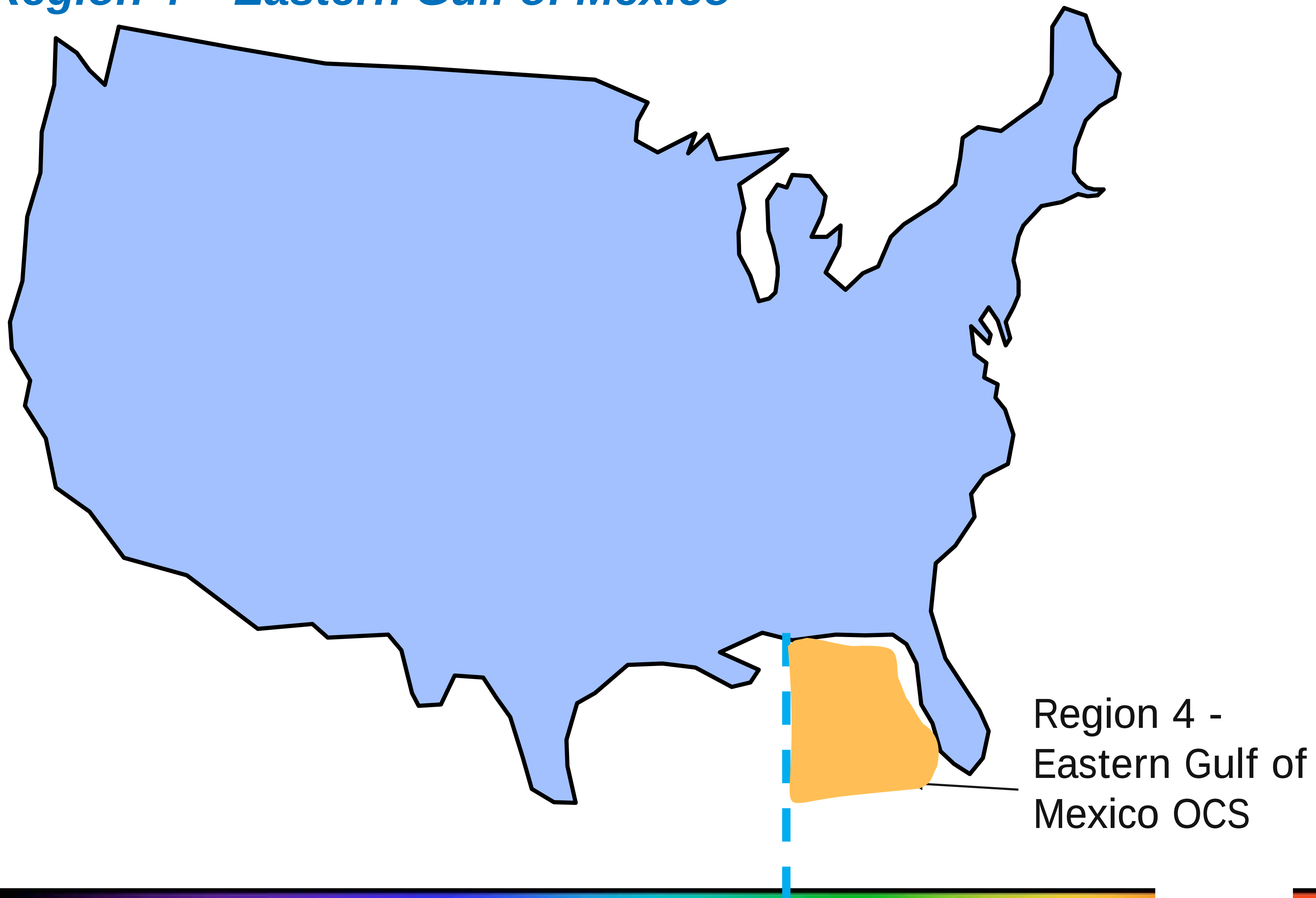
- Offshore wells
  - Oil and grease limits before discharge
    - *29 mg/l monthly average*
    - *42 mg/l daily maximum*
  - No other parameters are limited by national standards
  - Discharges are regulated through NPDES (National Pollutant Discharge Elimination System) general permits



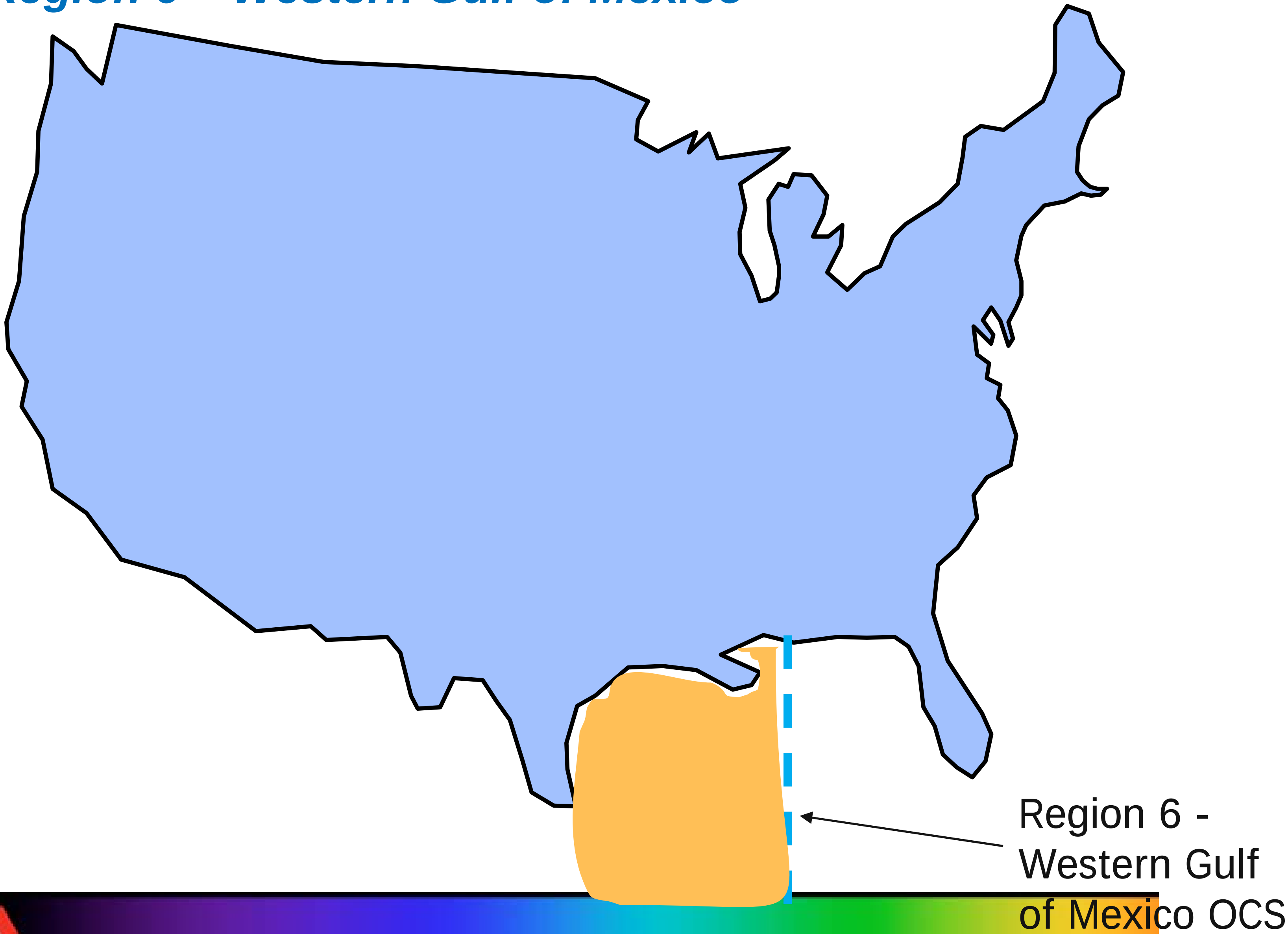
Basis for U.S. Offshore Produced Water Standards

- Oil and grease limit used as a "surrogate" for other pollutants
  - When oil and grease are controlled, other pollutants will also be controlled
- Limit is based on a statistical analysis of data from 60 U.S. platforms
  - Monthly average = 95th percentile = 29 mg/l
  - Daily maximum = 99th percentile = 42 mg/l

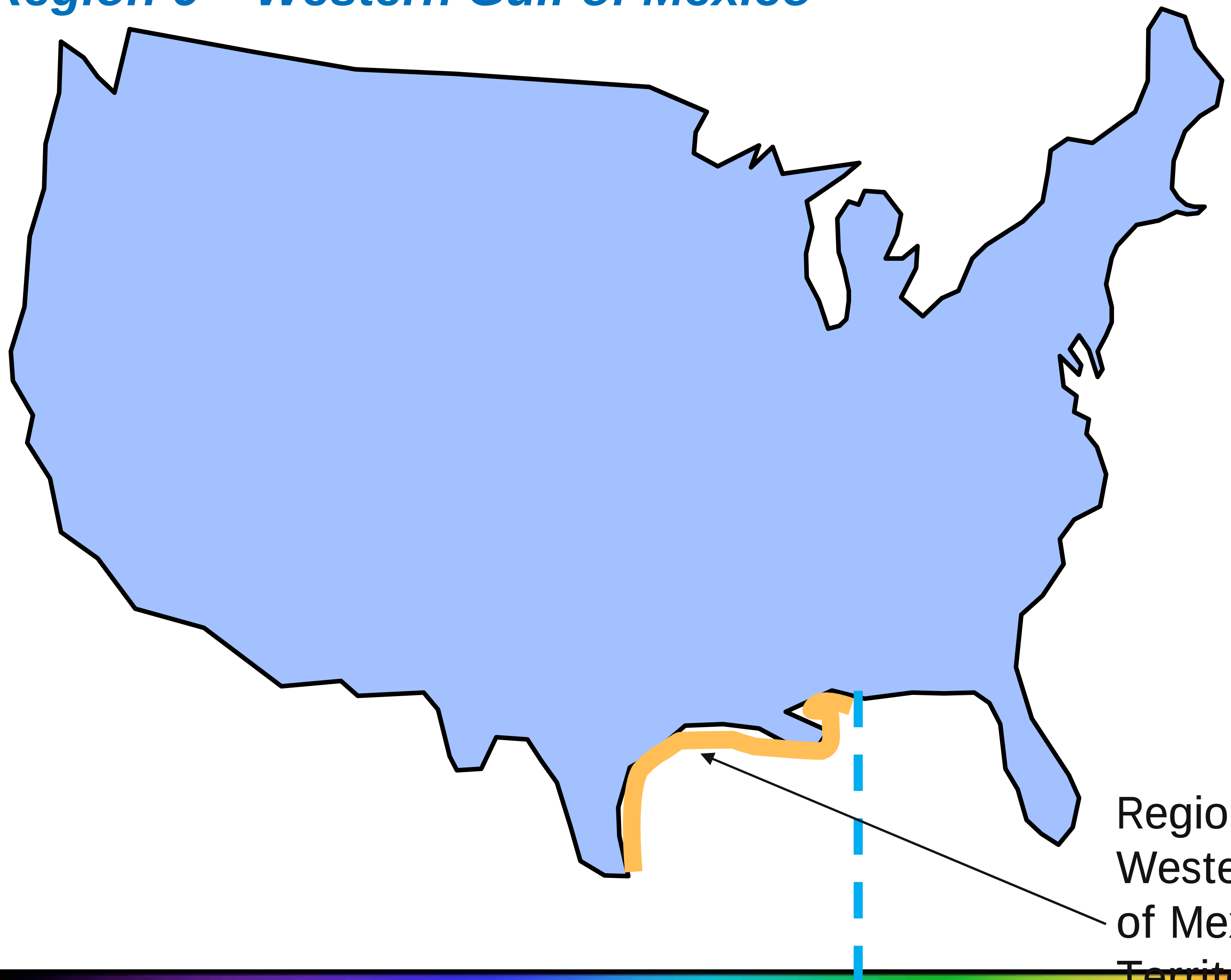
EPA Region 4 – Eastern Gulf of Mexico



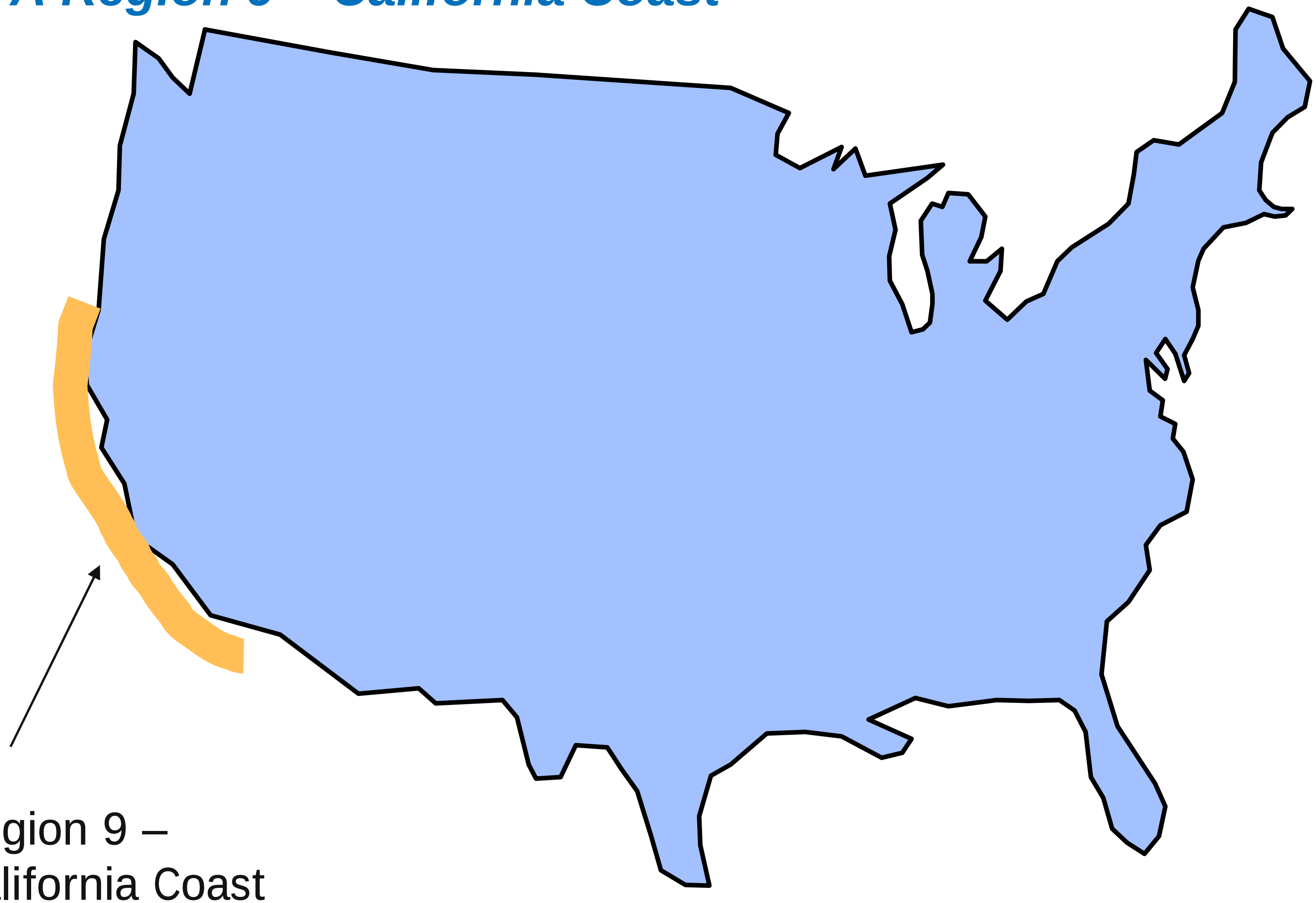
EPA Region 6 – Western Gulf of Mexico



EPA Region 6 – Western Gulf of Mexico

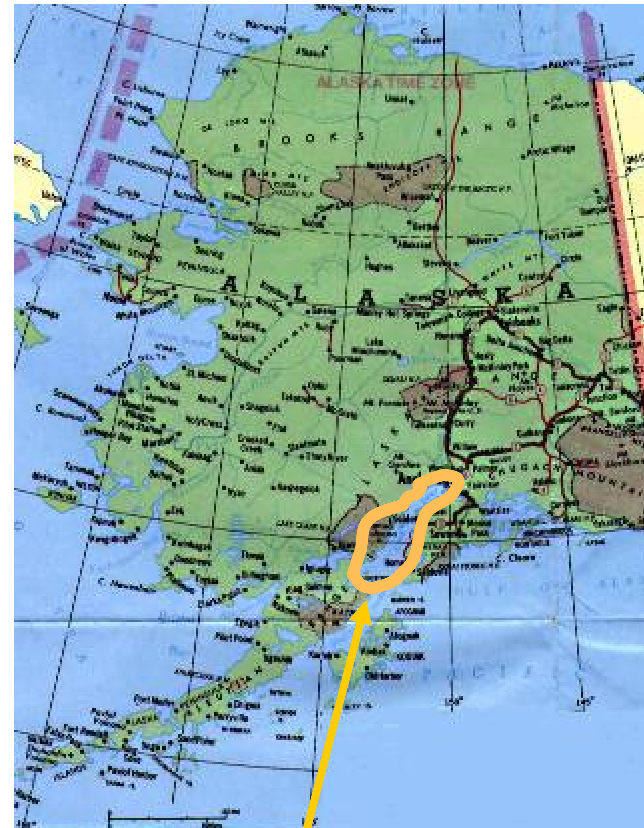


EPA Region 9 – California Coast



Region 9 –
California Coast

EPA Region 10 - Alaska



Region 10 – Cook Inlet, Alaska

Produced Water Controls in EPA Permits

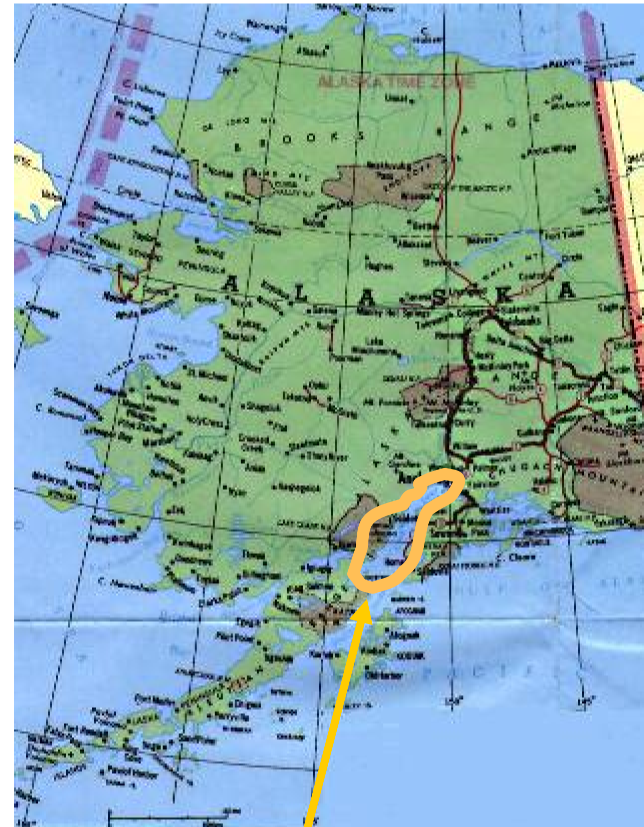
- Oil and grease limits
- Toxicity tests
  - Limits based on water quality modeling
- Limits on other pollutants
- Restrictions or prohibitions on discharge
- Studies

Comparison of Toxicity Requirements in EPA Permits

Permit	Date Issued	Type of Test	Species
Region 4,	12/04	Chronic	Mysid shrimp (*Mysidopsis bahia*) Inland silverside minnow (*Menidia beryllina*)
Region 6, OCS	10/07	Chronic	Mysid shrimp (*Mysidopsis bahia*) Inland silverside minnow (*Menidia beryllina*)
Region 6, Territorial Seas	8/05	Chronic plus 24-hour acute test using full-strength effluent	Mysid shrimp (*Mysidopsis bahia*) Inland silverside minnow (*Menidia beryllina*)
Region 9, California	12/04	Chronic	Red abalone (*Haliotis rufescens*) Giant kelp (*Macrocystis pyrifera*) Topsmelt fish (*Atherinops affinis*)
Region 10, Cook Inlet	7/07	Chronic	Topsmelt fish (*Atherinops affinis*) Mussel (*Mytilus* sp.) or Pacific oyster (*Crassostrea gigas*) Purple sea urchin (*Strongylocentrotus purpuratus*) or sand dollar (*Dendraster excentricus*)

Toxicity Test Species

EPA Region 10 - Alaska



Region 10 – Cook Inlet, Alaska

Comparison of Other Produced Water Requirements

Permit	Discharge Prohibition	Other Limits	Other Requirements
Region 4	- Within 1,000 m of Area of Biological Concern	N/A	- Notification before using new chemicals
Region 6, OCS	- Within Area of Biological Concern or National Marine Sanctuary	N/A	Note: previous permit required study of produced water discharges to hypoxic zone. Study results showed no impacts.
Region 6, Territorial Seas	- Within 1,000 m of Area of Biological Concern	N/A	N/A
Region 9, California	NA	- Limits on 9 metals, cyanide, and phenols - Monitoring for 26 chemicals and toxicity	- Annual discharge volume limits are set for each platform - Conduct study of on-line oil-and-grease monitors - Companies must submit a study to the EPA to determine the feasibility of disposal of produced water by means other than discharge
Region 10, Cook Inlet	- To shallow water or other sensitive areas - Within certain distance of coastal marsh, river mouth, parks, or wildlife areas	- Limits for each of the 9 platforms for 8 toxic pollutants and effluent toxicity	- Operators discharging greater than 100,000 gallons/day (~380 m^3/day) of produced water must plan and conduct a study that addresses the fate and transport of pollutants in the water column and sediments within 3 years

North Sea Approach to Minimizing Produced Water Risk

- Emphasizes control of the chemical products used in the well and during treatment such that the combined impact will be acceptable
- Follows a more complicated framework of requirements
- Based on OSPAR Convention

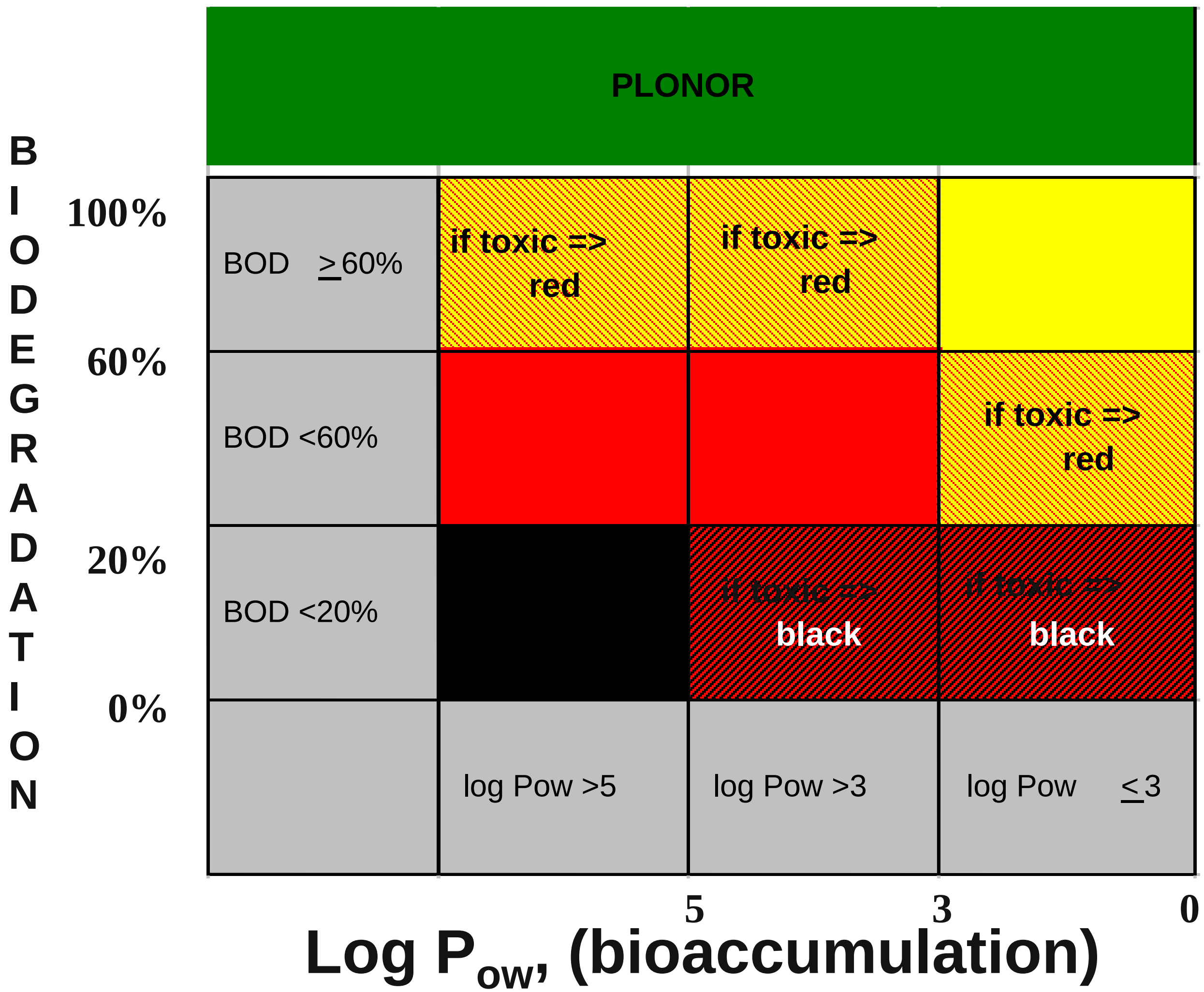
North Sea Regulatory Requirements

- Long-standing oil and grease limit of 40 mg/l
- Changes made in 2006
  - Oil and grease limit of 30 mg/l
  - Achieve 15% reduction in total oil loading compared to 2000 level

North Sea Approach Considers Impacts and Risks

- Use risk assessment approach to authorize discharges
- OCNS (offshore chemical notification system)
  - Chemicals must be tested and pre-approved before they can be used
  - Must consider biodegradation, bioaccumulation, and toxicity
  - Chemicals on PLONOR (poses little or no risk) list can have reduced screening
- Evaluate whether predicted environmental concentration (PEC) exceeds predicted no effect concentration (PNEC)
  - PEC/PNEC should be <1

Screening Criteria



Black = no discharge permitted
Red = to be substituted
Yellow = acceptable
Green = PLONOR and water

"If toxic" applies if measured toxicity by EC-50 or LC-50 is less than 10 mg/l.
Product toxicity should be used unless component toxicity is available.

Substances with less degradation than 20%, must be tested on:

- *Skeletonema*
- *Acartia*
- *Corophium*

Source:
J. McMahon,
Baker Petrolite

Norway Has Additional Controls

- CHARM model used to estimate PECs and PNECs

PNEC is determined from all available acute and chronic toxicity data for each compound group of the EIF:

✓One compound is selected as a representative for each group
✓All available data are evaluated (OECD quality criteria)
✓The highest toxicity value is selected as basis
✓PNEC is reached by dividing this by an assessment factor

The assessment factor compensates for the variable data quality, lab/field differences ++

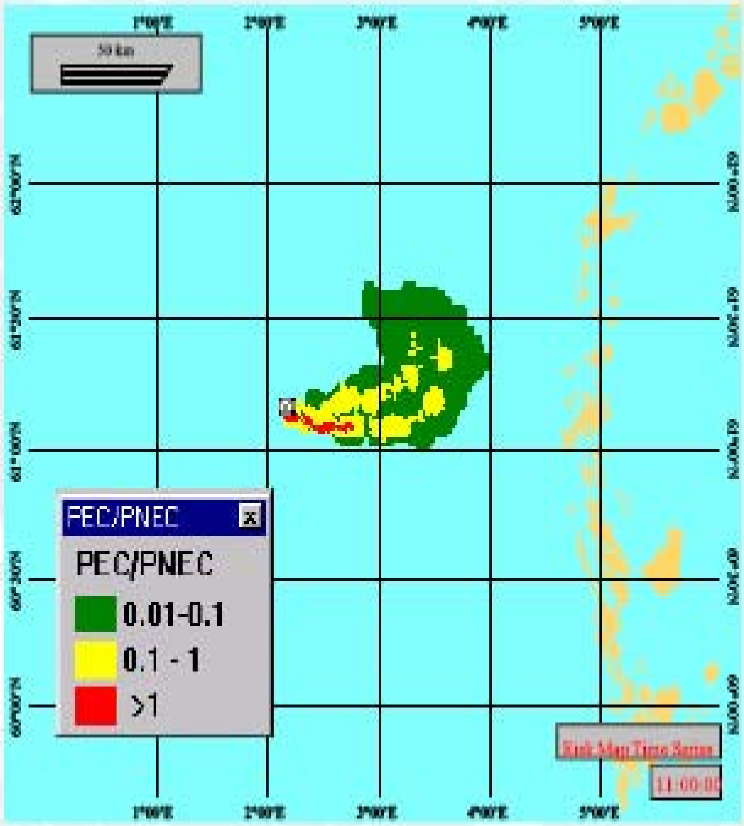
Assessment factor criteria	Assessment factor
Acute toxicity data only	1000
Chronic toxicity for one level (fish)	100
Chronic toxicity for two levels (fish and algae)	50
Chronic toxicity for fish, algae and zooplankton	10

Source:

S. Johnsen Statoil, 2003

More on the Norwegian Approach

- Norwegian industry further developed the DREAM model
  - Used to calculate EIF (environmental impact factor) and the volume of water surrounding a platform that has PEC/PNEC > 1



Risk map showing area (volume) as function of the PEC/PNEC ratio

Source:

S. Johnsen Statoil, 2003

OSPAR and Other Regional Conventions

Convention	Oil in Water Limit	Other
OSPAR (North East Atlantic)	30 mg/l	Pre-approval of chemical additives
HELCOM (Baltic Sea)	15 mg/l; up to 40 mg/l if BAT cannot achieve 15 mg/l	Pre-approval of chemical additives
Kuwait Convention and (Red Sea region)	40 mg/l ; 100 mg/l max.	
Barcelona Convention (Mediterranean)	40 mg/l; 100 mg/l max.	

Why Are the Two Approaches Different?

- Number of offshore wells and discharges
- Length of time offshore production has occurred
- National/regional culture and politics
- Different analytical methods
- Human nature

Comparison of the Number of U.S. Offshore to North Sea Producing Wells

Country/Region	# Platforms /Offshore Fields	Producing Oil Wells (2004)
Denmark	19	225
Netherlands	12	69
Norway	40	801
UK	174	1,383
North Sea Total	245	2,478

Source: Oil & Gas Journal, December 19, 2005

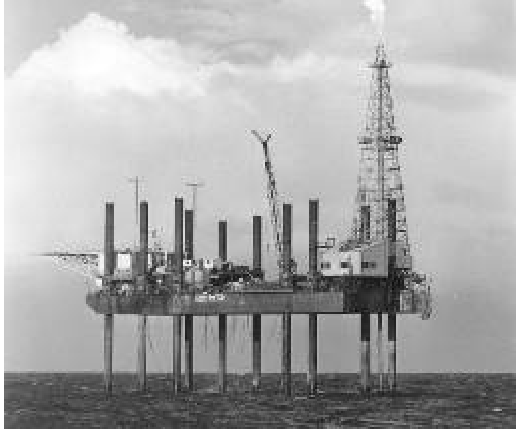
Country/Region	# Platforms	Producing Oil & Gas Wells (2002)
U.S. Gulf of Mexico	3,895	6,948

Source: U.S. Department of Energy, Energy Information Administration, and U.S. Minerals Management Service

Effect of Number of Wells on Risk Management Approach

- U.S. has had thousands of offshore wells to regulate for several decades
- North Sea, and particularly Norway, has far fewer discharges to regulate
  - This allows for more platform-specific analyses and studies
- Parallel example can be seen by comparing strategies between EPA Regions
  - Region 6 (Gulf of Mexico) has thousands of platforms
  - Region 9 (California) has 22 platforms
  - Region 10 (Cook Inlet) has 9 platforms
- Region 6 permit requirements are general, while Region 9 and 10 permits allow for platform-specific requirements

Duration of Offshore Experience



- U.S. began in 1940s
  - Kerr-McGee drilled the first well from a fixed platform offshore out-of-sight of land in 1947.
  - By 1949, 11 fields were found in the Gulf of Mexico with 44 exploratory wells.
- North Sea
  - The first offshore hole in the North Sea was made by the drilling platform *Mr. Louie* in May 1964 thirty miles north of the island of Juist, in the German sector
  - The Drilling Barge *Sea Gem* was the first rig ever to find hydrocarbons in the British North Sea sector in September 1965
  - In May 1963, Norway asserted sovereign rights over natural resources in its sector of the North Sea. Exploration started in July 1966. First oil came in August 1969.

Effect of Duration of Experience on Risk Management Approach

- The U.S. had already drilled hundreds to thousands of offshore wells by the time the first North Sea wells were drilled
- Certain produced water management practices were already established
- Early U.S. platforms did not include space for extensive produced water treatment
  - Many were relatively small compared to the North Sea platforms
- When first round of U.S. offshore permits were being written in the 1980s, agencies needed to look at existing facilities and technologies
- North Sea started later and had larger facilities to work with

Culture/Political Differences

- European culture, law, and politics have developed over a much long time frame than U.S. culture
- European nations have had to live side-by-side with other nations for many centuries and have developed different ways of dealing with shared resources (i.e., North Sea water quality) than have North American countries
- Much of Europe leans toward “green” politics and policies

Effect of Culture/Politics on Risk Management Approach

- There is a wide range of politics and societal attitudes about oil and gas in different parts of the U.S.
  - Citizens and regulators in California and Florida do not strongly support offshore production
  - Texas and Louisiana do support offshore production
- Most U.S. offshore production is off the coast of Texas and Louisiana
  - Consequently, there has been less strong objection to produced water management practices there than in Europe or in California and Florida
- U.S. discharge policy is based on setting standards, then letting industry figure out how to do it most effectively and economically
  - EPA does not generally get involved in how the limits are met

Analytical Methods

- Measurement of oil and grease depends on the analytical method used
  - Oil and grease is not a single chemical substance
  - The test measures the sum of many different hydrocarbons and other organic substances that happen to be detected by the analytical method
- The U.S. oil and grease standards are based on statistical analysis of hundreds of samples measured using an analytical method that included Freon as the extraction solvent
- The phase-out of Freon caused EPA to change its approved analytical method to use hexane as an extraction solvent
  - The current compliance samples are being made using a different analytical method

Effect of Analytical Methods on Risk Management Approach

- The North Sea region uses still different analytical methods for oil and grease
- Conclusion: the U.S. and the North Sea are not measuring exactly the same commodity “oil and grease”
- Although oil and grease is a reasonable indicator of the hydrocarbon and other organic concentrations in the produced water, the effectiveness of regulatory controls based solely on oil and grease are not as precise as regulators may believe

Source: Turner Designs

Effect of Human Nature on Risk Management Approach

- Humans are stubborn and tend to show strong “pride of ownership” for their own ideas, systems, and procedures
- Even if one society sees parts of the other society’s system that look better or appear to be more effective, there will generally be strong resistance to dropping your own system and adding major features from the other system
- This “regulatory inertia” has contributed to development and maintenance of two distinct approaches to regulating and managing risk from produced water discharges

Conclusions

- Oil and grease is the baseline of produced water regulatory controls in most countries
  - Most jurisdictions use additional controls beyond oil and grease limits
- The two best-established systems (U.S. and North Sea) have followed dramatically different approaches to manage produced water risk
  - Both approaches successfully manage risk but place the management controls on opposite ends of the process
    - *North Sea emphasizes inputs*
    - *U.S. emphasizes outputs*

Conclusions (continued)

- Is one approach better than the other?
  - One may be more effective than the other in some situations
  - Conversely, one may be more constraining or restrictive than needed to ensure environmental protection

Example of Critical Dilutions for Toxicity

Table 1: Produced Water Critical Dilutions
Table 1-A: Critical Dilution (Percent Effluent) for Discharges with a Depth Difference Between the Discharge Pipe and the Sea Floor of Greater than 0 Meters to 4 Meters

Discharge Rate	Pipe Diameter (inches)					
(bbl/day)	>0" to 5"	>5" to 7"	>7" to 9"	>9" to 11"	>11" to 15"	>15"
0 to 500	0.05	0.05	0.05	0.05	0.05	0.05
501 to 1000	0.12	0.12	0.12	0.12	0.12	0.12
1001 to 2000	0.29	0.29	0.29	0.29	0.29	0.29
2001 to 3000	0.49	0.48	0.48	0.48	0.48	0.49
3001 to 4000	0.66	0.64	0.64	0.64	0.64	0.64
4001 to 5000	0.9	0.87	0.85	0.85	0.86	0.87
5001 to 6000	1.13	1.11	1.07	1.07	1.08	1.09
6001 to 7000	1.36	1.33	1.30	1.28	1.28	1.30
7001 to 8000	1.57	1.55	1.51	1.47	1.48	1.50
8001 to 9000	1.80	1.78	1.74	1.68	1.68	1.70
9001 to 10,000	2.02	2.00	1.95	1.89	1.88	1.90
10,001 to 15,000	3.09	3.17	3.08	3.02	2.92	2.88
15,001 to 20,000	3.90	4.26	4.15	4.07	3.95	3.77
20,001 to 25,000	4.60	5.26	5.25	5.10	5.00	4.60
25,001 to 35,000	5.68	6.92	7.28	7.00	6.86	6.30
35,001 to 50,000	6.83	8.80	9.67	9.80	9.35	8.74
50,001 to 75,000	8.23	11.1	12.8	13.9	14.2	13.1