Monitoring Storm Water Quality and Quantity from Gas Well Construction Sites

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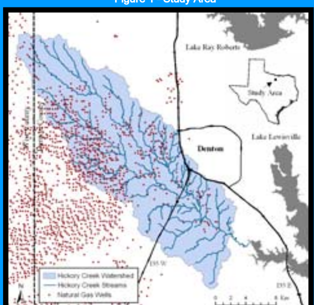
The Problem - Nonpoint Source Pollution

- Natural gas production has increased within Denton County over the last several years, with over 2000 currently active wells (Figure 1)
- Construction of a typical gas well pad site disturbs 2-5 acres
- Disturbed areas resulting from construction can have soil erosion rates 2 to 40,000 times greater than pre-construction conditions (Harbor, 1999)
- Sediment is the single most widespread pollutant affecting the water quality in rivers and streams (USEPA, 1998)
- It is estimated that 10 percent of the total sediment load to U.S. surface waters is from construction activities (Willett, 1980)

Background - Oil and Gas Activity

- Recently, the USEPA made certain storm water discharges from oil and gas field operations and construction activities associated with oil and gas production and exploration exempt from NPDES permitting (USEPA, 2006)
- It is estimated that up to 650 wells will be drilled within the ETJ of the City of Denton over the next few years, possibly as many as 250 in the Hickory Creek watershed (Figure 1)
- The City of Denton implemented local environmental regulations for oil and gas development, and began research to examine the storm water impacts of gas well construction activities.

Figure 1 - Study Area



Research Objectives

- Demonstrate a novel overland flow collection and sampling methodology for small, highly modified natural gas well sites
- Evaluate and refine modeled rainfall/runoff relationships, optimize automated stormwater sampling approaches, and describe observed TSS concentrations

Methods

Site Selection

- Sites were evaluated based on topography, soil type and the means of adjacent areas to be used for reference sites
- GIS was used to delineate drainage areas and provide detailed soil information (NRCS-SSURGO database)

Natural Gas Well Site Characteristics (Figure 2a-c)

- Site is comprised of a tightly packed rock base ("pad") approximately one to two acres in size
- Pad is surrounded by an additional two to four acres of graded, disturbed soil
- Pad has a slope of ~1.5%, surrounding area has a slope of ~2-20%

Figure 2a
Completed Natural Gas Well Site

Figure 2b
Layout of a typical gas well development site

Figure 2c
Sampling Weir deployed at site
Following rainfall

Sampling Program

- Requires a structure to concentrate and measure overland sheet flow - project used a partially contracted, 90° V-notch weir
- Automated samplers used for collection. These samplers require operators to:
  1. set an appropriate minimum flow threshold (begin and end sampling),
  2. select and implement an appropriate sampling interval based on flow or time, and
  3. decide whether to collect discrete or composite samples
- Understanding rainfall/runoff relationship is key for sampling program design and operation.

Methods Continued

Flow Control Structure

- Size of the weirs was based on the modeled peak discharge of the drainage area using the rational method (Figure 3)
- Sampling intervals were based on volumetric depth of runoff.

Rainfall/Runoff Modeling

- The NRCS method was used to estimate runoff depth resulting from a given rainfall amount (Figure 3)
- Initial curve number was based on literature value for newly graded developing urban area (91-94) (USDA, 1986)

Figure 3 - Hydrologic Models

Rational Method

$$Q = F\,C\,I\,A$$

- Q = maximum rate of runoff (cfs or m^3/s)
- C = runoff coefficient or fraction or rainfall that becomes runoff
- I = average rainfall intensity (in./hr. or mm/hr.)
- A = drainage area (acre or hectare)
- F is conversion factor that is usually omitted when Englis units are used, but for metri units F equals 0.278

NRCS Method

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

- Q = runoff (in. or mm)
- P = rainfall (in. or mm)
- S = potential maximum retention after runoff begins (in. or mm). S is related to the soil and cover conditions of the drainage area through the CN value by:

$$S = z\,(100 / CN - 1)$$

- z = 10 for English measurement units, or 254 for metric
- CN = runoff curve number

Results

- Based on predicted peak discharge (2yr -24hr storm), a 2 foot, 90° v-notch weir was constructed and installed
- Using the NRCS method, runoff depths were calculated for various rainfall amounts.
- Rainfall amounts and runoff depths were used to produce estimates of volumetric depth of runoff.
- Volumetric depth of runoff estimates were used to calculate the number of samples resulting from three volume based sampling intervals (0.5, 1.0, and 2.0 mm, see Table 1).
- Approximately 12.5 mm of precipitation is necessary to generate a sufficient volume of runoff for sampling (Table 1)
- A 0.5 mm flow interval effectively samples small storms, but exceeds the 24 bottle capacity of the sampler for large storms
- A 2.0 mm flow interval is effective for larger storms, but collects too few samples for characterizing small storms
- A 1.0 mm flow interval produces adequate sample numbers for most storms, although compositing samples may be necessary to completely capture very large storms
- Using data from 21 storms, the Curve Numbers ranged from 90.5 to 98.5, with an average of 94.5 (Table 2)

Results Continued

Table 1 - Volumetric Runoff Intervals

	Predicted	Number of Samples			Total
Rainfall(mm)	Runoff (mm)	0.50 mm	1.00 mm	2.0 mm	Volume (m^3)
6.25	0.38	0.00	0.00	0.00	3.09
12.50	3.08	6.00	3.00	1.00	24.98
18.75	7.14	14.00	7.00	3.00	57.86
25.00	11.91	23.00	11.00	6.00	96.44
37.50	22.52	45.00	22.00	11.00	182.38
50.00	33.87	67.00	33.00	16.00	274.31
62.50	45.60	91.00	45.00	22.00	369.28
75.00	57.54	115.00	57.00	28.00	466.01

Table 2 - Summary of Events Samples,
TSS concentrations and CN values

	Site 1	Site 2	Site 3	Site 4
Number of storm events sampled	10	6	3	2
Total number of samples	107	76	42	6
TSS minimum (mg/L)	90	90	228	470
TSS average Event Mean Conc (mg/L)	3,672	2,724	2,457	3,235
TSS, median of all samples (mg/L)	1,560	1,232	1,575	3,130
TSS , maximum (mg/L)	13,410	8,730	13,110	5,540
Average Curve Number (CN)	95.5	96.0	92.0	93.0

Conclusions

- Hydrologic models are applicable to small natural gas well sites
- The curve number, back-calculated from observed data, was somewhat similar to the suggested curve number for newly graded pervious areas in developing urban areas
- Average Event Mean Concentration TSS values ranged from 2,457 to 3,672 mg/L
- Methodology demonstrates an mechanism for effectively sampling storm water runoff from small sites
- Additional storm events samples are necessary to effectively characterize TSS and rainfall/runoff relationships under a variety of different precipitation scenarios

References/Acknowledgments

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