Gravel roads, pads and infiltration characteristics.

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Goal:

Part of the CCWMO's implementation of stormwater rules, BMP's, standards, etc. is that we treat Class V gravel surfaces (parking lots, twp roads, gravel pads, etc) as impervious. We do this based on accepted knowledge that once class V is compacted by vehicles either during construction or after use, it acts like any other impervious surface. *We are trying to find some literature or recent studies that document this assumption. Has EOR completed any studies or can EOR point us to any literature that supports this assumption? If so. Please let me know and as this request is on a tight timeframe, the sooner the better. Much appreciation.*

Overview

While there is considerable variability in terminology regarding dirt or gravel roads and parking lots, there is consistent agreement in their effects upon dramatically reducing infiltration and increasing runoff volumes and suspended solids loading. These types of transportation conveyance structures consist of some degree of gravel/rock covered by fine soils and compacted for load-bearing support. These structures do not lend itself to infiltration and hence has been the subject of research to reduce excessive sediment erosion and runoff. Gravel and dirt roads are widely employed for lower vehicle traffic volumes (generally less than 400 vehicles per day but up to 1000 vehicles per day with engineered designs and maintenance).

- Maine (Kennebec SWCD and Maine Department of Environmental Protection (2010). "There are three basic types of soil materials used for building camp roads: gravel, sand, and fines (listed in order from largest to smallest particle size). Gravel and sand particles, coarse material, are readily distinguishable to the naked eye. Fines (silts and clays) are generally comprised of particles too small for the eye to see. Each soil material has specific properties that make it useful for different aspects of road building. Coarse material provides strength and has large voids between the particles that provide good drainage. Fines fill the voids between the coarse material particles holding them together, and on the road surface, decrease infiltration of water into the road."
- WCCA NR 115 Guidebook: Chapter 2 Impervious Surface Limits. http://www.ncwrpc.org/NR115/ .
  "Typical gravel materials used for roads and parking lots are engineered and compacted to withstand heavy loads. These compacted gravel materials form a seal through which water will not readily infiltrate. Runoff from gravel is similar to paved surfaces with only a slight reduction in runoff. It would be difficult to call a typical gravel driveway pervious. Many counties consider this to be impervious."

Imperviousness as indicated from NRCS Curve Numbers.
Various engineering approaches have been developed relating land use and runoff potential by Hydrologic Soil Groups by the NRCS and other lead agencies. One such summary was published in the Minnesota Stormwater Manual (2005) and is included below (Table 8.4, Curve Numbers for Antecedent Moisture Condition II). In this table, the curve numbers for paved, dirt and gravel roads reflect the low infiltration properties as CN's generally are quite high (e.g. range 76-93).

Table 8.4 Curve Numbers for Antecedent Moisture Condition II (Source: NRCS)

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
Meadow				
Good condition	30	58	71	78
Forest				
Poor	45	66	77	83
Fair	36	60	73	79
Good	30	55	70	77
Open Space				
Poor	68	79	86	89
Fair	49	69	79	84
Good	39	61	74	80
Commercial				
85% impervious	89	92	94	95
Industrial				
72% impervious	81	88	91	93
Residential				
1/8 ac lots (65% impervious)	77	85	90	92
1/4 ac lots (38% impervious)	61	75	83	87
1/2 ac lots (25% impervious)	54	70	80	85
1 acre lots (20% impervious)	51	68	79	84
Impervious Areas	98	98	98	98
Roads (including right of way)				
Paved	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Row Crops				
Straight row – Good	67	78	85	89
Contoured row – Good	65	75	82	86
Pasture				
Good	39	61	74	80
Open Water	99	99	99	99

Minnesota Stormwater Manual HSG Soil Infiltration Rates for Comparison.

Table 12.INF.7 Design Infiltration Rates			
Hydrologic Soil Group	**Soil Textures***	**Corresponding Unified Soil Classification****	**Infiltration Rate [inches/hour]**
A	Gravel, sand, sandy gravel, silty gravel, loamy sand, sandy loam	**GW** – Well-graded gravel or well-graded gravel with sand **GP** – Poorly graded gravel or poorly graded gravel with sand	1.63
		GM – Silty gravel or silty gravel with sand **SW** – Well-graded sand or well-graded sand with gravel **SP** – Poorly graded sand or poorly graded sand with gravel	0.8
B	Loam, silt loam	**SM** – Silty sand or silty sand with gravel	0.6
		ML – Silt **OL** – Organic silt or organic silt with sand or gravel or gravelly organic silt	0.3
C	Sandy clay loam	**GC** – Clayey gravel or clayey gravel with sand **SC** – Clayey sand or clayey sand with gravel	0.2
D	Clay, clay loam, silty clay loam, sandy clay, silty clay	**CL** – Lean clay or lean clay with sand or gravel or gravelly lean clay **CH** – Fat clay or fat clay with sand or gravel or gravelly fat clay **OH** – Organic clay or organic clay with sand or gravel or gravelly organic clay MH – Elastic silt or elastic silt with sand or gravel	< 0.2

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: Rawls, Brakensiek and Saxton (1982); Rawls, Gimenez and Grossman (1998); Bouwer and Rice (1984); and Urban Hydrology for Small Watersheds (NRCS). The rates presented in this infiltration table use the information compiled from these sources as well as eight years of infiltration rates collected in various infiltration practices located in the South Washington Watershed District.

*U.S. Department of Agriculture, Natural Resources Conservation Service, 2005. National Soil Survey Handbook, title 430-VI. (Online) Available: http://soils.usda.gov/technical/handbook/.

**ASTM standard D2487-00 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

Gravel roads defined impervious by rule.

Hence, many state, local and regional governmental units define dirt and gravel roads as impervious surfaces by rule. For example, Wisconsin Rule NR 115.02 (Definitions) states: "Impervious surface" means an area that releases as runoff all or a large portion of the precipitation that falls on it, except for frozen soil. Rooftops, sidewalks, driveways, gravel or paved parking lots, and streets are examples of surfaces that typically are impervious."

Brief Scientific Literature Review:

Literature relating gravel roads and infiltration characteristics were based on historical gravel/dirt road research (USDA/US Forest Service) associated with logging roads and erosional sediment losses. More recent infiltration research related to tropical areas of SE Asia and the Caribbean experiencing excessive erosion.

- Gravel, paved and abandoned road unit hydrographs, below, share the classic impervious cover/urban runoff pattern of rapid peak runoff to storm events.

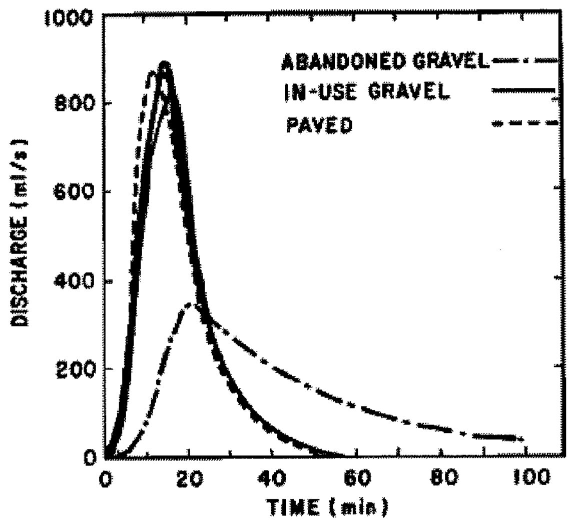


Fig. 4. Unit hydrographs from each road type, normalized for a catchment area of 850 m^2.

http://www.fs.fed.us/psw/publications/reid/psw_1984_reid001.pdf

- Reid and Dunne (1984) were examining sediment losses from gravel logging roads in the Pacific Northwest and found very low infiltration rates (e.g. 0.5 mm/hour or 0.02 inch/hour). "Thus even the gravel roads are almost impermeable during winter storms, and an infiltration capacity of 0.5 mm/h was selected for use on the gravel surfaced roads that had not been abandoned."
- Luce and Cundy, 1994. Infiltration rates for unpaved roads tend to be very low; values in Idaho, Colorado, and Montana varied between 5 x 10-5 and 8.8 mm h-1 with a geometric mean of 0.11 mm h-1 (= 0.004 inch/hour).
- Luce (1997) observed forest dirt/gravel road infiltration rates of 0-4 mm/hour that were increased, following road ripping of substrates to 20-40 mm/hour.
- Ziegler, A and W. Giambelluca.
  "Previous research has identified at least three distinct road features that can alter storm flow response in temperate mountainous watersheds:
  - highly compacted road surfaces and disturbed roadside margins reduce infiltration of rainwater, increasing the likelihood of overland flow generation
  - cutbanks can intercept subsurface flow, rerouting it as overland flow; 4
  - ditches and culverts capture both subsurface flow and surface runoff, and channel it more rapidly to streams. 5

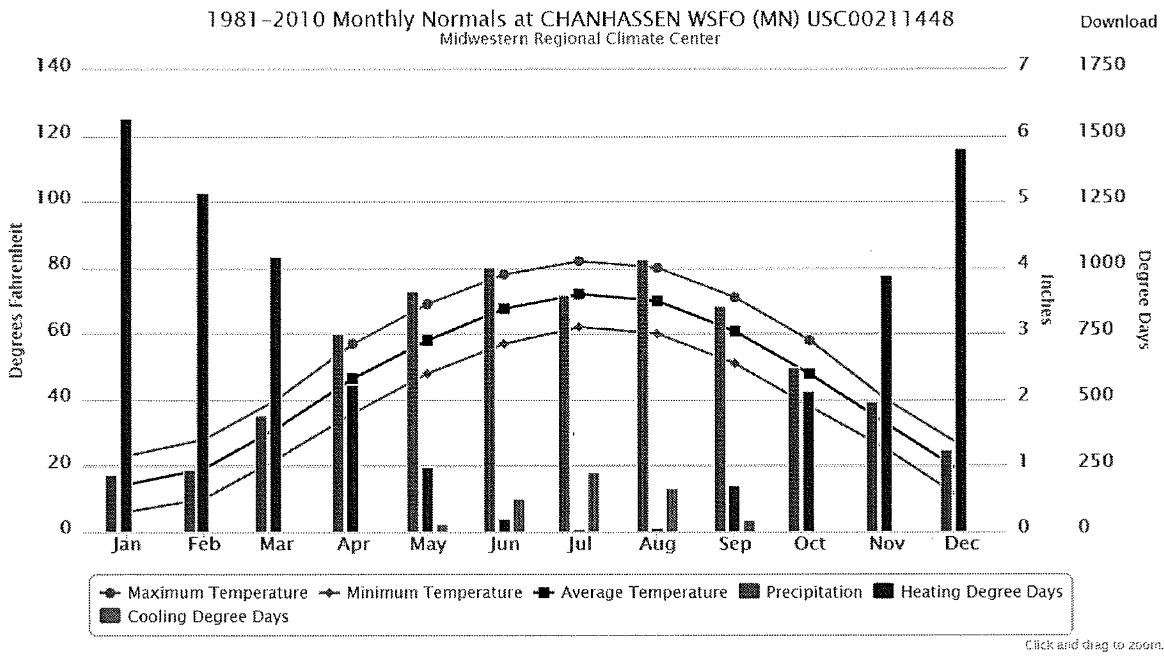
Horton overland flow (HOF) is thought to be rare in fully vegetated, undisturbed areas where infiltration rates are high. However, in areas where infiltration has been reduced by human activities, such as vegetation removal or compaction, the Horton mechanism can be a dominant pathway of water movement to stream channels. In this respect, highly compacted, largely bare, unpaved road surfaces are likely source areas for HOF in mountainous watersheds. While roads may also enhance runoff by intercepting subsurface flow, 12 HOF alone may explain most of the increased runoff and subsequent soil erosion associated with roads in many tropical watersheds-if the road infiltration rates are sufficiently low. For example, in several studies conducted in the tropics, rural roads, tracks, and paths were found to be active runoff-generating components owing solely to their low infiltration capacities. 13

We found support for a HOF-dominated runoff regime on mountainous roads during a preliminary pilot study conducted recently in northern Thailand. 14 Field measurements and simulations of excess rainfall (rainfall - infiltration) showed the following regarding the importance of unpaved roads in generating HOF:

- saturated hydraulic conductivities were approximately one order of magnitude lower on unpaved road surfaces than on any other land-surface type;
- during the rainfall collection period, rainfall intensities never exceeded the median saturated hydraulic conductivity of any landuse except road surfaces and highly disturbed roadside margins;
- during most storms, a significant portion of rain falling on roads does not infiltrate;
- compared to non-road surfaces, predicted excess rainfall was generated sooner during a rain event on an unpaved road surface-and on nearly all of its area; and
- for frequently occurring, small rainfall events, road-related surfaces contribute a large portion of simulated basin-total excess rainfall despite their relatively small areal extent (< 0.5% of basin area). "

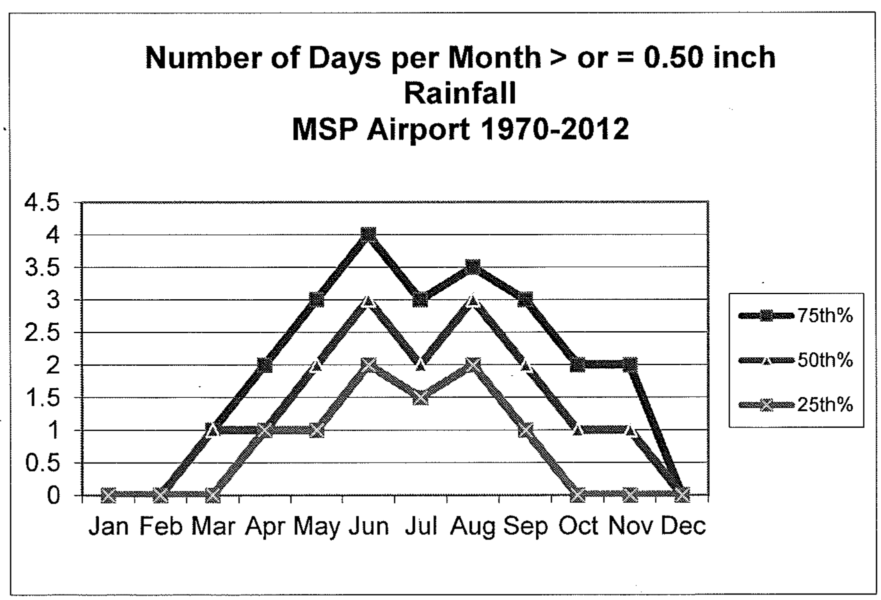
Hydrologic Change and Accelerated Erosion in Northern Thailand.
http://www2.hawaii.edu/~seassa/explorations/v1n1/art3/v1n1-art3.html

Precipitation Overview:



What is a typical rain event?

General annual climate data have been summarized in the above graphic "1981-2010 Monthly Normals for Chanhassen WSFO". Precipitation is distributed throughout the year with 3 - 4 inches per month typically observed during the growing season. A closer examination of precipitation events per month shows that about 2-3 events per month greater than 0.5 inch rainfall. In total, there are typically about 118 days per year with precipitation greater than 0.01 inch in the Twin Cities area.



What rain events may generate runoff from a compacted Class V gravel pad?

Site Overview:

- Description: 4 acre compost pad, 12 inches thick and have 100% by weight passing through a 1" sieve and a minimum of 15% by weight passing through #200 sieve. The soils should be compacted within 5% of optimum moisture content and reach an in-place unit weight of 140 pounds per cubic foot. Continual heavy truck traffic will continue to compact the soils.
- 3% slope. Slopes will lessen the effects of initial abstraction/depressional storage and increase runoff thus reducing infiltration opportunities.
- The infiltration rate was monitored using a double ring infiltrometer with a reported value of 0.19 inches/hour (4.8 mm/hour).
    - The monitored infiltration rate is higher than rates suggested from the literature pertaining to gravel/dirt roads (i.e. range of 0. 1- 0.5 mm/hour or 0.004 – 0.02 inch/hour). Without seeing the installation of the Double Ring, this author is unclear to what degree of surface and subsurface distortions may have occurred that may have affected test results.
- Initial abstraction/depressional storage for paved roads is low and on the order of about 0.05 to 0.125 inches. Precipitation amounts exceeding these values will runoff.

i. Based on Hydrology Guide for Minnesota (USDA, SCS) Table 3-3, a 24 hour storm event with a CN of 90 indicates 0.01 inch of runoff at 0.3 inches of rainfall. The same table but for a CN of 98 indicates runoff of 0.01 inch beginning with a rainfall of 0.1 inch. Hence, precipitation is quickly converted to runoff for the range of imperviousness anticipated for the compacted gravel pad.

ii. Based on above factors and assumptions, it is my opinion that the vast majority of rainfall is converted to runoff with very small amounts of infiltration.

References:

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http://www.ncwrpc.org/county_ftp/NR115/Cover.pdf

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http://docs.legis.wisconsin.gov/code/admin_code/nr/100/151.pdf

Ziegler, Alan and Thomas W. Giambelluca. Hydrologic change and accelerated erosion in Northern Thailand. University of Hawaii at Manoa.
http://www2.hawaii.edu/~seassa/explorations/v1n1/art3/v1n1-art3.html