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3 Part 630 Hydrology

4 National Engineering Handbook

5 **Chapter 12: Hydrologic Effects of Land Use and Land Treatment**

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45 630.1200 General

46 Chapter 12 describes the effects that runoff volume has on hydrograph shape and timing. The
47 chapter includes techniques for estimating the effects. The hydrologic effects described are
48 changes in volumes of direct runoff and changes in lag that affect peak rates of direct runoff.
49 The descriptions do not include effects on hydrograph shape. Procedures in this chapter are now
50 implemented in readily available computer programs. This chapter also discusses the impacts of
51 changing land use and of fires on the runoff volume.

52

53 630.1201 Volume effects

54 Land use and land treatment measures reduce the volume of direct runoff during individual
55 storms by either increasing infiltration rates, increasing surface storage, or both. Other factors
56 influencing runoff volume generally are of minor importance. Interception increases, for
57 example, are appreciable only under certain climatic and vegetative conditions and generally
58 need not be considered in Natural Resources Conservation Service (NRCS) watershed studies.
59 However, by increasing the volume or amount of vegetation, the volume of runoff can be
60 reduced. The reverse is also true. Reduction of vegetation caused by over grazing or other land
61 use can increase the volume of runoff by compaction of the soil and reducing the
62 evapotranspiration.

63 The unit hydrograph principle states that, with other things constant, the peak rate of flow varies
64 directly with the volume of flow (runoff). This principle is the basis for proportionate reductions
65 in peaks when volumes are reduced (see National Engineering Handbook (NEH) 630, Chapter 16
66 (USDA NRCS, 1999)).

67 Table 12–1 lists the principle effects of land use and treatment measures on direct runoff. The
68 degree of effect of any single measure generally depends on the extent and quality of the
69 treatment that can be installed. Contour furrows can be built to have a small or a large effect by
70 changing the dimensions of the furrows. The primary effect of a land use change depends on the
71 change in cover. A change from spring oats to spring wheat would ordinarily be barely

72 noticeable, while a change from oats to a permanent meadow could have a large effect. Graded
 73 terraces with grass outlets increase overall infiltration and overall storage to some extent. Lime
 74 and fertilizers, by increasing plant or root density, can indirectly reduce direct runoff volumes.
 75 There are other soil amendments that are being employed and low impact developments (LIDs)
 76 in urban areas, such as compost, are commonly used. Other soil amendments include zeolite,
 77 gypsum, and liquid amendments such as ammonium laureth sulfate.

78 **Table 12- 1.** Principle effects of land use and land treatment measures on direct runoff

Measure	Reduction in direct runoff volume because of:	
	Increasing infiltration rates ¹	Increasing surface storage
Land use that increases plant or root density ²	X	
Increasing mulch or litter	X	
Contouring		X
Contour furrowing		X
Level terracing		X
Graded terracing		X
Soil additives	X	

79 ¹Assuming soils are not frozen. ²Example: Row crop to grass for hay; poor pasture to good pasture.

80

81 **630.1202 Lag effects**

82 Lag, as used here, means the delay between the production of direct runoff on upland areas and
 83 its appearance at a given cross section location in a stream channel. Lag is also described in
 84 NEH 630, Chapter 15 (USDA NRCS, 1999).

85 Land use and treatment measures can produce lag effects by a) increasing infiltration (reducing
 86 surface runoff) and causing the increased infiltration to appear some time later as subsurface
 87 flow, or b) causing a delay in the arrival of surface runoff by increasing the flow length or by
 88 reducing the velocity of flow from added flow resistance.

89 Either effect is best studied by the methods described in NEH 630, Chapters 15 and 16 (NRCS,
 90 1999). Table 12–2 shows the relative effects of land use and treatment measures on the two
 91 types of lag. The subdivisions of small and large watersheds do not depend solely on size in
 92 square miles, but on a combination of varying soils and land use and drainage area. The methods
 93 of Chapters 15 and 16 are necessary in quantitative studies of lag. The use of computer models
 94 is advised in many watershed studies to estimate the impact of land use change and land
 95 treatment measures on peak flows in a watershed.

96

97 **Table 12- 2.** Relative effects of land use and treatment measures on types of lag

Measure	Effects on subsurface flow ¹		Effect of increasing surface flow length or decreasing velocity	
	Small watersheds	Large watersheds	Small watersheds	Large watersheds
Land use that increases plant or root density ²	Can be large	Can be large	Not usually considered	
Increasing mulch or litter	Can be large	Can be large	Not usually considered	
Contouring	Can be large	---	Can be large	
Contour furrowing	Can be large	Can be large	Not usually considered	
Level terracing	Can be large	Can be large	Not usually considered	
Graded terracing	Usually negligible	Usually negligible	Can be large	Negligible

98 ¹Assuming soils are not frozen; ²Example: Row crop to grass for hay; poor pasture to good pasture.

99

100 **630.1203 Determination of Effects of Land Use Change**

101 **(a) Determination of effects on volume**

102 The same procedure used in determining the present hydrologic conditions of a watershed is used
 103 to estimate future hydrologic conditions. The future effects of land use and treatment changes

104 can be estimated with relatively little additional work. Assuming that present conditions have
 105 been studied, the procedure is:

106 **Step 1.** Determine the hydrologic soil-cover complex number and antecedent runoff condition
 107 (ARC) II for future land use and treatment conditions (See NEH 630, Chapters 7, 8 and 9).

108 **Step 2.** Obtain Curve Numbers for ARC I, II, and III.

109 **Step 3.** Prepare a working table similar to Table 12–3.

110

111 **Table 12- 3.** Sample working table for estimation of effects of future land use and land
 112 treatment on direct runoff volumes

Selected values of P (inches)	Direct runoff Q (inches) ¹					
	---ARC ² I---		---ARC II---		---ARC III---	
	Present	Future	Present	Future	Present	Future
	<u>56</u> ³	<u>44</u>	<u>75</u>	<u>65</u>	<u>89</u>	<u>82</u>
0.5	<0.01	<0.01	0.03	0.01	0.11	0.16
1	0.04	0.01	0.17	0.09	0.40	0.26
2	0.27	0.13	0.65	0.42	1.18	0.87
3	0.65	0.37	1.30	0.92	2.07	1.64
4	1.13	0.70	2.05	1.53	3.00	2.49
5	1.70	1.11	2.86	2.21	3.95	3.38

113 ¹Computed with Ia = 0.05S; ²ARC is Antecedent Runoff Condition; ³Curve Number for given ARC.

114

115 **(b) Determination of effects on lag**

116 The effect of causing a delay in the arrival of surface runoff by increasing the distance of flow is
 117 easily computed when it must be considered. Increased infiltration appearing some time later as
 118 subsurface flow is seldom easy to evaluate quantitatively. Fortunately, in most flood prevention
 119 surveys the changes in the hydrograph because of this lag effect can generally be ignored.
 120 Special studies are needed to determine the source areas (which may vary with infiltrated
 121 volumes) and watershed retention.

122 Quite often, lag produced by increased infiltration can be assumed to result from slower drainage
 123 from the surface and increased opportunity for infiltration. The slower drainage causes a delay
 124 in surface runoff arrival. The technique that follows can be used to estimate expected changes in
 125 hydrograph quantities. In practice, lag from increased flow resistance is ordinarily neglected.

126

127 (c) Determination of surface storage effects

128 Under certain situations, watersheds may contain surface storage areas that must be accounted
 129 for in runoff computations. For example, storage in closed-end level terraces and contour
 130 furrows can be evaluated on a watershed or sub-watershed basis using the equation:

$$131 \quad Q_s = (A_s(Q_o - S_s) + (A_o Q_o)) / (A_s + A_o) \quad [12-1]$$

132 where:

133 Q_s = runoff with storage in effect, in inches,

134 A_s = area draining into storage including storage pond area, in square miles (or other area units),

135 S_s = storage, in inches,

136 Q_o = runoff with no storage, in inches, and

137 A_o = area not draining into storage, in square miles (or other area units)

138 When S_s exceeds Q_o , only the storage equal to Q_o is effective. For example, if $S_s = 3.0$ inches
 139 and $Q_o = 1.2$ inches, then 1.8 inches of storage have not been used and the effective storage is
 140 1.2 inches. For example, when $S_s > Q_o$, use $A_s (Q_o - S_s) = 0$.

141 **Note:** Equation [12–1] and subsequent Equations [12–2], [12–4], [12–5a], and [12–5b] are for
 142 use when runoff and storage volumes are distributed uniformly (or nearly so) on a watershed.

143 When the distribution is not uniform, the watershed is divided into sub-watersheds on which the

144 distribution may be considered uniform (See remarks accompanying Equations [12–5a] and [12–
145 5b]).

146 Figure 12–1 shows hydrographs for adjacent treated and untreated watersheds. Additional
147 information can be found in Allis (1953). Two effects are evident in Figure 12-1. Some of the
148 reduction in peak rate is a result of the lesser amount of runoff from the treated watershed.
149 Given the data as shown in Figure 12-1, the estimated peak for the treated watershed would be:

150
$$1.74(1.35/1.68) = 1.40 \text{ in/hr}$$

151 because $(q_1/Q_1) = (q_2/Q_2)$ when runoff is uniformly (or nearly so) distributed on each
152 watershed. However, the measured peak flow rate for Watershed W-5 is 0.87 inch per hour.
153 The difference is primarily because of a lag caused by graded terraces and open-end level
154 terraces (which tend to grade) in W-5.

155 Following the methods described in NEH 630, Chapters 15 and 16 (USDA NRCS,1999), the
156 additional lag can be computed from data in Figure 12–1. The time to peak (T_p) for W-3 is about
157 0.72 hour, and for W-5, about 1.05 hours. The increase in lag (because the storm duration is
158 essentially identical for both hydrographs) is $(1.05 - 0.72) = 0.33$ hour.

159 Infiltration in the storage area (pond), including that caused by increased head, is generally
160 assumed to offset storm rainfall on the storage pond area. When this infiltration is large or small,
161 it can be accounted for on a volumetric basis by changing Equation [12–1] to read:

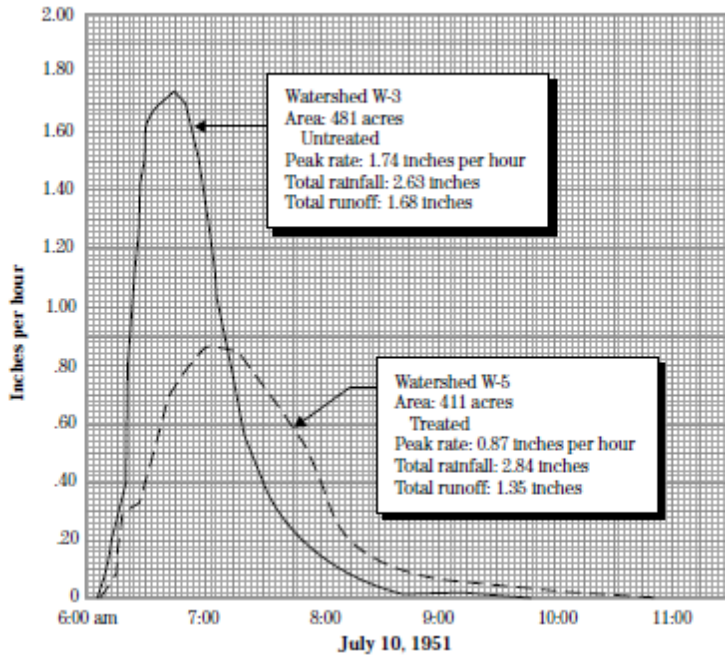
162
$$Q_s = (A_p (P - F) + (A_s - A_p)(Q_o - S_s) + A_o Q_o) / (A_s + A_o) \quad [12-2]$$

163 where:

164 A_p = average pond surface area, in square miles,

165 P = storm rainfall, in inches, and

166 F = total infiltration on the area occupied by the pond, in inches.



167

168 **Figure 12- 1.** Effects of storage on lag

169

170 If P is less than F, use (P – F) equal to zero. When other data are lacking and the average depth
 171 of the pond is less than about 3 feet, F may be approximated using the following equation:

172
$$F = D f_c(1.5h + 1) \quad [12-3]$$

173 where:

174 F = total infiltration on the pond area, in inches,

175 D = storm duration for Equation [12-3],

176 f_c = minimum infiltration rate, in inches per hour, and

177 h = average depth of pond during time D, in feet,

178 Acres or square feet may be used instead of square miles in Equations [12-1] and [12-2], but the
 179 units chosen must be compatible for all the areas in a particular computation.

180 The effect of storage on snowmelt runoff is generally computed using Equation [12–1] because
 181 the increase in infiltration caused by head in the pond area is usually negligible because of the
 182 temperature. Infiltration is important during the snow melt season and when trying to simulate
 183 the daily impact of the snow pack melt on the water balance

184 When this infiltration is important, Equation [12–2] becomes

$$185 \quad Q_s = ((A_s - A_e)(Q_o - S_s) + A_o Q_o - A_p(Q_o - F))/(A_s + A_o) \quad [12-4]$$

186 unless there is rainfall on the pond surface during the melt period, in which case Equation [12–2]
 187 is used. The effect of the earthwork in increasing the average depth of snow in an area (by
 188 retaining drifting snow) is important only in small areas and is generally ignored.

189 According to unit hydrograph theory, the effect of surface storage on peak rate of flow is
 190 proportional to the effect on volume of flow when the storage and runoff are about equally
 191 distributed over the watershed:

$$192 \quad (q_s/q_o) = (Q_s/Q_o) \quad [12-5a]$$

193 or

$$194 \quad q_s = q_o (Q_s/Q_o) \quad [12-5b]$$

195 where:

196 q_s = reduced peak

197 q_o = original peak

198 Equation [12–5b] is adequate for many watersheds. However, when the distribution of Q_o and S_s
 199 is not sufficiently uniform or when a watershed has a complex drainage pattern, is unusually
 200 shaped, or has channel improvements, q_s must be estimated by determining the storage effects on
 201 a sub-watershed basis, preparing hydrographs on a sub-watershed basis, and routing flows.

202 This routing procedure is often needed for large watersheds of several square miles in size
203 because the distribution of Q_o and S is nearly always **not uniform** on larger watersheds.

204

205 **(d) Determination of fire effects**

206 The general impacts of fires in either agricultural lands or forests is the destruction of the
207 vegetation. The impact of the fire in many cases is listed as fair, moderate or high. In some
208 cases, for forests, the impact from fire dissipates to the pre-fire conditions within 3-5 years.

209 In other cases, the properties of the soils have changed because of the fire, specifically the
210 infiltration capacity of the soil is reduced through creation of hydrophobic layers. The USDA
211 Forest Service Rocky Mountain Research Station and the Natural Resource Conservation Service
212 have publications that list suggested pre- and post-fire CNs as well as the impact of fire on soil
213 infiltration rates. The NRCS Hydrology Technical Note No. 4, Hydrologic Analysis of Post-
214 Wildfire Condition (USDA NRCS, 2016), provides guidance and the selection of post-fire CNs
215 based on investigated cases. Wildcat5 (Hawkins and Barreto-Munoz, 2016) for Windows® is a
216 computer program developed for the U.S. Forest Service that can be used to evaluate the impact
217 post-fire conditions.

218

219 **630.1204 References**

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