

Attributes of Successful Stock Water Ponds in Southern Arizona

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Abstract.—The attributes of 20 ponds (or stock tanks) on the Nogales Ranger District of the Coronado National Forest were studied in detail by groups. Two contrasting groups, judged to be either functional (n = 11) or nonfunctional (n = 9) were used in the study. Differences between the groups were evaluated on the basis of attributes of the ponds themselves, the contributing watersheds, and the local climate and modeled hydrology. There are no differences associated with the pond shape, materials used for dam construction, watershed Curve Number, hydrologic soil group, geology, range or hydrologic condition, mean number of days at capacity per year, or the fraction of runoff trapped. Differences are more apparent when considering pond depth, maximum pond capacity, watershed drainage area, and percent of days with no stored water.

Introduction

Stock tanks (stock ponds) are important in rangeland management in their obvious role of stock watering. The water supply they provide allows for widespread use of forage resources over otherwise waterless areas, a surface water source during extended dry periods, as well as providing benefits for wildlife and associated aquatic resources. Also, at least at the local level, they have unavoidable hydrologic impacts.

Stock tanks are costly, and potential environmental impacts - both positive and negative - are likely. Therefore, informed planning can minimize costs and unproductive installations, and avoid environmentally harmful effects. From a water development standpoint, the total surface water supply in arid areas is limited, so that efficient use calls for thoughtful placement of stock tanks. Thus, it is important to know at the conception and planning stage the likelihood of a successful effort. Or in other words: "What makes a good site for a stock tank?"

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Approach

A "good" site depends on the intent of development. Given the wide spectrum of benefits and costs possible, and the various lenses that different user groups use to view them, land managers develop pragmatic reality-based impressions of goodness. Some ponds obviously "work" well and some others obviously do not. This view may be composed of the cost of construction, the hydrologic /water supply dimensions, durability/maintenance concerns, and incidental benefits.

The construction dimension includes geomorphic suitability of the site, availability of suitable building materials, and heavy machinery access. The hydrologic concern includes the maximum amount and duration of water storage possible and the proximity to forage resources in the management scheme. The durability includes the need for periodic maintenance, sedimentation, spillway repairs, etc. Also, incidental uses such as recreation and wildlife and Endangered Species habitat may influence the worthiness. This work was aimed at isolating and contrasting these management-defined characteristics of stock tank success and failure.

Methods

Location

The location of this study was the Nogales Ranger District of the Coronado National Forest in southern Arizona. Pond elevations vary from about 1200 to 1800 meters, and average annual rainfall (there is little snow) ranges from ca 43 to 71 cm/yr. About 70% of this falls during the summer monsoons season as thunderstorms. Vegetative types include desert grasslands and broadleaf woodlands dominant in southern Arizona. Characteristic of this climate and setting, watershed runoff is almost entirely rainstorm response. There is little or no base flow or snowmelt, and few springs in the area.

Stock Tank Selection

Based on professional experience, management personnel from the Nogales Ranger District of the Coronado National Forest designated a series of candidate ponds based on the questions: "Did the pond fill at any time?", and "Did the pond provide adequate water supply?" as the guiding elements in the selection. Based on practical matters of information availability, access and other logistical and data factors, a total of 20 ponds were selected for study; 9 functioning and 11 nonfunctioning. These are shown in table 1.

Site and Watershed Factors

Site factors

Using existing agency files or specific site surveys the pond factors of the soils, the pond depth and storage capacity at spillway elevation, and the shape were determined. Limited coverage of this is also given in table 1.

Watershed factors

Available data on soils, geology, vegetative type and conditions were assembled for the 20 sites. Based on these, an AMC-II Runoff Curve Number was assigned to each watershed from handbook tables. This was mainly used to drive the hydrologic evaluations described next.

Climatic/Hydrologic Characteristics

A major concern in stock tank utility is the frequency and duration of filling. Such hydrologic data are not available for the sites, but was evaluated through the use of an elementary daily time step model based on a representative two years of rainfall and evaporation data from the Nogales, Arizona weather data. For each site, adjustments on daily values were based on regional regressions developed for this purpose. Daily runoff was generated for each watershed by the CN method based on moisture status, with the expected CN range derived from the land information and handbook values. The model included evaporation, storage, and spills from the ponds themselves. Model runs allowed the number of "dry" days (dry pond) and "wet" days (full pond) to be tabulated.

Table 1. Selected information on stock tanks and watersheds.

Tank Name	Pond			Watershed					
	Elev (m)	Volume (m3)	Depth (m)	DA (ha)	Elev (m)	Veg. type	HSG	CN	Precip (cm/yr)
Nonfunctioning (9)									
Beach	1286	4613	2.44	26	1362	Grassland	D	70	50.3
Box Canyon	1426	962	2.44	23	1603	Grassland	D	79	60.5
Fish	1707	1702	3.05	34	1811	Woodland	C	71	71.2
Lower Turner	1192	4416	3.05	238	1312	Grassland	C	39	46.3
Old Forester	1219	6315	3.66	43	1282	Grassland	C	79	46.7
South Boundary	1305	4552	2.74	115	1506	Grassland	D	74	55.5
Upper Turner	1219	5625	2.74	26	1262	Woodland	C	33	46.5
Warsaw #2	1305	1838	4.57	45	1414	Grassland	D	79	52.7
Warsaw #3	1256	925	3.05	47	1308	Woodland	D	79	50.0
Functioning (11)									
Agua Cercada	1253	13679	4.27	173	1372	Grassland	D	62	50.3
Barrel	1561	2997	2.74	34	1603	Woodland	B	37	59.8
Boundary	1207	2361	1.83	115	1367	Grassland	D	71	48.4
Castle Rock	1250	7660	4.57	27	1297	Grassland	D	78	46.9
Coches	1158	9658	3.96	111	1292	Grassland	D	75	46.7
Greaterville	1634	7994	3.66	68	1707	Woodland	D	68	66.9
Japanese	1317	2171	2.74	38	1366	Woodland	D	69	45.5
Lobo	1329	43492	7.32	496	1530	Woodland	D	86	58.5
Melendrez	1756	2331	3.96	3	1774	Woodland	C	74	71.1
Sierra	1164	5316	3.35	29	1204	Grassland	B	40	43.7
Warsaw	1280	7857	3.05	22	1329	Woodland	D	76	50.1

Note: "Woodland" = Broadleaf Woodland. "Grassland" = Desert Grasslands. HSG = Hydrologic Soil Group. CN is the table AMCII Curve Number based on soils, cover, and condition.

Results

Tables 2 and 3 give group summaries and statistical inference information for most of the variables considered. Group comparisons are made via "t" tests as shown. There are no significant differences at the traditional higher (i.e., 90-95%) confidence levels, but consistent evidence at more moderate levels.

Pond Materials and Characteristics

The functioning and nonfunctioning ponds showed no differences based on dam construction materials. A preferred clay content range around 20% was common, though it varied from 14% to 24% for nonfunctioning ponds to 8% to 32% for functioning ponds. Pond shape, which is not given in the tables here, was found to be completely unimportant.

Table 2 shows the summary findings on the differences between groups in accordance with pond characteristics. Given the relentless draw of evaporation from pond surfaces in hot arid climates, simple pond depth can be expected to be important. The criteria developed by Deal et al. (1997) were used as a measure of comparison. Most (64%) of the functioning ponds were deeper than recom-

mended; most of the nonfunctioning ponds were shallower. However, as shown in table 2, the difference - while present - is not overpowering (72%),

The related attribute of pond capacity (or volume) was also evaluated. Aside from its geomorphic dependence on depth, a large capacity allows greater capture of the rarer extreme inflows. Table 2 shows a similar (75% probability) separation of the groups.

Watershed and Hydrologic Factors

Hydrologic Behavior

The Runoff Curve Number (CN) assigned from soils, vegetation, and land condition data use handbook estimates as beginning points in the hydrologic simulations. These represent the presumed fundamental influences on event runoff generation for the contributing watersheds. As shown in table 2, there is no difference between the two groups on the basis of Curve Number.

For the components that define CN, there were no differences found in vegetative type, range condition hydrologic condition, geologic type, or hydrologic soil groups.

From the model studies described briefly above, and as shown in table 3, there were - surprisingly - no apparent differences between the two groups in the mean number of filled days per year, or in the fraction of the runoff

Table 2. Pond and watershed results.

	Volume (m ³)	Depth (m)	DA (ha)	CN (-)
Nonfunctioning				
Minimum	925	2.44	23.0	33.0
Mean	3439	3.08	66.3	66.3
St Dev	2081	0.67	70.2	18.0
Maximum	6316	4.57	238.0	79.0
Functioning				
Minimum	2171	1.83	3.0	37.0
Mean	9592	3.77	101.5	66.9
Std Dev	11820	1.42	134.0	15.3
Maximum	43492	7.32	496.0	86.0
Differences				
Mean	6154	0.87	35.1	-0.1
Pooled S	8918	1.15	114.7	16.1
"t"	0.69	0.59	0.31	-0.01
Pr(t)	75	72	62	0

Notes: Pr(t) = probability of a lesser t statistic, in percent.
CN is dimensionless.

Table 3. Hydrologic simulation results.

	Capacity Fraction (%)	Dry Days (#/yr)	Capacity Days (#/yr)
Nonfunctioning			
Minimum	1.3	0	0
Mean	19.1	47.4	16.2
St Dev	70.7	82.1	10.1
Maximum	100.0	236.0	29.0
Functioning			
Minimum	1.5	0	0
Mean	19.6	14.0	16.6
Std Dev	29.8	33.6	9.3
Maximum	100.0	9.3	33.6
Differences			
Mean	0.6	-33.4	0.4
Pooled S	30.7	60.2	9.6
"t"	0.02	-0.56	0.04
Pr(t)	0	71	0

Note: Pr(t) = probability of a lesser t statistic, in percent.

trapped by the ponds (i.e., the capacity fraction). However, the number of dry days was less for the functioning group, again at a modest level (71%) of confidence. It should be noted that many of these are not primary measured variables, but auxiliary measures produced from handbook tables or by modeling with estimated and extrapolated input.

Summary

There were no strong discriminating factors between functioning ponds and nonfunctioning ponds. However, several factors survive if the high rejection levels customarily used are reduced to the vicinity 70%. Such lower levels of assurance are not uncommon in natural resources management.

The watershed factors with little or no relevance were Curve Number, geologic type, hydrologic soil groups,

vegetative type, vegetative and hydrologic condition. The site factors of construction soil and pond shape were not important. Similarly, the hydrologic factor of number of filled days was not important. Factors of modest identifiable importance and associated probability levels were pond capacity (75%), pond maximum depth (72%), drainage area (62%), and number of dry days (71%).

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