A Practical Method for Estimating the Capacity of Stockwatering Ponds (Stockponds)

Don W. Young[1]

In 1979, the Arizona State Land Department (ASLD) was faced with a crucial problem. Literally thousands of water rights claims belonging to the state had been neither located nor filed upon in the pending adjudication of the San Pedro River watershed. At that time there were only four hydrologist/water resource positions within the hydrology section of the ASLD. It became obvious that a methodology was needed whereby a survey of water rights claims could be made as expeditiously as possible, while retaining an acceptable level of accuracy in quantifying those claims.

Measurement methods available at the time included (1) plane table survey, (2) instrument survey, (3) the SCS method, and (4) "guesstimate." Both plane table and instrument survey methods require two persons to perform—a luxury not afforded to the agency.

The SCS (Soil Conservation Service) method utilizes pond circumference for estimating the volume of small ponds. This method effectively treats all ponds as though they are of circular configuration and uniform depth, that is, shaped like a plate with vertical sides. Field experience has shown this not to be a reasonable assumption, and utilizing this method often grossly overestimates the capacity of stockponds.

Historically, many ranchers have simply guesstimated the capacity of their stockponds, with predictable results—volumes often varied by orders of magnitude. Primarily for this reason, ASLD decided to field measure all stockponds located on trust lands.

Each method of measurement was considered and rejected for one or more of the reasons alluded to above. Based on the experience of its field personnel, ASLD formulated a new method for estimating the volume of stockponds.

[1]Arizona Office of the Attorney General, Water Rights Adjudication Team, Phoenix, AZ.

Development of the ASLD Method

ASLD staff devised a method for estimating the capacity of stockponds, or Estimated Maximum Volume [EMV], which employs the geometric surface shape and three-dimensional configuration of ponds found in the field. Shapes and dimensional relationships used to develop this method were derived from the experience of field personnel who had visited and measured numerous stockwatering ponds, as well as actual field measurements.

Phase 1: Field observations led to the recognition of nine basic geometric surface shapes: [1] square, [2] rectangular, [3] triangular, [4] trapezoidal, [5] circular, [6] semicircular, [7] elliptical, [8] semielliptical, and [9] ellipsoidal (egg-shaped). The majority of stockponds conform to one, or a combination, of these surface shape categories (Figure 1).

Phase 2: The second phase of this project involved representation of the bottom configuration of the stockponds to develop their three-dimensional contours. Sampling of bottom configuration was accomplished through the use of a casting reel and fishing pole with a bobber modified to hold a clip through which the line would pass. An Alka-Seltzer™ tablet was inserted in the clip to keep it open, allowing the line to pass freely through the clip until the sinker reached the bottom of the pond. When the Alka-Seltzer™ tablet dissolved, the clip closed on the line. The line was then reeled in, and the length of line from bobber to sinker was measured, thereby indicating the depth of the stockpond at the point measured.

Numerous stockponds with surface configurations shown in Figure 1 were gridded and measured to develop a sample representative of bottom configuration for each shape. Other stockponds were instrument-surveyed when empty. Thus, the three-dimensional contours began to take shape, as shown by the example in Figure 2.

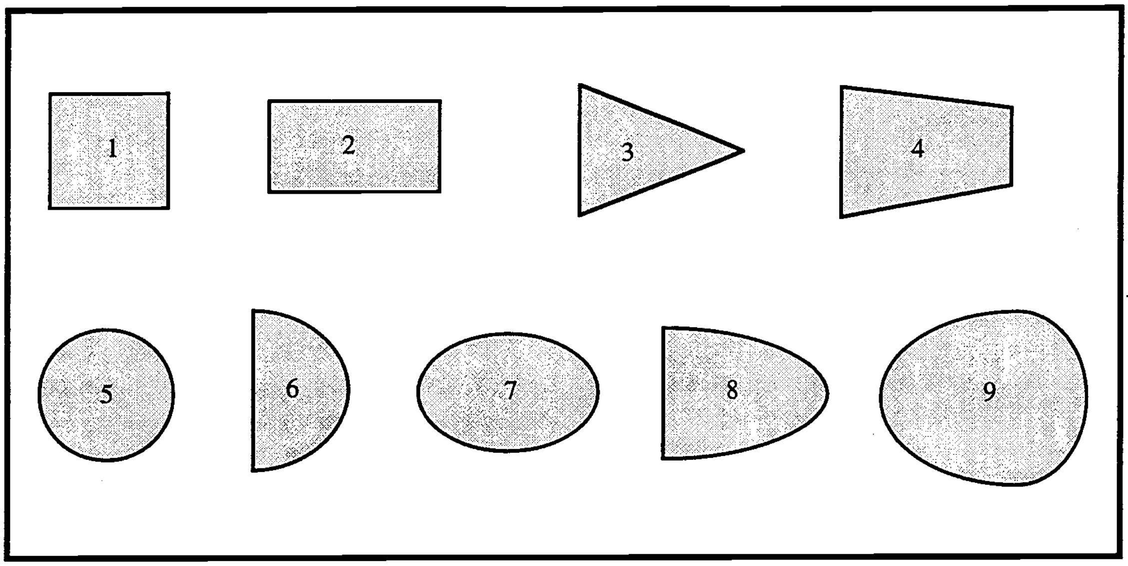

Figure 1. Basic surface configurations of stockponds identified in the field.

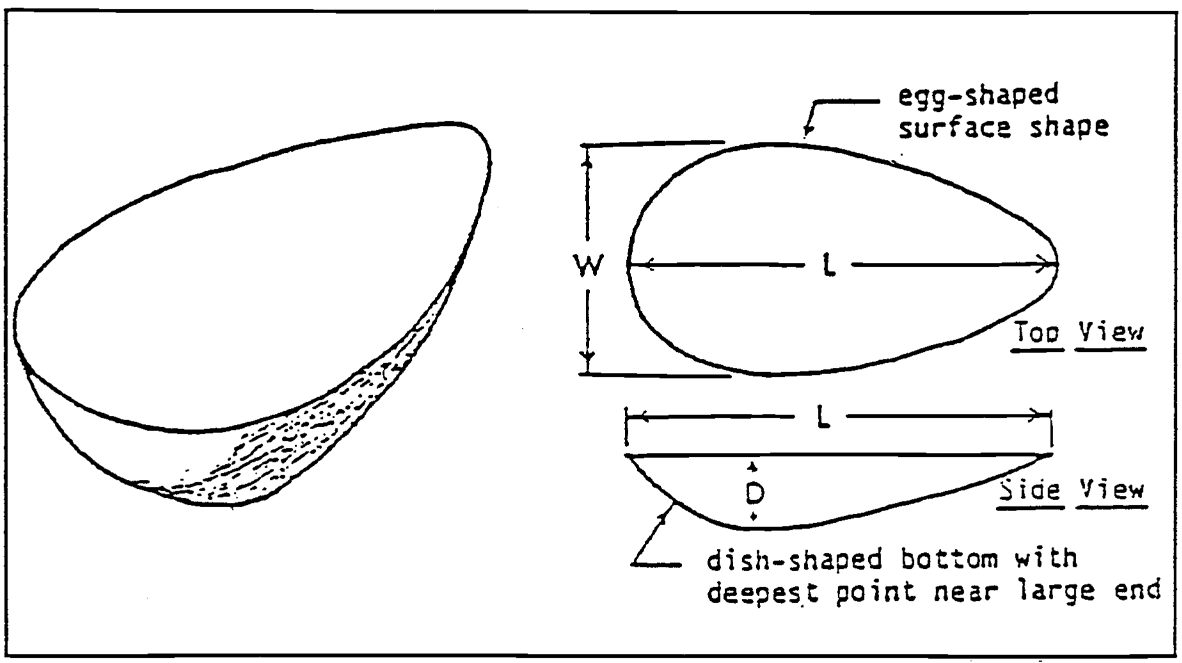

Figure 2. Three-dimensional representation of an ellipsoidal stockpond.

The next phase of the project was the most tedious. Each three-dimensional configuration had to be expressed mathematically. Geometric shapes within geometric shapes were drawn with angles and slopes, with relationships to each other carefully noted. The researchers then constructed complex mathematical formulae to express the total geometric design of each representative stockpond configuration (see Figure 3).

Next, an exact volume (V_e) formula was developed for the ellipsoidal configuration using the following assumptions:

- Volume I is one-half the volume of the ellipsoid illustrated by CN-24 (see Appendix).
- Volume II is a cylinder with an end area that is a section of a parabola. (Using a parabolic segment rather than an elliptical segment greatly simplifies the resulting equation and incurs negligible error.)
- Volume III is bounded in the xz-plane by a semiellipse having semiaxes of W/2 and 3D, and in the yz-plane by a parabola having a maximum depth D.

$$V_e = \frac{WDL(\pi+4)}{(12)(43,560)} - \frac{WD^2(7\pi+128)}{(64)(43,560)}$$

This was further simplified to an approximated volume formula:

$$V_a = 13LWD$$

and the comparative error between V_e and V_a calculated by:

$$\text{Percent error} = 100\left[\frac{0.952}{(1-3.938h)} - 1\right] \quad \text{where } h = D/L$$

(Percent error ranges between -5% and +8% for ratios of $D/L \leq 0.03$. For ratios of $D/L > 0.03$, the exact formula should be used.)

Evaluation of EMV Method

Since the development of the EMV method, the state of Arizona has been interested in obtaining data comparing various methods of measuring stockwatering ponds. Several techniques have been used by various parties to the general water rights adjudications and by the Arizona Department of Water Resources, not all of which provide consistent or accurate results (Young and Cunningham 1993, 1996).

In the early 1990s, the U.S. Fish and Wildlife Service (USFWS) was considering various methods whereby it could train its personnel to investigate water rights claims associated with its

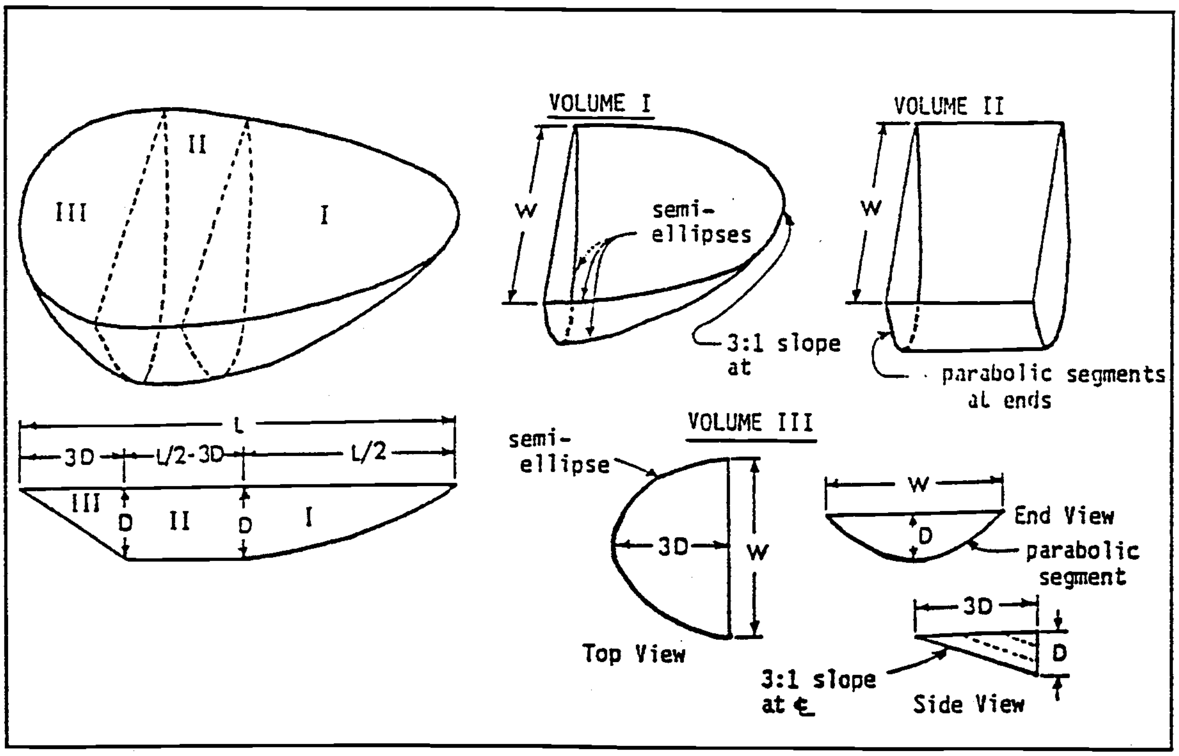

Figure 3. Geometric relationships among various segments of an ellipsoidal stockpond.

wildlife refuges in order to have the federal government's claims accurately represented, in a timely manner, in the adjudications. USFWS was interested in which methods were available, how they compared, and how (or whether) they were accepted in the context of the adjudication process (Young and Cunningham 1993, 1996).

In September 1991, the Arizona Office of the Attorney General (AG) and USFWS entered into a cooperative agreement to perform a research project on the Buenos Aires National Wildlife Refuge (BANWR), located approximately 40 miles southwest of Tucson, Arizona, to evaluate various methods of measuring stockwatering ponds (Young and Cunningham 1993, 1996).

The survey instrument used by USFWS to perform stockpond measurements is a laser-based system operating in the infrared mode to protect the eyes of the surveyor. Computer functions incorporated into the instrument permit collected data to be downloaded to a PC. Once the data are downloaded, the geodimeter surveying software permits the user to compute various survey parameters. The computer generates a contoured map of the stockpond and then computes the inside volume from the spillway elevation (top contour at the spillway) to produce the maximum volume (in acre-feet) of water that can be contained in the stockpond (Young and Cunningham 1993, 1996).

Table 1 is a summary of the data derived from the geodimeter-contoured plots and the ASLD field sheets for the stockponds surveyed. The calculated EMV of each stocktank is shown for both methods, as well as the error between the methods.

Table 1 shows the average percent error (absolute) between the two methods at just over 13 percent. In hydrologic terms this is acceptable. It must be remembered that the ASLD method utilizes capacity formulae relating to the as-built geometry and depth of stockwatering ponds. As a pond silts in, the geometry and the depth change dramatically. However, with the ASLD method the geometry would appear to remain the same. Of course, all instrument survey methods measure the existing geometry and depth of a stockpond.

In addition, the average difference in volumes of all stockponds surveyed is only 0.45 af—an insignificant volume of water when considering the potential impact of all stockponds upon a hydrologic system. Other studies indicate that retention volumes associated with stockwatering ponds have an insignificant impact on the hydrol-

Table 1. BANWR stockpond volumes measured using ASLD-EMV and GS400 methods, showing associated error (n = 17).

Stockpond Name	Volume (af)-ASLD	Volume (af)-GS400	Difference (af)	Percent Error
Ashcroft East Tank	0.47	0.34	0.13	27.7
Ashcroft West Tank	1.64	1.51	0.13	7.9
Ashcroft West Sandtrap	0.02	0.02	0	0
Halloween Tank	0.14	0.1	0.04	28.6
Herman Tank East	0.7	0.66	0.04	5.7
Herman Tank West	0.44	0.49	-0.05	-11.4
Horse Tank 1 (lower)	0.53	0.48	0.05	9.4
Horse Tank 2 (middle)	0.49	0.48	0.01	2
Horse Tank 3 (upper)	0.53	0.48	0.05	9.4
Jane's Tank	0.7	0.6	0.1	14.3
Lopez Tank	18.23	14.81	3.42	18.8
Lower Wilber Tank	0.89	0.89	0	0
McKay "A" Tank	2.48	1.99	0.5	20.2
Marijuana Tank	2.75	2.25	0.5	18.2
Marijuana Tank Sandtrap	0.82	0.68	0.15	18.3
Snake Tank	0.85	0.73	0.12	14.1
Tequila Tank	12.67	10.2	2.47	19.5
			7.66/n*	|225.5|/n*
Totals	44.35	36.71	0.45	|13.3|

ogy of a watershed (Milne and Young 1989; Young 1994a, 1994b; Young and Sejkora 1995; Young et al. 1996; Young and Lang 1996).

Conclusions and Discussion

- Utilizing the EMV method allowed ASLD field personnel (as well as ranchers and other property owners) to estimate stockpond capacities quickly and reliably. Most importantly, it required only one person to make the measurements—an asset when manpower is limited. The EMV method was utilized by ASLD in making water rights filings on the majority of its stockpond claims. Certain federal agencies and private individuals also utilized the EMV method in quantifying stockwatering ponds.
- The ASLD method produces an accurate estimation of the original as-built capacity of stockwatering ponds over a wide range of sizes and configurations—an important consideration when quantifying stockponds for water rights filing purposes. Arizona statutes permit an owner to periodically clean out stockponds that have silted in, as long as the original capacity of the tank is not increased. It is to the water right holder's benefit to file for the original capacity of the stockponds so they may be cleaned without penalty of exceeding the water right amount. This gives the ASLD method the advantage over survey methods for estimating the capacity of stockponds.
- The ASLD method is reasonably simple to perform, with a minimum of training required for field personnel.
- The ASLD method has limitations, however, with respect to impoundments that are nonconforming to standard geometric shapes and/or are very large in size (>15 af). Such unusually configured tanks would be more accurately measured by an instrument survey method.
- The ASLD method was scrutinized by the special master in the general streams adjudications in Arizona during *de minimis* hearings, and was considered by the Maricopa County, Arizona, Superior Court to be consistently accurate for its intended purpose (Superior Court Memorandum Decision 1994).
- The EMV method was originally published in 1979 and disseminated for public use by the Arizona Water Commission (predecessor of the Arizona Department of Water Resources; see appendix, "Guide For Determining Stockpond Capacity").

Acknowledgments

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