Paper presented at the joint Conference of the Arizona Hydrological Society and the American Institute of Professional Geologists, September 14, 2014, Prescott Az.

POTENTIAL FUTURE DECLINES IN BASE FLOW TO THE UPPER VERDE RIVER DUE TO GROUNDWATER EXTRACTION FROM THE BIG CHINO SUB-BASIN AND SURROUNDING AREAS – AN APPLICATION OF THE NARGFM[1]

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ABSTRACT

This report builds on earlier work by the USGS in cooperation with the Arizona Department of Water Resources and Yavapai County to develop a regional flow model for northern Arizona. The USGS, in conjunction with the Verde River Basin Partnership (VRBP) and the Town of Clarkdale, subsequently applied the model in a series of simulations to gain a greater understanding of the past and potential future human impacts on the Middle Verde River's streamflow[2].

The work discussed in this paper was carried out to: (A) test the accuracy and predictive capability of the model within the Big Chino and Little Chino sub-basins; (B) illustrate the historical change in base flow at the USGS Paulden and Clarkdale streamgages; and (C) perform forward-looking simulations for the period 2005-2110 that evaluate potential effects on base flow in the upper Verde River resulting from; (1) unchanged water demand from 2005 through 2110, (2) continuing drought, (3) increased water demand, (4) extraction of the ADWR allocated 12,000 acre-feet per year (ac-ft/yr) of groundwater from the central part of the Big Chino sub-basin beginning in 2020, and (5) the cumulative effect of cases (1) through (4).

My testing of NARGFM showed that excellent agreement was found between historically observed and simulated groundwater elevations within the area of concern. In addition, simulated trends in both groundwater elevation and discharge to the Verde River are accurate to within industry-standard ranges.

My forward-looking simulations using the NARGFM show that the cumulative effect of continuing drought, increased water demand, and extraction of 12,000 ac-ft/yr (16.6 cfs) of groundwater from the Big Chino, will decrease the base flow to the Verde River by 12.8 cfs at the Paulden streamgage by the year 2110. Since the base flow at the Paulden streamgage in 2005 was approximately 19 cfs, this would leave only 6.2 cfs in the river.

Declines in groundwater levels were also evident, and indicate that regional planning within Yavapai County is needed both to support future water supplies and to develop a long-term water management strategy that protects the Verde River.

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[1]NARGFM. "Regional Groundwater-Flow Model of the Redwall-Muav, Coconino, and Alluvial Basin Aquifer Systems of Northern and Central Arizona" (USGS Scientific Investigations Report 2010-5180).

[2]Garner et al. "Human Effects on the Hydrologic System of the Verde River, Central Arizona, 1910-2005 and 2005-2110, Using a Regional Groundwater Flow Model" (USGS Scientific Investigations Report 2013-5029).

Revised April 2015

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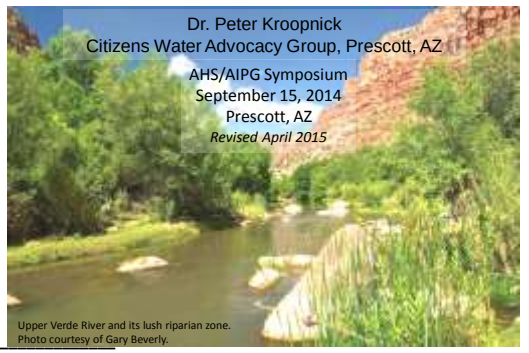
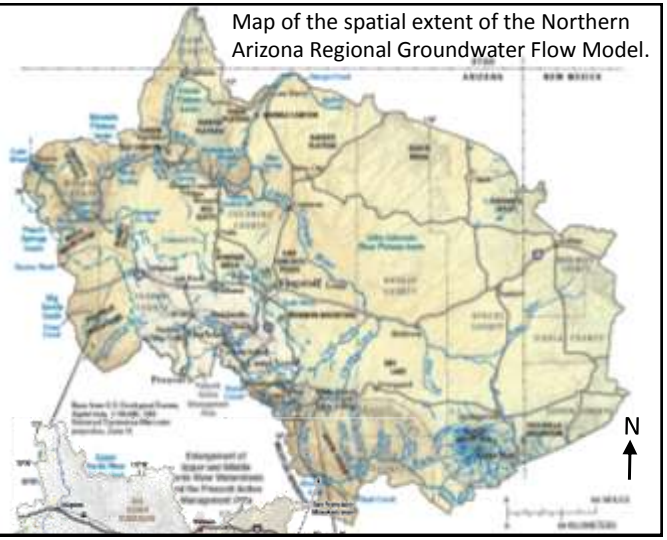
September 15, 2014
Prescott, AZ
Revised April 2015



Upper Verde River and its lush riparian zone.
Photo courtesy of Gary Beverly.

[1]NARGFM. "Regional Groundwater-Flow Model of the Redwall-Muav, Coconino, and Alluvial Basin Aquifer Systems of Northern and Central Arizona" (USGS Scientific Investigations Report 2010-5180).



Map of the spatial extent of the Northern Arizona Regional Groundwater Flow Model.

N

Regional Groundwater-Flow Model of the Redwall-Muav, Coconino, and Alluvial Basin Aquifer Systems of Northern and Central Arizona -- NARGFM

By D.R. Pool, Kyle W. Blasch, James B. Callegary, Stanley A. Leake, and Leslie F. Graser

Prepared in cooperation with the Arizona Department of Water Resources and Yavapai County.
USGS Scientific Investigations Report 2010–5180

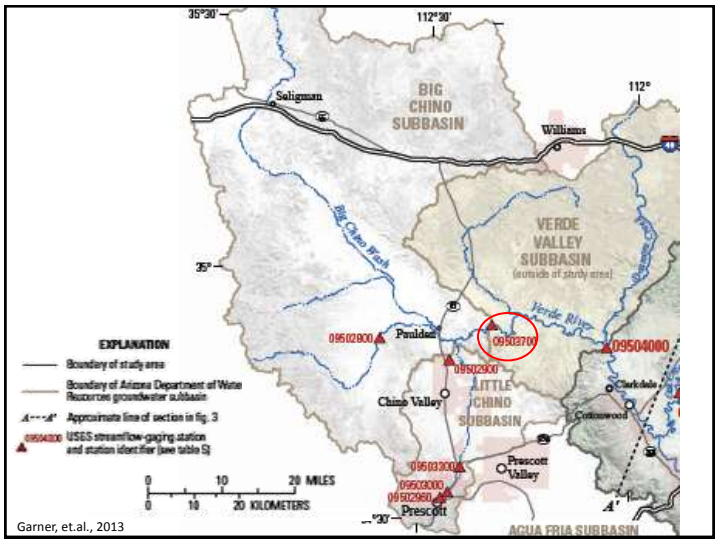
- ✓ NARGFM is a numerical flow model (MODFLOW) of the groundwater flow system in the primary aquifers in northern Arizona.
- ✓ Developed to simulate interactions between the aquifers, perennial streams, and springs for predevelopment and transient conditions during 1910 through 2005.
- ✓ Only a regional model can simulate the effect of changes in any basin or sub-basin on another.
- ✓ Intended to be used by resource managers to help assess the adequacy of the regional groundwater supply and the potential effects of increased groundwater use, due to population growth, on water levels, streamflow, and riparian vegetation.

However, the communities of Prescott, Prescott Valley and Chino Valley objected to the use of this model as a management or planning tool, describing the model as inaccurate for the Big Chino Valley and the Prescott AMA in its predictions and even in concept.

Meanwhile, The USGS, in cooperation with the Verde River Basin Partnership and the Town of Clarkdale, used the NARGFM to explore the effects of past and possible future human stresses on the hydrologic system of the Verde Valley and northern Arizona. **(Garner et. al., 2013.** Human Effects on the Hydrologic System of the Verde Valley, …, USGS 2013-5029**)**

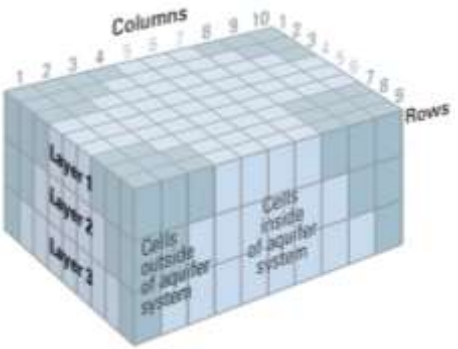
This presentation follows the procedure adopted by Garner but for the Big and Little Chino.

- Use the NARGFM to calculate water budgets that included simulation of known natural and human stresses for 1910–2005.
- Apply three new profiles of hypothetical future human stresses for 2005–2110.
- Subtract the newly calculated water budgets from one another so as to isolate only the relative changes in their values that were attributable to human stresses.



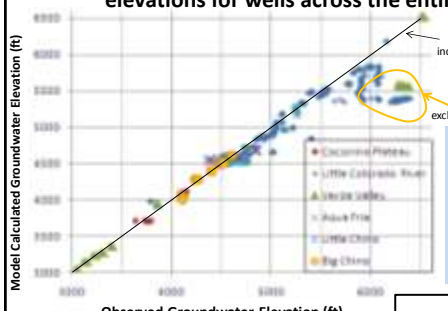
Garner, et.al., 2013

Conceptual diagram showing a 3-layer grid representing a groundwater-flow model's spatial discretization. after Leake 1997)



NARGFM details
600 rows – 370 miles
400 cols – 250 miles
Cell size 1 km = .62 mi
3 layers
9 stress periods (~10 yrs)
1910 – 1938 steady state
1939 – 2005 transient
Calibrated with 93 wells

Comparison of observed vs calculated groundwater elevations for wells across the entire NARGFM area.



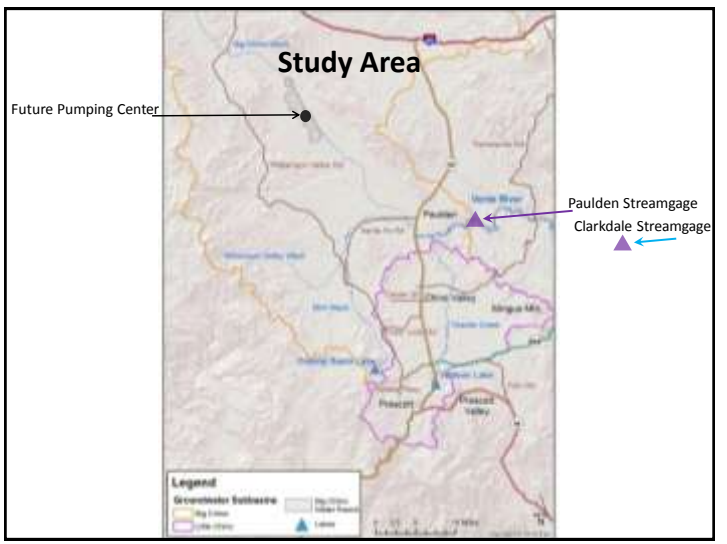
Points on the line represent wells in which the observed and calculated groundwater elevations match. Data between 1938 and 2005 included. A perfect match means the model is calibrated.

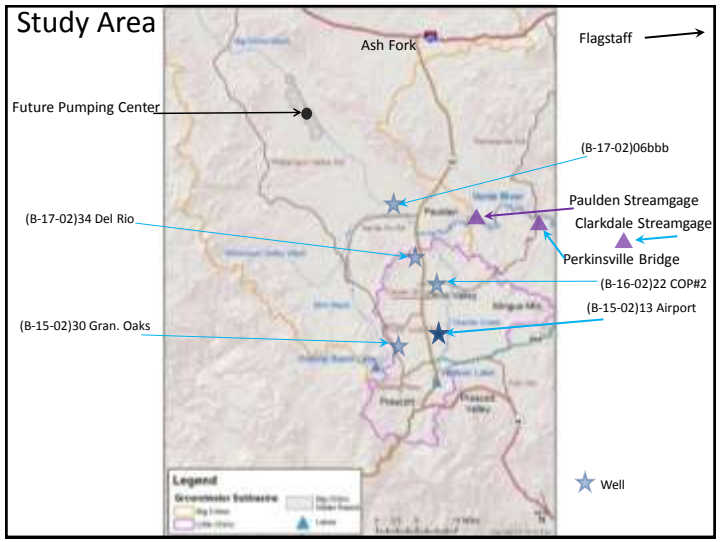
Summary of statistics For Residuals (obs. – calc., feet amsl)

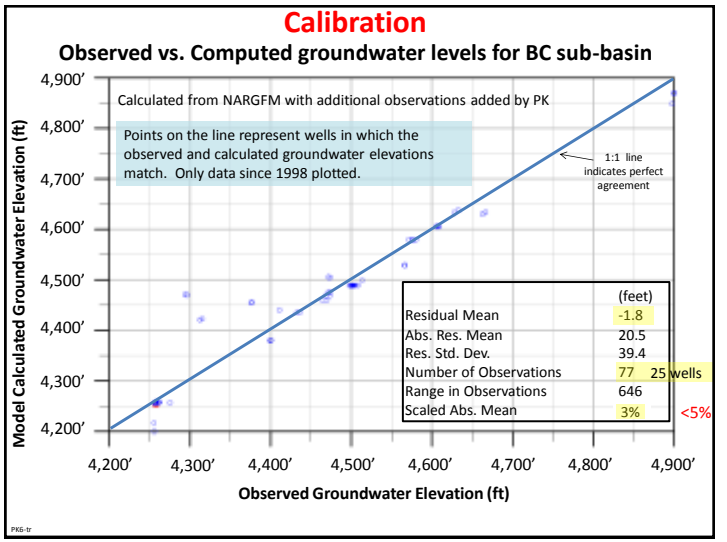
Note: Outliers (>300 ft residual) were removed (500 obs). None were in the area of interest.

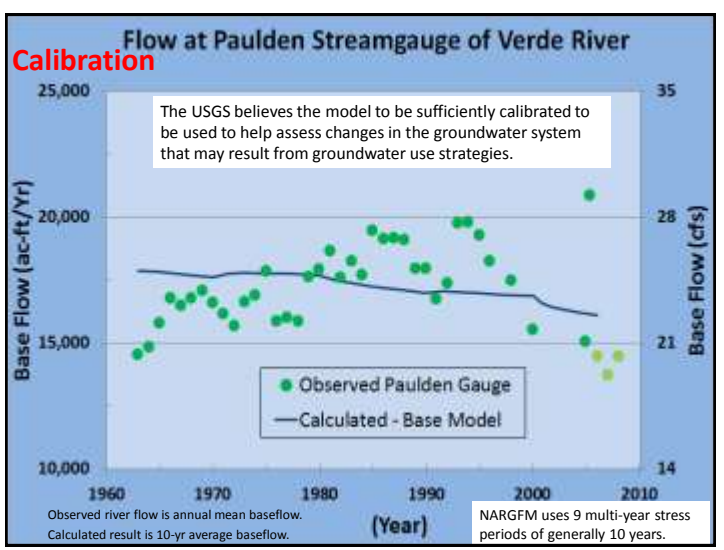
Residual Statistics (feet), excluding outliers	
Average residual	44.5
Absolute average	57.0
Standard Deviation	66.7
Number of Obs. 93 wells	3,217
Root Mean Square Deviation	67.0
Range of Observations	3,500
Scaled average	1.3%
Scaled Abs. average	1.6%
Scaled Root Mean Square Deviation	1.9%

<5%



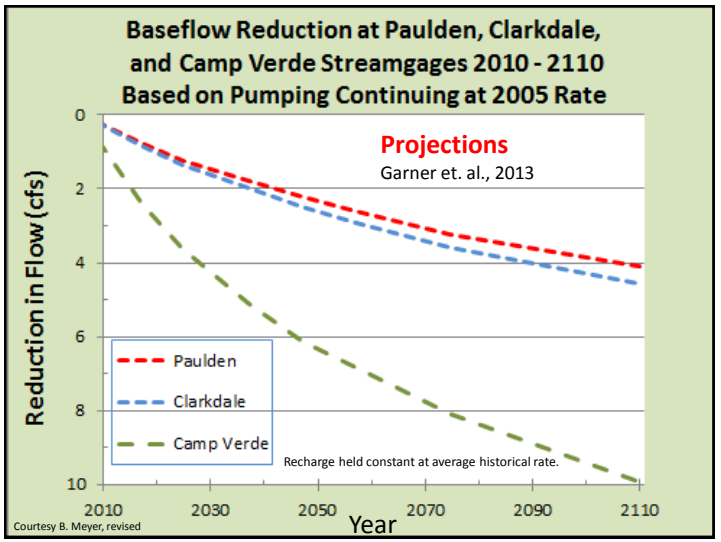


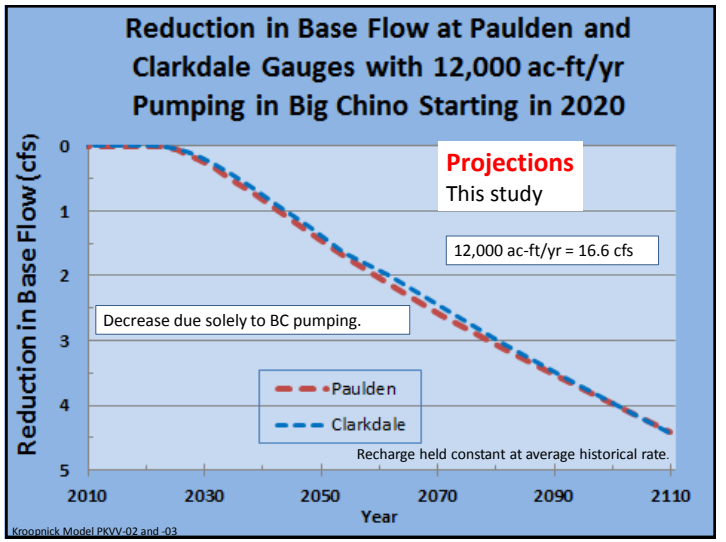


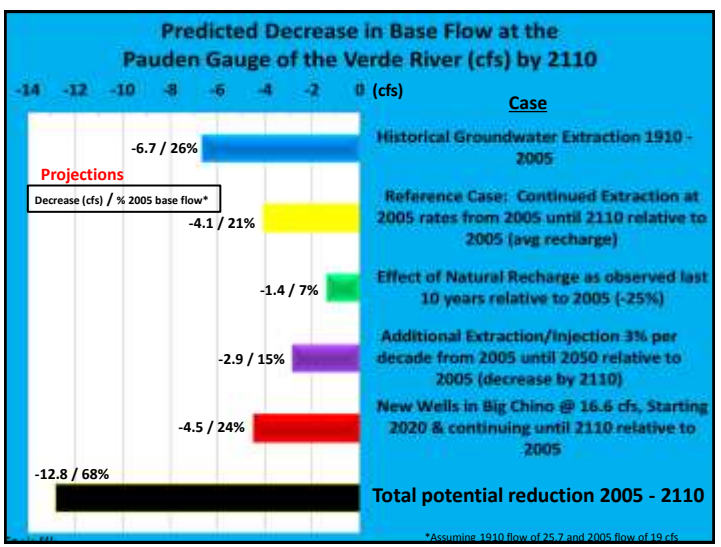


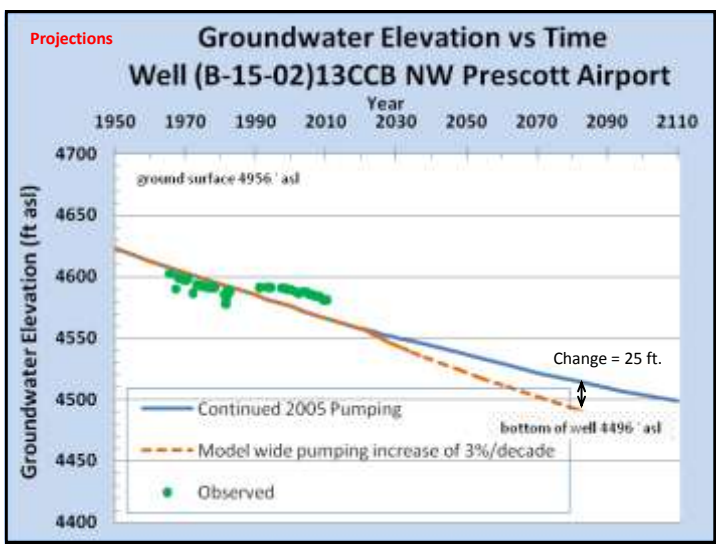
Projected changes – this work

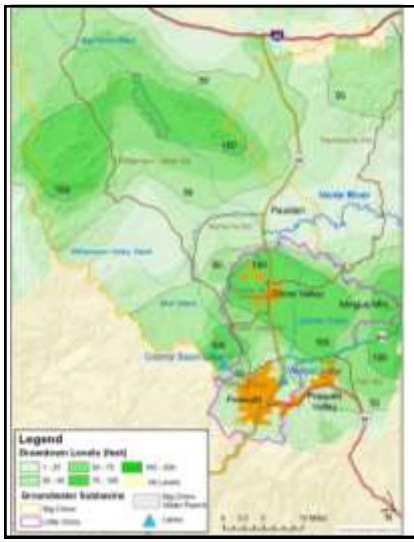
- Garner showed the historical changes in base flow at the USGS Paulden and Clarkdale streamgages – 1910 – 2005 (Garner et. al., 2013).
- Perform forward-looking simulations for the period 2005-2110 that evaluate potential effects on base flow in the upper Verde River resulting from:
  - (1) unchanged water demand from 2005 through 2110 – recharge average historical,
  - (2) increased water demand -- 3% per decade to 2060 for entire domain,
  - (3) extraction of the ADWR allocated 12,000 acre-feet per year (ac-ft/yr) of groundwater from the central part of the Big Chino sub-basin beginning in 2020, and
  - (4) the cumulative effect of cases (1) through (3).


Baseflow Reduction at Paulden, Clarkdale, and Camp Verde Streamgages 2010 - 2110 Based on Pumping Continuing at 2005 Rate
Reduction in Flow (cfs)
Year
Projections
Garner et. al., 2013
Paulden
Clarkdale
Camp Verde
Recharge held constant at average historical rate.
Courtesy B. Meyer, revised


Reduction in Base Flow at Paulden and Clarkdale Gauges with 12,000 ac-ft/yr Pumping in Big Chino Starting in 2020
Reduction in Base Flow (cfs)
Year
Projections
This study
12,000 ac-ft/yr = 16.6 cfs
Decrease due solely to BC pumping.
Paulden
Clarkdale
Recharge held constant at average historical rate.
Kroopnick Model PKVV-02 and -03


Predicted Decrease in Base Flow at the Pauden Gauge of the Verde River (cfs) by 2110
(cfs)
Projections
Decrease (cfs) / % 2005 base flow*
-6.7 / 26%
-4.1 / 21%
-1.4 / 7%
-2.9 / 15%
-4.5 / 24%
-12.8 / 68%
Case
Historical Groundwater Extraction 1910 - 2005
Reference Case: Continued Extraction at 2005 rates from 2005 until 2110 relative to 2005 (avg recharge)
Effect of Natural Recharge as observed last 10 years relative to 2005 (-25%)
Additional Extraction/Injection 3% per decade from 2005 until 2050 relative to 2005 (decrease by 2110)
New Wells in Big Chino @ 16.6 cfs, Starting 2020 & continuing until 2110 relative to 2005
Total potential reduction 2005 - 2110
*Assuming 1910 flow of 25.7 and 2005 flow of 19 cfs


Projections
Groundwater Elevation vs Time
Well (B-15-02)13CCB NW Prescott Airport
Year
Groundwater Elevation (ft asl)
ground surface 4956 ' asl
Change = 25 ft.
bottom of well 4496 ' asl
Continued 2005 Pumping
Model wide pumping increase of 3%/decade
Observed



Projected
Cumulative Regional Decrease in Groundwater Elevation Between 2005 and 2110

Calculated combining all cases

CONCLUSIONS

- Forward-looking simulations using the NARGFM show that the cumulative effect of increased water demand, continuing drought, and extraction of 12,000 ac-ft/yr (16.6 cfs) of groundwater from the Big Chino, will decrease the base flow to the Verde River by 12.8 cfs at the Paulden streamgage by the year 2110.
- Since the base flow at the Paulden streamgage in 2005 was approximately 19 cfs, this would leave only 6.2 cfs in the river.
- Sierra Club seepage runs for 2007 through 2010 show additional decreases of between 2 and 9 cfs between the Paulden and Perkinsville Bridge streamgages*. Thus, it is likely that part of the Upper Verde River near and above Perkinsville would be dry by 2110 based on the cumulative effects discussed above.
- Groundwater level decreases greater than 100 ft. will occur in several areas.

**Seepage run data supplied by G. Beverly.*