INTRODUCTION

• Model development at Temple
  ➢ A long history (1937-present)
  ➢ Many scientists participating in:
    Data collection
    Component construction
    Structural design
    Validation
    Application
# TEMPLE MODELING GROUP

<table>
<thead>
<tr>
<th>Name</th>
<th>Role/Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jimmy Williams</td>
<td>Systems modeling &amp; EPIC/APEX dev. (1965)</td>
</tr>
<tr>
<td>Jeff Arnold</td>
<td>SWAT developer (1983)</td>
</tr>
<tr>
<td>Jim Kiniry</td>
<td>ALMANAC developer (1980)</td>
</tr>
<tr>
<td>Paul Dyke</td>
<td>Agricultural Models (1987)</td>
</tr>
<tr>
<td>Cole Rossi</td>
<td>SWAT developer/support (2004)</td>
</tr>
<tr>
<td>Raghavan Srinivasan</td>
<td>GIS Specialist &amp; SWAT interface developer (1992)</td>
</tr>
<tr>
<td>Armen Kemanian</td>
<td>Cropping systems modeling (EPIC/APEX) (2006)</td>
</tr>
<tr>
<td>Ken Potter</td>
<td>Soil Scientist (1989)</td>
</tr>
<tr>
<td>Tim Dybala</td>
<td>NRCS Civil Engineer (WRAT Team) (1992)</td>
</tr>
<tr>
<td>Jay Atwood</td>
<td>NRCS Economist (1991)</td>
</tr>
<tr>
<td>Name</td>
<td>Position</td>
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<tr>
<td>Mike White</td>
<td>SWAT development/support</td>
</tr>
<tr>
<td>Santhi Chinnasamy</td>
<td>Hydrologic modeling/SWAT (1998)</td>
</tr>
<tr>
<td>Mauro Diluzio</td>
<td>Hydrology/GIS modeling (1997)</td>
</tr>
<tr>
<td>Carl Amonett</td>
<td>NRCS Soil Conservationist (WRAT Team) ()</td>
</tr>
<tr>
<td>Todd Marek</td>
<td>NRCS Civil Engineer (WRAT Team) (2005)</td>
</tr>
<tr>
<td>Nancy Sammons</td>
<td>SWAT User support (1973)</td>
</tr>
<tr>
<td>Georgie Mitchell</td>
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<tr>
<td>Evelyn Steglich</td>
<td>EPIC/APEX User support/training (1997)</td>
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<tr>
<td>Avery Meinardus</td>
<td>Programmer (1994)</td>
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<tr>
<td>Name</td>
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<tr>
<td>Larry Francis</td>
<td>Program Analyst</td>
</tr>
<tr>
<td>Bill Komar</td>
<td>Database administration</td>
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<tr>
<td>Paul Duckworth</td>
<td>GIS specialist</td>
</tr>
<tr>
<td>Melanie Magre</td>
<td>Interface manual editor</td>
</tr>
<tr>
<td>Theresa Pitts</td>
<td>Programmer</td>
</tr>
<tr>
<td>Shawn Quisenberry</td>
<td>Program analyst</td>
</tr>
<tr>
<td>Deborah Spanel</td>
<td>Biological Science Tech/ALMANAC</td>
</tr>
<tr>
<td>Jaehak Jeong</td>
<td>Hydrologic modeling</td>
</tr>
</tbody>
</table>
INTRODUCTION

TEMPLE MODELS

• ALMANAC, EPIC, APEX, SWAT
  – Operate on spatial scales ranging from individual fields to river basins
  – Daily time step
  – Continuously updated and improved as a result of user interaction and feedback
PARTICIPATION IN OTHER MODEL DEVELOPMENT

• GLEAMS
• SPUR
• WEPP
• WEPS
• NLEAP
APEX
AGRICULTURAL POLICY / ENVIRONMENTAL EXTENDER MODEL

- Whole farm/watershed scale
- Subarea component (EPIC)
- Routing (water, sediment, nutrients, pesticides)
- Groundwater & reservoir
- Feedlot dust distribution
- Daily time step
- Capable of simulating 100’s of years
- (2000)
The EPIC MODEL

- Weather
- Hydrology
- Erosion (wind & water)
- Carbon
- Nutrients (N, P, & K)
- Pesticides
- Salinity
- Crop Growth
- Tillage
- Grazing
- Manure Management
- Economics
WEATHER

- Measured or Simulated
- Temperature (Max and Min)
- Precipitation
- Radiation
- Relative humidity
- Wind speed and direction
WEATHER SIMULATION

- WXGN
  - Stand alone weather generator built into EPIC

- WXPM
  - Stand alone program for computing monthly input statistics
<table>
<thead>
<tr>
<th>TX1007.INP</th>
<th>STATION = BRACKETT  STA ID = 1007  STATE = TX  CO = KINNEY</th>
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<td>29.317  LONG - -100.414  ELEV - 340.7  Y-M-D 2008 528</td>
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<td>17.34  20.23  23.92  28.33  31.04  33.90  35.18  35.18  32.62  27.88  22.39  18.24  TMX</td>
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<td>0.070  0.073  0.065  0.063  0.118  0.092  0.053  0.072  0.117  0.084  0.068  0.070  PWJD</td>
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<td>0.239  0.333  0.279  0.317  0.244  0.329  0.448  0.298  0.282  0.377  0.279  0.218  PWJR</td>
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</table>
WEATHER SIMULATION

• MODAWTHC
  – Stand alone program for converting monthly precipitation to daily
    • Inputs (for each year of record)
      – Monthly maximum temperature
      – Monthly minimum temperature
      – Monthly precipitation
      – Average number of wet days per month
    • Outputs
      – Daily weather file
      – WPM1 file
EPIC WEATHER GENERATOR (WXGN)

- Precipitation
  - Rainfall
    - Occurrence
      - Generated random number compared with wet-dry probabilities
    - Amount
      - Generated from skewed normal distribution
      - Generated from modified exponential distribution
Root Zone

Shallow (unconfined) Aquifer

Vadose (unsaturated) Zone

Hydrologic Balance

Evaporation and Transpiration

Precipitation

Infiltration/plant uptake

Surface Runoff

Lateral Flow

Percolation to shallow aquifer

Return Flow

Deep percolation
HYDROLOGY

• Surface Runoff

• Volume
  – SCS curve number
  – Green & Ampt

• Peak rate
  – Modified rational
  – SCS TR-55
Curves on this sheet are for the case \( \lambda = 0.2S \), so that
\[
Q = (P - 0.2S)^{0.5}
\]
<table>
<thead>
<tr>
<th>Land use</th>
<th>Cover Treatment or practice</th>
<th>Hydrologic condition</th>
<th>Hydrologic soil group</th>
<th>Land Use Number</th>
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<tr>
<td>Fallow</td>
<td>Straight row</td>
<td>----</td>
<td>A  77</td>
<td>B  86</td>
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<tr>
<td>Row crops</td>
<td>Straight row</td>
<td>Poor</td>
<td>72</td>
<td>81</td>
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<tr>
<td>&quot;</td>
<td>Good</td>
<td>67</td>
<td>78</td>
<td>85</td>
</tr>
<tr>
<td>Contoured</td>
<td>Poor</td>
<td>70</td>
<td>79</td>
<td>84</td>
</tr>
<tr>
<td>&quot;</td>
<td>Good</td>
<td>65</td>
<td>75</td>
<td>82</td>
</tr>
<tr>
<td>Contoured &amp; terraced</td>
<td>Poor</td>
<td>66</td>
<td>74</td>
<td>80</td>
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<tr>
<td>&quot;</td>
<td>Good</td>
<td>62</td>
<td>71</td>
<td>78</td>
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<tr>
<td>Small grain</td>
<td>Straight row</td>
<td>Poor</td>
<td>65</td>
<td>76</td>
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<tr>
<td>&quot;</td>
<td>Good</td>
<td>63</td>
<td>75</td>
<td>83</td>
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<tr>
<td>Contoured</td>
<td>Poor</td>
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<td>Good</td>
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<td>Contoured &amp; terraced</td>
<td>Poor</td>
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<td>&quot;</td>
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<td>59</td>
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<tr>
<td>Close-seeded legumes or</td>
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<td>Poor</td>
<td>66</td>
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<tr>
<td>rotation meadow</td>
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<td>Good</td>
<td>58</td>
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<td>Contoured</td>
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<td>&quot;</td>
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<td>51</td>
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<td>Pasture or range</td>
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<td>&quot;</td>
<td>Fair</td>
<td>49</td>
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<td>Fair</td>
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<td>&quot;</td>
<td>Good</td>
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<tr>
<td>Meadow</td>
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<tr>
<td>Woods</td>
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<td>Fair</td>
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<td>Good</td>
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<td>Farmsteads</td>
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<td>Roads (dirt)</td>
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<td>72</td>
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<tr>
<td>(hard surface)</td>
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<td>Sugarcane</td>
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<td>Impervious (Pavement, urban area)</td>
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<td>98</td>
<td>98</td>
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</tbody>
</table>

1 Close-drilled or broadcast.  
2 Including right of way.  

Taken from the National Engineering Handbook  
HYDROLOGY

Sub Surface Flow

• Root Zone
  - Lateral
    ✓ Flow to down stream subarea
    ✓ Quick return flow
    ✓ Pipe flow
  - Percolation to shallow groundwater

• Ground Water
  - Water table Dynamics
  - Return Flow
  - Deep Percolation
HYDROLOGY

• Evapotranspiration
  – PET Equations
    • Penman
    • Penman-Montieth
    • Priestley-Taylor
    • Hargreaves
    • Baier-Robertson
EROSION

• Water
  – USLE
  – USLE modifications
    ✓ MUSLE
    ✓ Onstad-Foster
    ✓ RUSLE

• Wind
  – Manhattan, KS with Bagnolds energy equation
CARBON-NITROGEN TRANSFORMATIONS

EPIC/CENTURY

- Pools
  - Structural litter (1 year)
    - Has a fixed C/N ratio
  - Metabolic litter (<1 year)
    - Contains all the lignin from plant residues and roots
    - Made up of readily decomposable and water soluble organic matter
  - Biomass (<1 year)
    - Soil microbial biomass
  - Slow humus (5 years)
    - Soil organic matter which decomposes at rates intermediate to the microbial and passive humus components
  - Passive humus (200+ years)
    - Composed of old or stable soil organic matter
CARBON

Potential transformations
• Regulated by
  – Moisture
  – Temperature
  – Tillage/compaction
  – Oxygen
• Actual transformations
  – Regulated by
  – Nitrogen availability
  – Mineralization-Immobilization
• Losses
  – Respiration
  – Erosion
  – Runoff/leaching (soluble)
NUTRIENTS

• Nitrogen
  – Surface runoff
    ▪ soluble and adsorbed
  – Subsurface flow
    ▪ lateral and vertical
  – Mineralization
  – Immobilization
  – Denitrification
  – Volatilization
  – Nitrification
  – Crop uptake
NUTRIENTS

• Phosphorus
  – Surface runoff
    ▪ soluble and adsorbed
  – Leaching
  – Mineralization
  – Immobilization
  – Adsorption-desorption
  – Crop uptake
PESTICIDE FATE
GLEAMS

- Surface runoff
  - soluble and adsorbed

- Leaching

- Degradation
  - from foliage and soil

- Washoff from plants
  - rainfall or irrigation
TILLAGE

Functions

- Mixing
- Surface roughness
- Ridge interval and height
- Conversion from standing to flat residue
PLANT GROWTH

• Simulates about 100 crops

• Potential daily growth
  – based on radiation and leaf-area-index

• Actual daily growth constrained by stresses:
  – Water
  – Temperature
  – Nutrients
  – Aeration

• CO2 affects
  – growth and water use
PLANT COMPETITION

• Developed in ALMANAC model (Kiniry, et al.)
• Up to 10 crops growing in the same space
• Competing for
  – Light-function of LAI and height
  – Water
  – Nutrients
• Any combination of plants, trees, brush, weeds, grasses, or field crops
APEX

- Management capabilities
  - Irrigation
  - Drainage
  - Furrow diking
  - Buffer strips
  - Terracing
  - Waterways
  - Fertilization
  - Manure management
  - Lagoons
  - Reservoirs
  - Crop rotation and selection
  - Pesticide application
  - Grazing
  - Tillage
ECONOMICS

Cost and income accounting
ROUTING COMPONENT

• Water
  – Overland flow
  – Channel
  – Floodplain
  – Sub-surface

• Sediment
  – Modified Bagnolds stream power
  – Deposition – degradation
    ▪ Overland flow
    ▪ Channel
    ▪ Floodplain
**ROUTING COMPONENT**

- Nutrients and pesticides
  - Soluble materials considered conservative
  - Adsorbed materials sediment transported
  - Enrichment ratio concept
APEX

• Applications
  – Evaluate effects of global climate/CO$_2$ changes
  – Design environmentally safe, economic landfill sites
  – Design biomass production systems for energy
  – Livestock farm and nutrient management (manure and fertilizer)
  – Forest management
  – Evaluate effects of buffer strips nationally
  – Simulate runoff, erosion/sediment yield, nutrient and pesticide losses from cropland
New EPIC/APEX Developments
CENTURY CARBON

- Replaced previous mineralization-immobilization component with CENTURY equations.
- Tested with several data sets and reported by Izaurralde.
- Used in National CASMGS runs by Jay Atwood (NRCS).
- Used in National CEAP runs by Jay Atwood.
GIS EPIC recently developed by Junguo Liu (Switzerland/China).

Used to simulate and map world wide crop yields.
CroPMan and WinEPIC

- Windows interfaces for EPIC developed at Temple (Gerik and Harman)

- CroPMan is most useful for individual farm crop productivity and was designed for use by crop consultants and extension specialists.

- WinEPIC is more general--useful in solving a range of problems. It was designed for use by researchers and individuals with a greater understanding of crop physiology and related processes.
HAIL OCCURRENCE/DAMAGE COMPONENT

- Developed the hail model as a part of EPIC in cooperation with Drs. Wang and Little of Tarleton State University.
- Model simulates hail occurrence based on daily probabilities.
- Simulates hail damage based on long-term means and standard deviations.
- The model was applied to the state of Kansas and produced realistic results for five major crops in all nine districts of the state.
- Developed for use in crop insurance.
SOUTHERN OSCILLATION INDEX WEATHER SIMULATOR

• EPIC weather simulator has the option to consider the five phases of the SOI in generating rainfall.

• The model generates from one of five monthly weather parameter files depending on the phase of the SOI.

• Particularly useful in drought studies and real time simulation.
EPIC DYNAMICS--SOIL, ATMOSPHERIC CO₂, TECHNOLOGY

- Rawls equations use to calculate field capacity and bulk density as carbon changes.
- Soil layer thickness changes as bulk density/carbon change.
- Atmospheric CO₂ changes with time--Izaurralde.
- Developed a linear technology change that affects the crop harvest index.
- All of these relationships can be set static or dynamic.
• Drip irrigation was added as an another irrigation option.
• Water is applied automatically at a specified soil depth.
• Rice paddys--constructed as large furrow dike. Puddling operation added (reduces saturated conductivity of second soil layer).
• Plastic mulch cover added--reduces evaporation; increases runoff.
• Automatic mowing operation added--lawns and golf courses.
THE GRAZING COMPONENT

• Subareas identified by owner.
• Owner may have livestock and poultry (up to ten herds)
• Herd attributes
  – Forage intake rate
  – Grazing efficiency
  – Manure production rate
  – Urine production rate
  – C and soluble and organic N and P fractions in the manure.
CONFINED AREA FEEDING

• Feed area may contain cattle, hogs, poultry, etc.

• Daily manure production is partitioned between liquid and solid.

• Manure applied automatically
  – From lagoons to liquid application fields.
  – From stockpile to solid application fields.
MANURE EROSION

- \( YMNU = 0.25 \times (Q \times q_p)^{0.5} \times PE \times SL \times RSDM^{0.5} \times \exp(-0.15 \times AGPM) \)
APEX FLOOD ROUTING

- Added hydrograph development and flood routing component.
- Uses a storage depletion method for hydrograph development and the variable storage coefficient flood routing method.
- Hydrographs are routed at any user selected time interval.
- Provides for stream flow simulation not just daily water yield. This feature allows operation on much larger watersheds than previous versions.
- Hydrographs provide potential increased accuracy for routing sediment, nutrients, and pesticides.
APEX SPATIAL RAINFALL SIMULATOR

- Generates storm centroid (draws uniform random number on X and Y axis).
- Generates rainfall amount from parameters of station nearest storm centroid.
- Rainfall amounts of other subareas a function of distance from storm centroid, rainfall duration, and N-S and E-W gradients.
- Final rainfall amounts adjusted with stochastic component.

FIG. 7. (b) Annual average predicted precipitation in the period 1960-2001.
SPATIAL RAINFALL GENERATOR

Watershed

- Represent Weather Stations (wp1)
- Storm centroid
APEX PLAYA RESERVIORS

- Worked with researchers at Texas Tech University in developing APEX reservoir component for application to playas.
- Playas have no spillways--losses are from evaporation and seepage.
- Modified model to reduce storage with deposited sediment.
- Used to determine water availability for ducks and geese.
APEX POINT SOURCES

• A point source can be entered in each subarea.

• Inputs are daily flow and soluble N and P.
RUSLE2

- A modified version of RUSLE2 was added to EPIC and APEX.

- The RUSLE2 slope length equation performed well on steep slopes in China.

- The RUSLE2 C factor equations simulate erosion realistically over a range in tillage (no till/conventional till).
FEEDLOT DUST COMPONENT

- Dust emission
  - Stocking rate
  - Moisture content

- Dust distribution
  - Wind speed
  - Wind direction
  - Distance from feedlot
  - Angle relative to wind direction
DUST DISTRIBUTION

Wind Direction

Feedlot

Dust distribution