MEDLI®

Technical Description
Version 1.3 - 2012

MODEL FOR EFFLUENT DISPOSAL USING LAND IRRIGATION

CRC FOR WASTE MANAGEMENT & POLLUTION CONTROL LTD

Queensland Government
Natural Resources Mines and Water
Department of Primary Industries

OVERVIEW

MEDLI® is a Windows® based computer model for designing and analysing effluent disposal systems for intensive rural industries, agri-industrial processors (e.g. abattoirs) and sewage treatment plants using land irrigation. It was developed jointly by the CRC for Waste Management and Pollution Control, the then Queensland Department of Primary Industries, and Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the mid-1990s. Version 1.3 was released in March 1999.

MEDLI models the effluent stream from its production in an enterprise through to the disposal area and predicts the fate of the water, nitrogen, phosphorus, and soluble salts. MEDLI is very flexible and can handle a wide range of industries such as piggeries, feedlots, abattoirs, sewage treatment plants, and dairy sheds, as well as any user-defined waste stream such as a food processing factory.

CLIMATE DATA

MEDLI requires daily time series climate data for
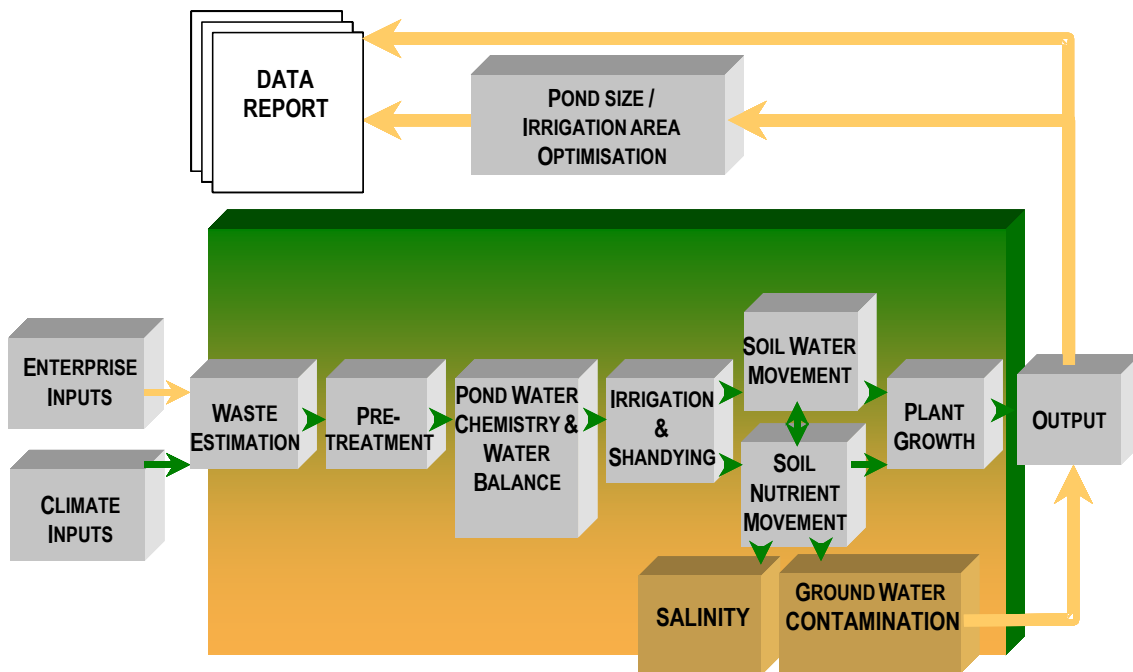
Modular structure of MEDLI

estimating crop water requirements, simulating crop growth and carrying out water balance computations. The data required are rainfall, temperature, Class A pan evaporation and solar radiation. Concurrent sequences of data for all the climatic variables are generally not available at sites where intensive rural industries (*e.g.* piggeries, feedlots, abattoirs) may be proposed. Long time sequences (e.g. ≥40 years) are needed to capture the effect of climatic variability.

To assist MEDLI users in obtaining weather data, a number of options are listed below:

- Queensland Climate Change Centre of Excellence (QCCCE) supplies data derived from interpolation of daily climatic surfaces for any location in Australia. Data files can be obtained either in MEDLI format from the DERM or can be purchased directly from QCCCE via the World Wide Web at http://www.longpaddock.qld.gov.au/silo/ and converted into MEDLI format using a climate conversion program supplied with MEDLI.

- Alternatively, users can contact the Bureau of Meteorology for the required data (not in MEDLI format) or input their own weather data into MEDLI.

WASTE ESTIMATION

The waste estimation component of MEDLI generates, for a given industry, the daily composition and volume of effluent before pretreatment, storage or irrigation.

User-defined Enterprise

The simplest MEDLI waste estimation module uses measured waste stream details. Temporal variation in waste stream characteristics may be assigned monthly or seasonally, or for any other nominated periods, including single days. The user could enter different waste stream details for every day if the data is available. MEDLI assumes these details then apply for every year of the simulation.

MEDLI also contains more complex modules for **estimating** waste streams for the following enterprises:
- Piggeries
- Feedlots
- Dairies

For all enterprises, MEDLI generates the following waste stream details on a daily basis:
- Volume (megalitres)
- Total Solids (TS) (mg/L)
- Volatile Solids (VS) (mg/L)
- Total Nitrogen (N) (mg/L)
- Total Phosphorus (P) (mg/L)
- Potassium (K) (mg/L)
- Total Dissolved Salts (TDS) (mg/L)

The waste stream can have a solids screening process applied, with the user having the option for overriding the default nutrient and solids removal percentages for the process.

For the STP, the relative rate of infiltration into the sewerage system during wet weather is taken into account when estimating daily effluent values.

Piggery

The composition and quantity of effluent that a piggery produces depends on a number of factors. These include:
- Ration fed to the pigs
- Age and weight of the pigs
- Amount of spilt feed and water
- Quantity of water used for flushing and cleaning
- Quality of waters used in the piggery
- Use of recycled effluent for flushing
- Methods of handling and treating the manure prior to disposal or use

MEDLI uses the Digestibility Approximation of Manure Production (DAMP) (Barth, 1985a) to predict the total solids and volatile solids in the manure of pigs fed diets of known composition.

A mass balance approach similar to that in the PIGBAL model (Casey *et al.,* 1996) is used to calculate nutrient and salt contents in the effluent.

The diet details, potable water quality and consumption, and herd composition are used to estimate the TN, TP, K and TDS contributed by each class of pig to the total daily waste stream. The herd composition is calculated indirectly from the production performance of the piggery. For Farrow to Finish units and Breeder units, MEDLI uses algorithms contained in the PIGBAL model. A user defined percentage of the total nitrogen excreted is assumed to volatilise from the shed.

To predict the overall volume of effluent from the piggery, the model requires the average flushing and hose down requirements per pig.

Technical / Waste Estimation / Piggery / Water Details

Potable Water Characteristics

Conductivity (dS/m)	1.00
Total Dissolved Salts (mg/L)	640
Total Nitrogen (mg/L)	0

Daily Cleaning Requirements (L)

	per Pig	Total
Total Flush Water	29.0	310677
Recycled Flush Water	23.2	248542
Hosedown	5.0	53565

Salinity Management of Anaerobic Pond

Conductivity (dS/m) at which use of recycled flushing water ceases	12.0
Conductivity (dS/m) at which use of recycled flushing water resumes	8.0

Daily Intake (L/head)

Sucker	1.0
Weaner	3.0
Grower	4.0
Finisher	8.0
Lac. sow	27.5
Dry sow	14.0
Gilt	12.0
Boar	14.0

Herd Intake (L/day)	60972
Herd Intake (ML/year)	22.27

Feedlot (*not activated in v1.3*)

Feedlots can be described in MEDLI using the Waste Estimation option. The feedlot model in MEDLI predicts the quantity and quality of the runoff entering the holding pond following rainfall. Design of a feedlot in MEDLI is very flexible with provision for selecting different herd compositions, diets, stocking density, pen configurations, and manure harvesting rates.

In addition to daily manure and nutrient outputs, daily time-series hydrology data relating to the feedlot catchment are generated. Daily data is generated for the first pen, and average data across all pens. The advantage in being able to focus on the behaviour of a representative pen is that the user can monitor the manure depth, nutrients, solids and moisture dynamics within the feedlot pad under any manure harvesting regime. The pad moisture content is of particular importance for odour modelling. Other important daily outputs are the runoff volume and the nutrient and salt concentrations in the runoff.

The feedlot summary report includes information on annual runoff, harvesting rates and average pad nutrient and dry matter composition.

Technical / Waste Estimation / Feedlot

Technical Data Categories: Herd >>, Management >>, Rations >>, Pens and Balance Area >>, Potable Water >>, Pad Properties >>, Nutrients in Cattle >>, Manure Details >>, Waste Decomposition >>

Technical / Waste Estimation / Feedlot / Herd

		Licenced Capacity (SCU)	10000	Total Mean No. of animals on Hand	7966
		Annual Mortality (%)	0.50		

	Market#1	Market#2	Market#3	Market#4
Percent of total SCU	70	20	10	0
SCU conversion	1.123	1.000	0.806	0.806
Maximum Head	8908	10000	12408	12408
Mean Occupancy (%)	80	90	95	95
Mean No. on Hand	4988	1800	1178	0
Entry Weight (kg)	450	320	280	280
Exit Weight (kg)	700	600	450	450
Daily Gain (kg/head)	1.40	1.60	1.70	1.70
Feeding Period (days)	178	174	99	99

Technical / Waste Estimation / Feedlot / Herd

		Licenced Capacity (SCU)	10000	Total Mean No. of animals on Hand	7966
		Annual Mortality (%)	0.50		

	Jap. Ox	Korean	Domestic	Other
Percent of total SCU	70	20	10	0
SCU conversion	1.123	1.000	0.806	0.806
Maximum Head	8908	10000	12408	12408
Mean Occupancy (%)	80	90	95	95
Mean No. on Hand	4988	1800	1178	0
Entry Weight (kg)	450	320	280	280
Exit Weight (kg)	700	600	450	450
Daily Gain (kg/head)	1.40	1.60	1.70	1.70
Feeding Period (days)	178	174	99	99

kg Holstein cows (Van Horn, 1994). These base estimates are scaled by the average liveweight of the cow and the time spent in the shed's hosedown area (usually 10%) to arrive at the nutrient and salt masses entering the pond system.

Technical / Dairy

Herd Parameters

No. of Cows Milked Daily	80
Average Liveweight (kg/cow)	635
% of Manure Excreted in Area to be Washed Down	10
Surface area contributing extra runoff from rainfall (m2)	

Water Details >> Effluent Details >>

Sewage Treatment Plant

This module requires the waste stream characteristics of the average dry weather flow volume following secondary treatment. MEDLI does not have the ability to predict the incoming effluent's characteristics nor the primary and secondary treatment processes. The average dry weather flow (ADWF) is dynamically adjusted according to the rainfall on that day and 5 preceding days and the relative infiltration efficiency rate into the sewerage system to calculate the new wet weather volume (Anderson and Ruge, 1994), and the concentrations entering the pond system.

The average dry weather flow details cannot be altered on a day to day or periodic basis, i.e. they remain constant for the entire simulation period. The modelled flow will never drop below ADWF and will only increase following rainfall events. There is no provision in the model to cope with expanding or fluctuating populations and associated changes in the effluent volume.

While rainfall events are used to adjust the volume of effluent treated, it is assumed the infiltration process contributes no additional nutrients or TDS.

POND CHEMISTRY AND WATER BALANCE

MEDLI's pond module is a modified version of a design model for treating pig wastes (Casey, 1995). The module consists of mass balances for the hydraulic, nitrogen, phosphorus, potassium and total dissolved salts components. It uses a number of empirically derived relationships. The model allows for up to four effluent ponds in series.

Nutrients in the incoming mass are partitioned between the sludge and the supernatant, and a transfer coefficient is used to estimate the nitrogen volatilisation from the pond surface.

The pond module's function is to predict water levels and nutrient and salt concentrations. A nominated pond can be used for recycling purposes and the last pond may be used for irrigation purposes.

Nitrogen loss via NH_3 volatilisation is most sensitive to lagoon surface area, whilst phosphorus, potassium and total dissolved salt concentrations in the supernatant are most affected by the amount of evaporation relative to rainfall and effluent recycling for shed flushing.

Anaerobic lagoons are commonly used as a component of the effluent management systems for intensive pig production, abattoirs, dairies and feedlots. In MEDLI, only the first pond can be anaerobic and as a consequence it accumulates sludge, and nutrients in the sludge. Subsequent ponds, regardless of their classification (e.g. facultative, aerobic or wet weather storage), do not accumulate sludge, do not calculate oxidation of nitrogen to nitrate, but do estimate NH_3 volatilisation.

Particular attention is paid to the Volatile Solids loading rate to the anaerobic pond, as this has been found to be closely related to odour nuisance (Barth, 1985b). The allowable loading rate is responsive to seasonal variations in air temperature. MEDLI uses the VS loading rate to estimate the optimal active volume required. Total solid loading rate (i.e. volatile and fixed solids) affects the rate of sludge accumulation in the anaerobic pond.

Once the active treatment volume of the anaerobic pond falls below a certain fraction of the design volume, the pond must be desludged.

Pond Water Balance

The pond water balance is calculated as a function of new inflow (i.e. rainfall and fresh effluent) and new outflow (i.e. evaporation, irrigation, seepage and overtopping). Effluent used for recycling is assumed to have no net effect on the pond level. Evaporation is calculated from Class A pan evaporation and a pond evaporation factor (e.g. Watts and McKay, 1986) whilst irrigation

extraction is determined by irrigation demand of the reuse area.

Leakage from the pond occurs at a user defined rate (usually equal to saturated hydraulic conductivity of the clay liner), whilst overtopping occurs when pond water level reaches the overflow pipe. Pond water level is adjusted by the net input/out volumes and pond geometry (e.g. trapezoidal cross section).

Ponds are hydraulically linked via passive overflow pipes and the major variation in pond level is usually restricted to the last pond in the series (the wet weather storage lagoon). Overtopping frequency and volume is a major output from this module.

IRRIGATION AND SHANDYING

The irrigation module calculates an irrigation demand based on soil water condition and crop water requirement. Whether this irrigation demand is applied is determined by limitations in the irrigation system and water availability. Availability of water is governed by the amount of water in the wet weather storage pond and by the availability of an external water source (shandying water).

Irrigation can be triggered as a daily amount, a given soil water deficit or a given percentage of the plant available water capacity. The latter two triggers are updated daily in the soil water balance module. A range of irrigation systems can be defined which influence the maximum irrigation rate possible (ML/ha/day) and the volatilisation loss of ammonia from the effluent during irrigation.

The shandying module enables the use of an external water source for the purpose of increasing the supply and quality of the irrigation water. This external source of water can be introduced when there is insufficient water in the storage pond and/or the effluent, or the pond effluent has too high a salinity and/or nitrogen concentration for sustainable irrigation.

SOIL WATER MOVEMENT

Modelling of the movement of water from irrigation and rainfall through the soil is a key part of the MEDLI program, ultimately determining irrigation frequency, pond overtopping, plant growth, nutrient and salt movement.

Soil Water Balance

Soil water movement is simulated as a one-dimensional (vertical) water balance, averaged over a field sized area. The water balance component was taken from PERFECT (Littleboy *et al.,* 1989, 1992) which was based on the Williams and LaSeur (1976) and Ritchie (1972) water balance models as used in CREAMS (Knisel, 1980) and similar models.

The soil profile has a maximum of four user defined layers of variable thickness, with each layer assigned an air dry component, lower storage limit, upper storage limit, total porosity, bulk density and saturated hydraulic conductivity. Soil water of each soil layer is updated on a daily basis by computing rainfall, irrigation, runoff, soil evaporation, transpiration and drainage.

Technical / Soil Water Parameters

Soil Profile Type: Krasnozem   No. of Layers: 4

Soil Layer Parameters

Layer	1	2	3	4
Soil Layer Thickness (mm)	100	500	600	800
Air Dry (% v/v)	4.2			
Lower Storage Limit (% v/v)	25.5	27.9	29.0	29.0
Drained Upper Limit (% v/v)	41.2	37.3	39.0	41.8
Plant Available Water Capacity (mm)	15.7	47.0	60.0	102.4
Saturated Water Content (% v/v)	46.6	49.8	50.6	52.7
Bulk Density (g/cc)	1.40	1.32	1.30	1.24
Porosity (% v/v)	47.2	50.2	50.9	53.2
Saturated Hydraulic Conductivity (mm/hr)	50.000	10.000	10.000	10.000

OK   Cancel   Help

Runoff and Evaporation Parameters

Curve No.	78
Stage I Drying Maximum(mm)	6.0
Slope of Stage II Drying (mm/day^0.5)	3.5

Soil Temperature Scalars

Lag	0.70
Wet Day Factor	0.50
Albedo	0.23

Runoff/Infiltration

Irrigation is assumed to infiltrate the soil surface with no runoff. Runoff from rainfall is predicted using the Curve Number technique (USDA-SCS, 1972) and is calculated as a function of daily rainfall, soil water deficit, plant total cover and the user-defined Curve Number.

Evaporation

Soil evaporation is based on a two stage evaporation algorithm by Ritchie (1972) as modified in PERFECT (Littleboy *et al.*, 1989). Stage 1 drying equals the potential evaporation rate (i.e. demand limited) and continues until the cumulative amount evaporated exceeds a user-defined limit. Stage II drying is a soil supply rate limited process, with the rate of evaporation proportional to the square root of time. This rate is calculated from another user-defined parameter. Both parameters are related to soil texture. Evaporation will remove soil water from the two upper profile layers until the top layer reaches its air dry moisture content and the second layer reaches its lower storage limit.

Transpiration

Plant transpiration is determined from soil water content, plant canopy cover and Class A pan evaporation. The potential transpiration demand is estimated as the product of canopy cover, daily pan evaporation and user-defined maximum crop coefficient. The plant will transpire this amount unless limited by its ability to extract water from the soil profile (potential extraction rate). Transpiration is partitioned across the different soil layers within the root zone such that the pattern of extraction favours the wetter layers, and only involves those layers with available soil water.

Deep Drainage

When a soil profile layer is above its defined Upper Storage Limit (i.e. Field Capacity) following an infiltration event, it is assumed that drainage occurs from this layer. The drainage algorithm from EPIC (Sharply and Williams, 1990) is used to predict the proportion of the drainable water (in excess of the Upper Storage Limit) that will drain on a particular day. The most important parameters are drainable porosity and saturated hydraulic conductivity. Under profile saturated conditions, drainage can also occur by saturated flow. The amount that can be infiltrated in one day is equivalent to half the saturated hydraulic conductivity. When a saturated profile cannot repartition all the predicted infiltration into saturated drainage, the excess is routed as runoff.

SOIL NUTRIENT MOVEMENT

Soil Nitrogen

Modelling the nitrogen cycle is important for sustainable design of effluent reuse schemes because nitrate ions are very mobile and can degrade the quality of groundwater. The total amount of nitrogen applied must be accounted for in crop uptake, denitrification, volatilisation, seepage to groundwater, and storage in the soil.

MEDLI has adopted a simplified approach to modelling the nitrogen dynamics in the soil on a daily timestep. Organic N and ammonium N has been assumed to be immobile, and to remain in the top soil layer. On conversion to nitrate, nitrogen can be leached with the drainage water to the lower profile layers, and into the groundwater. Only the irrigated organic N is considered to be highly labile and is mineralised at a high rate. The soil organic N initially present is considered to be less labile and is mineralised at a slower (user-specified) rate. The low C:N ratio of the effluent (usually 10 to 12) generally results in mineralisation reactions predominating over immobilisation reactions. Hence, no immobilisation of ammonium is assumed to occur.

The transformation of nitrogen from one form to another is based on first-order kinetics (adapted from HSPF) and a Michaelis-Menten function

(adapted from CERES-MAIZE). The user need only specify a rate of mineralisation of the soil organic N initially present, and the denitrification rate. Following CERES-MAIZE (Jones and Kiniry, 1986), the nitrification rate is predicted from the varying concentration of ammonium in the soil solution and a Michaelis-Menten type function with fixed parameter values (Godwin and Jones, 1991). These transformation rates are modified for the temperature and soil moisture status of the soil on any given day. The impact of carbon content and pH has not been included in MEDLI, although the transformation rates used may be modified to account for the expected mean pH and organic content of the soil of interest.

Soil Nitrogen Movement

Only nitrogen in the nitrate form is assumed to be potentially mobile. Nitrate may be denitrified and lost to the atmosphere as gaseous N, or it may be leached to lower soil profile layers. Leachate entering a soil layer is assumed to mix completely with the soil solution. The amount of nitrate that leaches from that layer is the product of the amount that is drained from that layer into the layer below (determined in the soil water balance module) and the nitrate concentration of the soil solution mix.

Ammonia volatilisation is only assumed to occur during the actual irrigation event. Once infiltrated into the soil, volatilisation losses from effluent are assumed to be negligibly small (Thompson *et al.,* 1987).

Phosphorus

Modelling of the phosphorus in soils is important for the sustainable reuse of effluent to ensure that the phosphorus holding capacity of the soil is not exceeded. Levels of soil phosphorus in excess of the soil's phosphorus holding capacity may result in seepage of phosphorus to groundwater, and high levels of phosphorus in runoff.

Phosphorus is supplied in the irrigation water as dissolved phosphorus, i.e. in the ionic form orthophosphate. Following the application of the effluent some of the phosphorus will be adsorbed to the soil, and some of the phosphorus is taken up by plants. The relative amount of phosphorus adsorbed to the soils and the phosphorus in solution depends on a number of factors (Barrow, 1983) including: soil type, iron and aluminium, oxides, pH of soil water, electrolyte composition of soil water, reaction time, soil temperature, phosphorus concentration in the soil water, soil phosphorus concentrations, and plant uptake requirements.

Phosphorus applied with irrigation water is partitioned between the solute phase and the adsorbed phase as determined by an adsorption isotherm. The adsorption isotherm is a function describing the equilibrium relationship between concentrations of the solute and adsorbed phases. Following the HSPF model, (Johnson *et al.*, 1984) we use the Freundlich form of the isotherm.

When phosphorus is applied in irrigation, the solute phosphorus level initially increases. The model determines the total amount of phosphorus in the solute and adsorbed phases, and redistributes the phosphorus such that their respective concentrations both lie on the isotherm.

Conversely, when the concentration in the solute phase is decreased by dilution as a result of rainfall infiltration, or removal by plant uptake, there will be desorption of phosphorus from the adsorbed phase into the solute phase.

MEDLI simulates the movement of phosphorus through a soil profile by modelling adsorption of phosphorus to soil particles, desorption of phosphorus into soil water, and plant uptake of phosphorus.

The amount of phosphorus leached through the soil layers is a function of its soil solution concentration and the total amount of drainage passing through that layer.

Technical / Soil Phosphorus

Soil Profile Type	Krasnozem			
Design Depth for Soil P Storage (mm)				2000

Soil Layer	1	2	3	4
Initial Soil Solution P (mg/L)	0.010	0.005	0.005	0.005
Freundlich Isotherm Parameters				
Adsorption Coefficient	153.9	309.0	309.0	309.0
Adsorption Exponent	0.33	0.25	0.25	0.25
Desorption Exponent	0.27	0.13	0.13	0.13

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Soil Salinity

The effect of soil profile salinity under the given irrigation/climate regime on plant growth is determined using *steady-state* algorithms. Hence, salinity is not modelled by a daily time step, but uses values averaged over a user-specified number of years (usually about 5 years). The fraction of total infiltrated water moving between the soil layers, and the salinity and quantity of rain and irrigation water is used to predict the root zone salinity, using mass balance algorithms taken from the steady-state leaching fraction model (USSL, 1954; Shaw and Thorburn, 1985). The yield reduction is then estimated from phenomenological relationships of plant salinity tolerance (e.g. Maas and Hoffman, 1977) for the specific crop of interest.

PLANT GROWTH

The plant growth modules predict the biomass accumulation and the quantities of N and P that are removed from the effluent irrigation site through crop growth and the export of harvested material. Flexibility is gained through the provision of a dynamic pasture growth model and a dynamic crop growth model.

Dynamic Pasture Model

The pasture module is selected if a plant species is grown continuously, allowing regrowth to occur following mowing (rather than resowing the crop as occurs for the dynamic crop module).

In this model, plant cover increases with thermal time according to a fixed sine-curve algorithm defined by the total thermal time to reach full cover. Nitrogen stress and low biomass production modify cover development to improve the prediction of cover for stressed pastures. Growth is considered to be a function of solar radiation, plant cover and radiation use efficiency. Radiation use efficiency can be lowered by the highest of any stress due to temperature, water regime and low plant nitrogen. Prediction of daily plant growth allows estimation of the removal of N and P by nutrient uptake and storage in the shoot biomass. It is assumed that when a user-defined yield is reached, the pasture is mowed and the harvested material exported off site.

Nutrient uptake is estimated by considering nutrient supply by the soil and nutrient demand by the plant. The nutrient demand by the plant is a function of the optimal nutrient concentration of the shoots. For pastures, this is considered to remain constant over the time period until harvest. Uptake proceeds to satisfy demand, provided there is sufficient nutrient in the soil solution of each soil layer, and the concentration in the soil solution is above a minimum value. An exception to this is where soil supply is such that nutrient demand is more than satisfied. In this instance, luxury uptake can occur up to a user-defined maximum shoot concentration.

Default parameter values are provided for forage sorghum, kikuyu and ryegrass.

Dynamic Crop Model

The crop module is selected if a plant species is resown after harvesting (rather than mowed and allowed to regrow as for the pasture model).

The crop model derives its leaf area development, biomass growth and nitrogen uptake algorithms from EPIC (Sharpley and Williams, 1990). The potential leaf area development, described by thermal time, is a fixed relationship defined by the user. Using the potential leaf area value, the actual leaf area is determined after taking into account the effect of growth stresses from temperature, water regime and low plant nitrogen conditions. Leaf area is used to determine the crop cover, using a Beer's law equation. Total biomass growth is then determined as a function of radiation, cover, radiation use efficiency and day length. As in the pasture model, radiation use efficiency can be reduced by the most severe of any growth stresses.

Prediction of daily plant growth allows estimation of the removal of N and P by nutrient uptake and storage in the shoot biomass. It is assumed that the shoot biomass is harvested and exported off site when the crop reaches its maximum leaf area. To re-establish, the crop must be resown

Nutrient uptake is estimated by considering nutrient supply by the soil and nutrient demand by the plant. The nutrient demand by the plant is a function of the optimal shoot nutrient concentration which declines with plant age until harvest. Unlike the pasture model, luxury uptake of nutrient is not simulated for crops.

Default parameter values are provided for forage sorghum.

Rotation
A combination of crop and pasture models can simulate a two-crops per year rotation cycle. Hence, a summer crop or pasture, followed by a winter crop or pasture may be chosen. The commencement date of the growth period for each crop is user-defined, and the pasture may be set to be either down at the start of its growth period or allowed to grow back through the previous crop or pasture.

Monthly Crop Cover
Where the parameters for determining dynamic plant growth are not known, but the yearly pattern of cover is known (as is often the case for tree crops), the hydrology of the irrigation site can be modelled. The monthly plant covers may be input to define the plant cover, along with an estimate of average rooting depth and maximum crop coefficient and pan coefficient values to predict transpiration and soil evaporation. This monthly
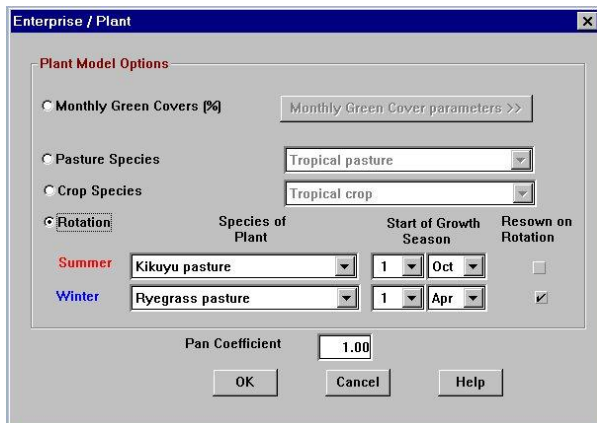
covers option does not provide an estimate of biomass yield or nutrient removal.

To determine the hydrology of a bare soil irrigation option, the plant growth modules may be turned off.

GROUNDWATER TRANSPORT

The groundwater model (PLUME) used in MEDLI is an extension of an earlier model which was applied to predict the fate of contaminants in the long-term, and over long distances in aquifers subject to diffuse source contamination. The basis for that model and comparisons between its performance and that of a well-established numerical solute transport model are documented in Dillon (1989).

The model allows for mixing of leachate with the groundwater flowing beneath the site. That is, it allows for dilution. It also allows for dispersion of leachate in the direction of flow, and in the vertical direction. This reduces the values of peak solute concentrations, consistent with the mixing processes normally observed in aquifers. However the model neglects lateral dispersion as the dimensions of the area irrigated with wastewater are likely to be sufficiently large that, in the zone where concentrations are of interest, negligible diminution of peak values by lateral dispersion is expected.

Solute concentrations downgradient of the wastewater irrigation area are calculated only on a transect in the direction of groundwater flow passing through the centre line of the wastewater irrigation area. The transect was chosen as it contains the peak values of predicted concentrations at any time, and it has the fastest rate of movement of solutes away from the irrigation area in groundwater.

Concentrations are calculated on a vertical profile at a series of time and distances, as in many situations contaminants are stratified in aquifers, generally with highest values near the water table. The tendency for stock and domestic bores to be shallow means that this vertical stratification can

be an important determinant of the concentrations recovered in those bores.

Longitudinal dispersion calculations use the one dimensional advection-diffusion equation and vertical dispersion is described by the diffusion equation. These equations and their uncoupled formulation are documented in Dillon (1989).
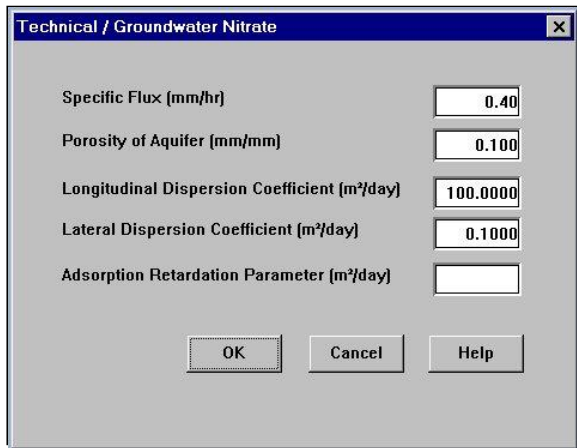

RESULTS

MEDLI can be run to produce either a Summary text based output or full Output incorporating a text and graphics data presentation. A full output run requires about 20 megabytes of data storage for a 100 year run. The summary output consumes about 1% of this storage requirement.

Summary Output
The Summary output provides general run identification information, and a summary of average monthly climate variables, the soil hydraulic properties, and the waste stream characteristics. Hydraulic, nitrogen, phosphorus and salinity mass balances are reported for the pond system including the frequency/size of pond
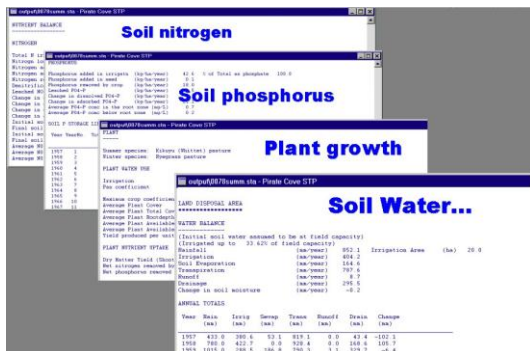

overtopping events. The nutrients stored and removed from the pond in the sludge and supernatant are also listed.

The hydrology components of the irrigation area (runoff, drainage, irrigation, transpiration etc) and components of the soil nitrogen, phosphorus and salinity balances are listed. Also, plant growth and any soil salinity restrictions and nutrient storage values are listed. The general summary concludes with information on groundwater quality due to nitrate leaching beneath the irrigation area. The summary can be printed or viewed on screen.

Full Output
The full output option saves daily results for all the parameters from the simulation and allows graphing of any output parameter at a range of time scales (daily, monthly, yearly) and statistical types (e.g. mean, minimum, maximum, total). The Full Output option allows graphing of various pond, plant, soil water, soil nutrient, irrigation and climate parameters. In addition, a comprehensive report file is available for tabulated results. Additional parameters specific to the pathogen and feedlot modules are generated if these options are chosen.
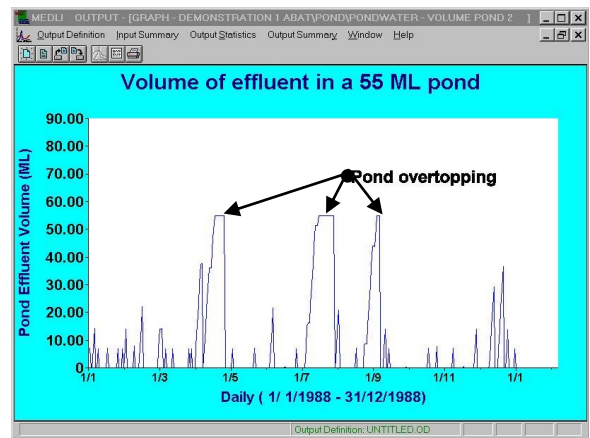
Overlaid graphs can be created using multiple parameters from the same run, or across multiple runs. A simultaneous text file can be opened for each graph to view the actual data. ASCII text files can be exported and used in other programs such as Excel. Graphs and time scales can be zoomed or compressed and there are printing and file saving capabilities.

Importing and Exporting Runs

The files associated with a MEDLI run may be uploaded or downloaded from disk by using the import and export facilities in MEDLI. Where advice is required regarding software problems encountered during a particular run, the export facility may be used to save the relevant run files to disk for later zipping and emailing to DERM (see Contact information, Page 14).

REFERENCES

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Computer Requirements

MEDLI Version 1.3 was developed under Windows 95 and NT operating systems is not compatible with Windows 2000 (with the Service packs installed) and later operating systems.

Included in the price of MEDLI is a software installation CD-ROM containing the software, manual, and **two hours** of technical support by phone. Daily climate data for any place in Australia can be purchased through us.

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Model for Effluent Disposal Using Land Irrigation