Chapter 5
Theoretical Modelling Approach

Published in:

- *Casey, N.H., Meyer, J.A. & Coetzee C.B. 1998. An investigation into the quality of water for livestock production with the emphasis on subterranean water and the development of a water quality guideline index system. Volumes 1 - Development and modeling. Report to the Water Research Commission. WRC Report No: 644/1/98. ISBN No:1 86845 739 0*
- *Casey, N.H., Meyer, J.A. & Coetzee C.B. 1998. An investigation into the quality of water for livestock production with the emphasis on subterranean water and the development of a water quality guideline index system. Volumes 3 - Appendix. Report to the Water Research*
- *Casey, N.H., Meyer, J.A. & Coetzee C.B. 2001. An extension to and further refinement of a water quality guideline index system for livestock watering. Poultry production systems and water quality for ostrich production. Volume 2. Report to the Water Research Commission. WRC Report No: 857/2/01. ISBN No: 1 86845 714 1*

Introduction

Since poultry consume approximately twice as much water as feed on a weight basis, it would seem logical that water content and quality should be considered in nutrition. Water of poor quality affects poultry performance in two ways. First, high concentrations of bacteria or toxic elements in the water affect the normal physiological processes of the body, resulting in inferior performance. Second, high concentrations of minerals in the water may clog the water system and subject the birds to water deprivation. Alternatively, faulty drinkers may flood the litter, causing leg problems and breast blisters in broilers raised on the floor. The management of laying hens in cages may be compromised.

It is imperative to have a set of Water Quality Guidelines (WQG) applicable to subterranean and other water sources. The need for, and importance of ground water, as a source of drinking water is increasing. Casey *et al*. (1993, 1994, 1996, 1998a, 1998b and 2000) questioned the validity of guidelines presently in use in southern Africa for assessing the quality of water for livestock production.

Some of the shortcomings of presenting a guideline on a mg/l basis are that they do not :

- offer any solution for areas which have inherently saline waters with high concentrations of potentially adverse Water Quality Constituents (WQC).
- take into account, to a large enough extent, the differing water quality requirements, in terms of quality and quantity of animals due to :
    - animal specific factors;
    - site-specific environmental factors;
    - nutritional factors;
    - livestock production system factors.
- take into account the effect of short-term exposure to WQC's.

- cater for differences in probable carry-over effects of potentially toxic substances to the user of the animal product after a limited exposure.
- cater for synergistic and antagonistic interactions between WQC's and the environment.
- base recommendations on the actual ingestion of a WQC for all sources (Casey *et al*. 1998a).

Prior to this work, international guidelines and levels for specific variables differed, and highlighted the need for each country to have its own relevant guidelines.

The aim of this project was to develop a process of determining acceptable levels for WQC taking into account ingestion rates, exposure time and species tolerance to constituents in poultry production systems in South Africa.

Establishing guidelines for water quality for poultry is difficult as growth and health depend on a multitude of factors. These factors have been shown to interact; a certain level of a water contaminant may not affect a bird's performance in one environment, while it could cause a problem in another. The only way to attempt the evaluation of the influence of water quality on poultry production is to base the research on flock performance under existing commercial conditions.

In Chapter 1 data on the different levels of minerals and metals found in groundwater of poultry farms across South Africa was presented. This data confirmed the need to develop a Water Quality Guideline Index System (WQGIS) for South African conditions. The range between the minimum and maximum levels of a specific constituent present in the water varied markedly. Constituent levels far in excess of the existing guidelines were prevalent. Constituents identified to be of concern in these results were investigated further and their effect on poultry production established.

An index system to assess the suitability of water for livestock production was required, as the present system does not fulfill this role. The index system should be based on the assessment of water intake for potentially hazardous variables, to determine the levels of ingestion of the variable concerned and, for palatability variables, to assess the impact of the variables on the water requirements and feed intake. These will be combined to form a water quality index (WQI) (Casey *et al*. 1996).

The results obtained in the experiments, detailed in previous chapters, served as motivation for a new approach to assessing water quality guidelines for poultry.

One objective in establishing a new set of water quality guidelines for poultry production systems was to provide producers with a system that is not as contradictory and static as those of Table 1.1. These guidelines will be presented in the form of an index system, incorporating all the influences of specific sites on water intake in a specific production system.

The only way to arrive at such a solution is through a modeling approach, in which the relationship between biological responses and their causes are predicted within site-specific factors.

Objectives of the Water Quality Guideline Index System (WQGIS):

- Provide a flexible management tool to make decisions about water quality for poultry.
- Provide a means for incorporating site-specific information in risk assessment for poultry watering.
- Provide supporting information to make decisions on the various components and their interactions in biological systems.
- Provide a water quality guideline index system that can be updated, as new research information becomes available (Casey *et al*. 1998a).

These objectives were achieved by:

- Modeling water quality guidelines on a livestock type, site-specific basis.
- Demonstrating principles of water quality and poultry production relationships.
- Developing of a software program.
- Providing the user with 2 water quality guideline systems :
    1. Generic WQGIS
    2. Specific WQGIS (Casey *et al*. 1998a)

A systems diagram of each of the applications of the model has been developed to illustrate how the components of the model interact.

Generic WQGIS

Introduction

The generic application level is a static water quality guideline, in that it makes use of single value comparisons. It exceeds previous guidelines in that it also indicates possible effects on poultry at given levels. The generic WQGIS is based on the Interim Water Quality Guidelines for Livestock Watering (Casey and Meyer 1996).

Generic Guidelines within incidence categories

A total of 20 water quality constituents are addressed in the Generic Guidelines within three incidence categories, based on local research set out in Table 5.1. (Casey *et al*. 1994; 1998).

Table 5.1 Potentially hazardous water quality constituents for poultry watering, selected on the basis of incidence of occurrence in the natural aquatic environment (Casey & Meyer 1996).

Potentially hazardous water quality constituents for poultry watering, selected on the basis of **incidence of occurrence** in the natural aquatic environment:		
High incidence	**Medium incidence**	**Low incidence**
Bicarbonates Calcium Chloride Chromium Lead Magnesium Nitrate Sodium Sulphate Total Dissolved Solids Zinc	Arsenic Cadmium Copper Iron Manganese Mercury	Fluoride Nitrite Selenium

The Generic guidelines are presented in alphabetic order for quick access in two main formats. The first indicates the probable effects that can be expected with increasing concentrations (available via the Results Screen, Types of Effects button). The second provides only cut-off Single Trigger Value Guidelines.

Definitions used for the Generic Guidelines (Casey *et al*. 1998a)

Potentially hazardous water quality constituents have either a:

- **High Incidence** of occurrence in the poultry aquatic environment;
- **Medium incidence** of occurrence in the poultry aquatic environment;
- **Low incidence** of occurrence in the poultry aquatic environment.

Symbols used (Casey *et al*. 1998a)

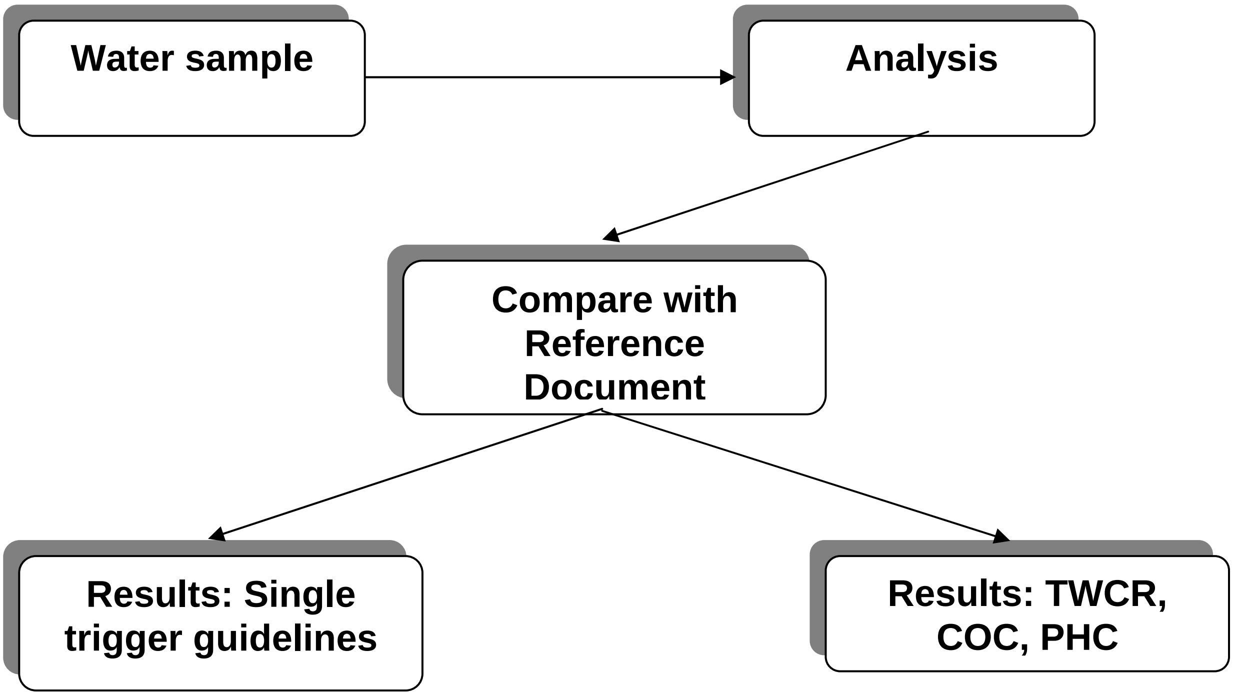
TWQR Target Water Quality Range. This is the range where adverse effects are ***unlikely*** to occur.

➢ The range in question, although ***likely*** to result in adverse effects, may be tolerated in either the short or long term, dependent on the site-specific factors. There may be synergistic and / or antagonistic interactions between constituents in the feed and the water; the design of the poultry production system and actual water ingestion rate.

PHC ***Potentially Hazardous Constituent (constituents in excess of the recommended guidelines).***

COC ***Constituent of Concern and COC (constituents within 10% of the recommended upper limit).***

Figure 5.1. Systems diagram of the Generic application level**.**



Listed below are tables showing water quality constituents in alphabetic order and the generic guidelines that apply to that constituent.

Arsenic - Medium incidence

Arsenic Range (mg/l)	**Effects – Poultry**
TWQR 0 – 0.05	*No adverse effects*
0.05 – 0.2	**Adverse chronic effects** such as depression, diarrhoea, leg weakness and depressed growth may occur. Short-term exposure could be tolerated>.
> 0.2	**Adverse chronic effects** such as - reduced egg production - reduced body weights and - reduced feed intakes may occur, although short-term exposure could be tolerated>.

Bicarbonate - High incidence

Bicarbonate Range (mg/l)	**Effects – Poultry**
TWQR 0 - 200	*No adverse effects*
200 – 500	As bicarbonate increases, body weight also increases. This observation may be more valid during periods of heat stress.
> 500	Long term exposure> could be tolerated if sodium or sulphate is present

Cadmium - Medium incidence

Cadmium Range (mg/l)	Effects – Poultry
TWQR 0 - 0.005	*No adverse effects*
0.005 - 0.01	**Adverse chronic effects** such as reduced growth and decreased egg production may occur, but are unlikely if the following interactions are observed: - Added dietary ascorbic acid protects against Cd induced anaemia. - Added Se and Zn reduce the effect of Cd toxicity. - Zn deficiency leads to increased liver Cd. - Fe deficiency leads to increased kidney Cd.
>0.01	**Adverse acute effects** such as nephritis and enteritis may occur. Immature birds are more susceptible than adults.

Calcium - High incidence

Calcium Range (mg/l)	Effects - Poultry
TWQR 0 - 75	*No adverse effects*
75 - 600	**Adverse chronic effects such as a decrease in body weight, lowered feed intakes and an increase in condemned carcasses can occur. This may be correlated with a negative effect on vaccines given in drinking water. Excessive scale may form and deposit in water pipes. Dietary Ca:P ratio (1.1-2.0:1) is important in growers. Excess Zn reduces Ca availability and thus egg production. Excess Ca reduces P, Mn and F absorption. Excess dietary fat renders Ca less available. Could be tolerated in the long term >.**
> 600	**There may be adverse chronic effects. Adverse acute effects such as embryonic abnormalities may occur. Could be tolerated in the long term >.**

Chlorides - High incidence

Chlorides Range (mg/l)	Effects - Poultry
TWQR 0 - 200	*No adverse effects*
200 - 500	**Adverse chronic effects** such as wet faeces, excessive water consumption, ascites and reduced eggshell strength may occur. Can be detrimental when more than 50 mg/l Na is present. Affects the taste of the water, and may corrode the water pipes. Can tolerate short and medium term exposure>.
>500	Adverse chronic effects such as osmotic disturbances, hypertension, dehydration and renal damage may occur. Chicks are more tolerant than turkey poults. Tolerance in chicks increases after 3 weeks of age>.

Chromium - High incidence

Chromium Range (mg/l)	Effects - Poultry
TWQR 0 - 0.1	*No adverse effects*
0.1 – 1	**Adverse chronic effects** such as a decreased growth rate may occur but are unlikely if feed concentrations are normal. Low toxicity. Fe, Zn and Vanadium are antagonistic to Cr. Long term exposure could be tolerated>.
> 1	**Adverse chronic effects** may occur, although short-term exposure could be tolerated>.

Copper - Medium incidence

Copper Range (mg/l)	Effects - Poultry
TWQR 0 - 0.002	*No adverse effects*
0.002 - 0.6	**Adverse chronic effects** such as decreased body weight and increased feed conversions may occur. It gives a bitter taste to water. Could be tolerated in the long term>.
> 0.6	**Adverse acute effects** such as muscular dystrophy and liver damage may occur. **Adverse chronic effects** such as reduced body weight and feather loss may occur. Short-term exposure could be tolerated>.

Fluoride - Low incidence

Fluoride Range (mg/l)	Effects - Poultry
TWQR 0 - 2	*No adverse effects*
2 - 10	**Adverse chronic effects** such as reduced feed and water intakes, lower growth rates and egg production may occur but are unlikely if: - feed concentrations are normal - exposure is short term>.
> 10	**Adverse chronic effects** as above and **adverse acute effects** such as skeletal fluorosis may occur. Excess Ca and Al reduce F toxicity and availability Short-term exposure could be tolerated>.

Iron - Medium incidence

Iron Range (mg/l)	Effects - Poultry
TWQR 0 - 0.2	*No adverse effects*
0.2 - 0.4	**Adverse chronic effects** such as lower body weights and feed intakes might occur but are unlikely if: - feed concentrations are normal - exposure is short. Could be tolerated long term? if adequate Cu is present.
> 0.4	**Adverse chronic effects** (as above) may occur. Clogging of pipes and coloration of water. Can interfere with vaccination programs. Long term exposure could be tolerated>.

Lead - High incidence

Lead Range (mg/l)	Effects - Poultry
TWQR 0 - 0.015	*No adverse effects*
0.015 - 0.1	**Adverse chronic effects** such as decreased egg size, lower hatchability and a decrease in performance may occur, but are unlikely if : - feed concentrations are normal; - exposure is short>.
> 0.1	**Adverse chronic effects** as above and **adverse acute effects** such as drowsiness, thirst, weakness, anorexia, diarrhoea, anaemia, crop stasis and peripheral paralysis may occur. It reduces the immune response, growth rate and egg production. Short-term exposure could be tolerated>.

Magnesium - High incidence

Magnesium Range (mg/l)	Effects - Poultry
TWQR 0 - 125	*No adverse effects*
125 - 250	**Adverse chronic effects** such as diarrhoea, intestinal irritation, watery droppings and lethargy may occur, but are unlikely if: - the sulphate level is low; - exposure is short>.
> 250	**Adverse chronic and acute effects** such as: Increased mortality and bone deformity, depressed growth rate and bone calcification, depressed egg production and watery faeces may occur. Possibly interferes with vaccination programs. Short-term exposure could be tolerated>.

Manganese - Medium incidence

Manganese Range (mg/l)	Effects - Poultry
TWQR 0 - 0.05	*No adverse effects*
0.05 - 0.6	Discoloration of water and turbidity deposits in pipes. Gives a bitter taste to water.
> 0.6	**Adverse chronic effects** such as a decrease in growth rate may occur. Excess P reduced Mn availability and excess Mn reduces Fe utilization. Short-term exposure could be tolerated>.

Mercury -Medium incidence

Mercury Range (µg/l)	Effects - Poultry
TWQR 0 - 1	*No adverse effects*
1 - 2	**Adverse chronic effects** such as lowered feed intakes, weight loss, weakness and eggshell thinning may occur if mercury is in the organic form, but should be tolerated if there is adequate intake of Se and Vit E and the exposure time is short>.
> 2	**Adverse chronic and acute effects** such as neuro, hepato- and renal toxicity may occur although short-term exposure> could be tolerated.

Nitrates - High incidence and Nitrites - Low incidence

Nitrates Range (mg/l)	Effects - Poultry
TWQR **0 - 25 (NO_3)** **0 - 4 (NO_2)**	*No adverse effects*
25 - 300 (NO_3)	**Adverse chronic effects** such as a decrease in performance could occur but are unlikely if: - more than 8000 IU of Vit A is present; - exposure is short>. Poultry are more resistant than ruminants.
> 300 (NO_3)	**Adverse chronic effects** such as decreased feed and water intakes, lower body weights and undesirable levels of methaemoglobin in the blood may occur. Condemned carcases may increase.

Selenium - Low incidence

Selenium Range	Effects - Poultry

(µg/l)	
TWQR 0 - 10	*No adverse effects*
10 50	**Adverse chronic effects** such as severe fatty metamorphosis, reduced weight gains, reduced reproductive performance, lowered hatchability, deformed embryos, liver necrosis, muscle atrophy and degeneration and emaciation may occur. Short-term exposure could be tolerated>.
> 50	**Adverse chronic effects** as above, but short-term exposure can be tolerated>.

Sodium - High incidence

Sodium Range (mg/l)	**Effects - Poultry**
TWQR 0 - 50	*No adverse effects*
50 - 250	**Adverse chronic effects** such as increased water consumption and wet litter may occur. Chloride and sulphate enhances effect. Could be tolerated if 500 mg/l bicarbonate is present.
> 250	**Adverse chronic effects** as above and **adverse acute effects** such as ascites resulting from pulmonary hypertension, increased mortality, reduced egg production, feed efficiency and egg weight, and reduced growth rate, particularly in males may occur. Short-term exposure can be tolerated>.

Sulphate - High incidence

Sulphate Range (mg/l)	**Effects - Poultry**
TWQR 0 - 125	*No adverse effects*
125 - 250	**Adverse chronic effects** such as decreased performance if the Mg or Cl levels are high may occur.
> 250	**Adverse chronic effects** as above may occur. Mg sulphate is more toxic than Na sulphate. May interfere with vaccination programs. Short-term exposure could be tolerated>**.**

Total Dissolved Solids - High incidence

Total Dissolved Solids Range (mg/l)	**Effects - Poultry**
TWQR 0 - 1000	*No adverse effects*
1000 - 3000	Slightly saline. **Adverse chronic effects** such as decreased feed intakes, water intakes and performance may occur. Short-term exposure could be tolerated.
> 3000	3000 - 10000 = Moderately saline 10000 - 35000 = Very saline > 35000 = Brine **Adverse chronic effects** as above may occur. Poultry more sensitive to high TDS than ruminants.

Zinc - High incidence

Zinc Range (mg/l)	**Effects - Poultry**
TWQR 0 - 1.5	*No adverse effects*
1.5 – 15	**Adverse chronic effects** such as decreased growth and fertility, skin disease, muscular dystrophy and reduced bone ash may occur. Gives an astringent taste to water. Long term exposure could be tolerated>.
> 15	**Adverse chronic effects** as above may occur. The composition in the diet affects Zinc toxicity. Zinc carbonate is more toxic than Zinc oxide. Short-term exposure could be tolerated>.

Generic Guidelines – Single Trigger Values

Constituents are labelled as single trigger guidelines when there is insufficient information available for formulating generic guidelines (Casey *et al*. 1998a).

Table 5.2 WQC addressed as Single Trigger Guidelines for the Generic System.

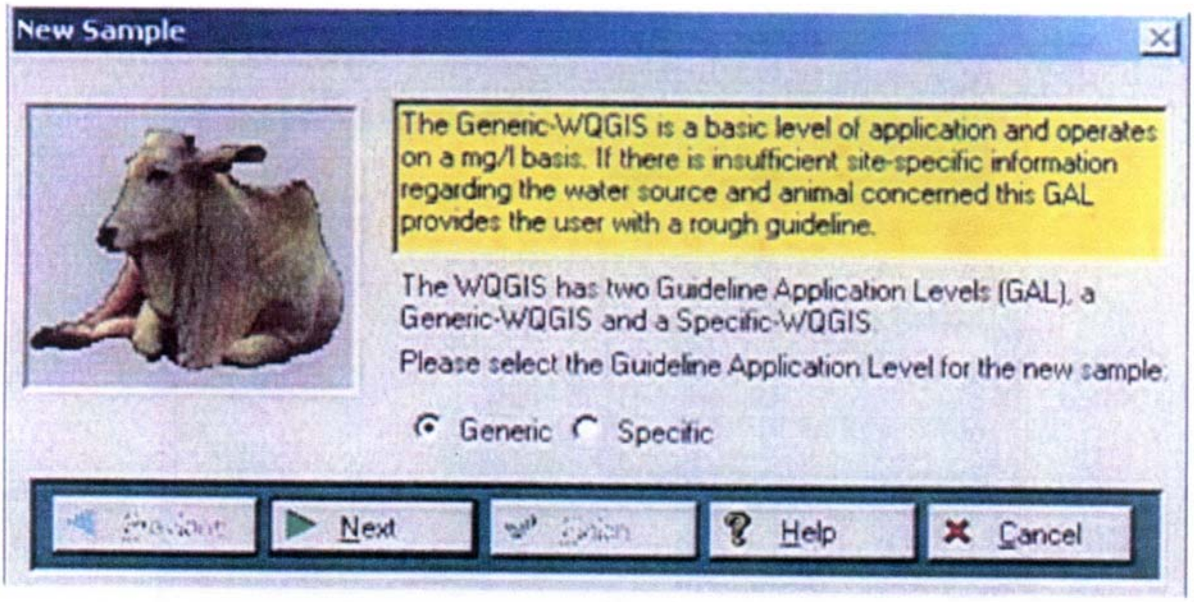
CONSTITUENT	TWQR
Aluminium	0 - 5 mg/l
Ammonium	0 - 2 mg/l
Antimony	0 - 0.006 mg/l
Bacteria	Total = 0 - 100 colonies / ml
	Coliform = 0 - 50 colonies / ml
Barium	0 - 2 mg/l
Beryllium	0 - 0.004 mg/l
Bismuth	0 - 0.001 mg/l
Boron	0 - 5 mg/l
Bromide	0 - 3 mg/l
Cesium	0 - 50 000 µg/l
Carbonate	0 - 500 mg/l
Cerium	0 - 2 mg/l
Cobalt	0 - 1 mg/l
Colour	0 - 15 colour units
Cyanide	0 - 0.2 mg/l
Dissolved oxygen	0 - 10 % saturation
Electrical conductivity	0 - 1980 mS/m
Gold	0 – 5µg/l
Hardness (CaCO3)	> 180 mg/l = hard
	< 60 mg/l = soft
Herbicides:	0 - 100 µg/l
2,4-D	0 - 100 µg/l
2,4,5-T	0 - 10 µg/l
2,4,5-TP	
Hydrogen Sulfide	0 - 0.3 mg/l
Indium	0 - 1 µg/l
Iodide	0 -1 mg/l
Lanthanum	0 - 1 µg/l
Lithium	0 - 5 mg/l
Magnesium sulphate	200 mg/l
Molybdenum	0 - 10 mg/l
Nickel	0 - 1 mg/l
Odour	0 - 3 threshold odour number
Pesticides:	
Aldrin	0 - 0.03 µg/l
Chlordane	0 - 0.3 µg/l
DDT	0 - 1 µg/l
Dieldrin	0 - 0.03 µg/l
Endrin	0 - 0.2 µg/l
Heptachlor	0 - 0.1 µg/l
Lindane	0 - 4 µg/l
Methoxychlor	0 - 30 µg/l
Toxaphene	0 - 5 µg/l
Parathion	0 - 500 µg/l
Malathion	0 - 500 µg/l

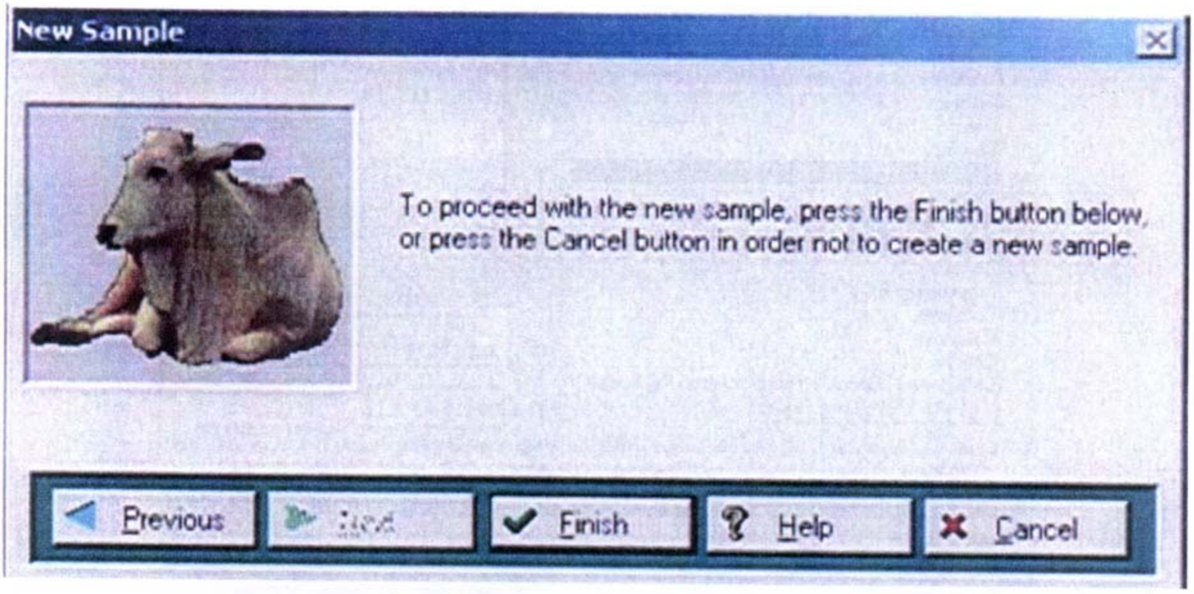
CONSTITUENT	TWQR
PH	6.4 – 9
Phosphate	0 - 2 mg/l
Potassium	0 - 2000 mg/l
Radio-activity	0 - 3 picocurie/l
Gross alpha	0 - 30 picocurie/l
Gross beta	0 - 1000 picocurie/l
^{3}H (tritium)	
Radium	0 - l µg/l
Rubidium	0 - 5 mg/l
Scandium	0 - 1 µg/l
Silver	0 - 0.05 mg/l
Sodium Bicarbonate	0 - 1000 mg/l
Sodium sulphate	0 - 1200 mg/l
Sodium chloride	0 - 1500 mg/l
Strontium	0 - 10 mg/l
Thallium	0 - 0.002 mg/l
Thorium	0 - 0.0005 mg/l
Tin	0 - 0.05 mg/l
Titanium	0 - 0.2 mg/l
Tungsten	0 - 0.5 mg/l
Turbidity	0 - 5 NTU
Uranium	0 - 0.2 mg/l
Vanadium	0 - 0.1 mg/l
Yttrium	0 - 0.001 mg/l
Zinc Sulphate	0 - 10 000 mg/l
Zirconium	0 - 1 µg/l

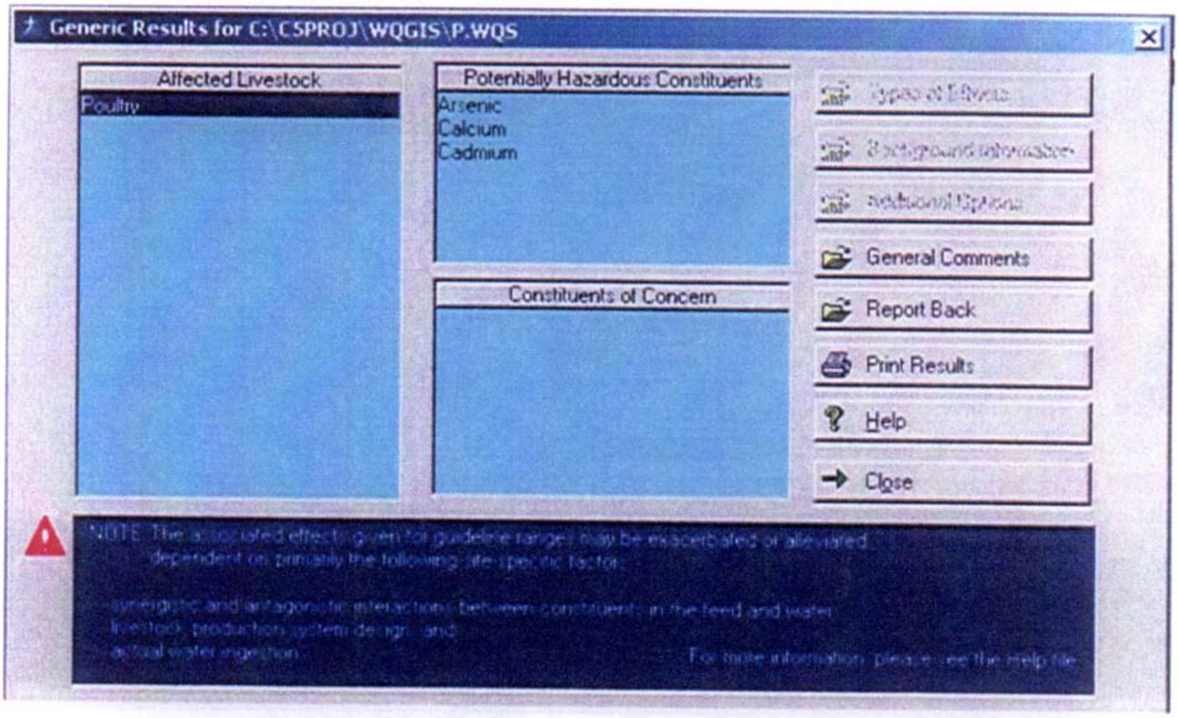
Generic WQGIS – Software Environment

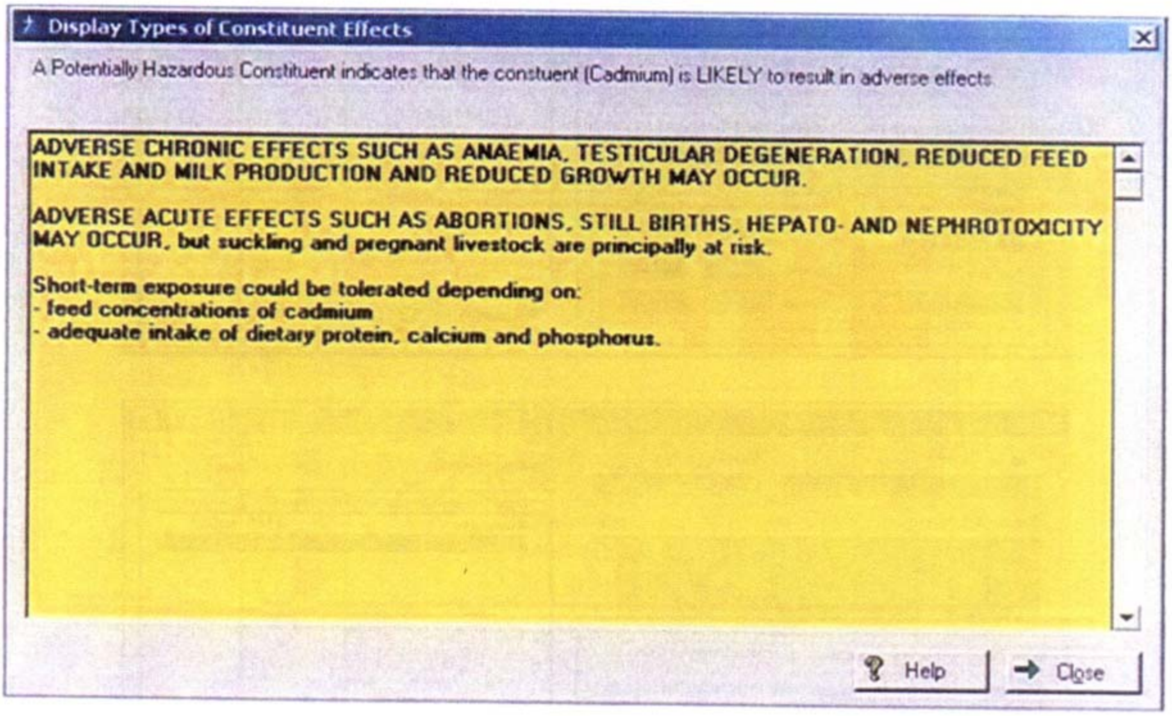
Some of the screens found in the Generic GAL are shown below in sequence of appearance.

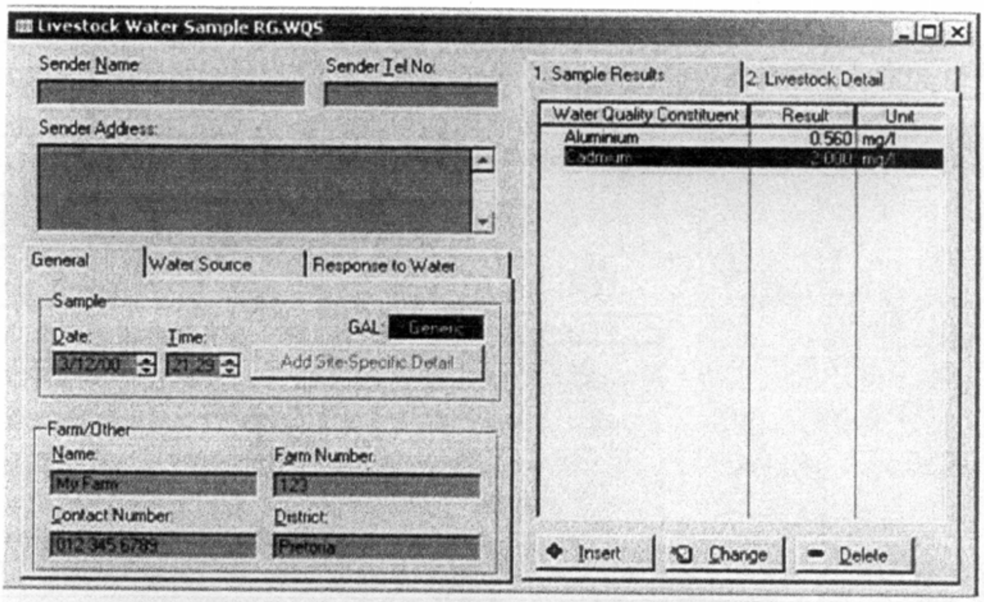
Screens 5.1 Generic WQGIS – Software environment

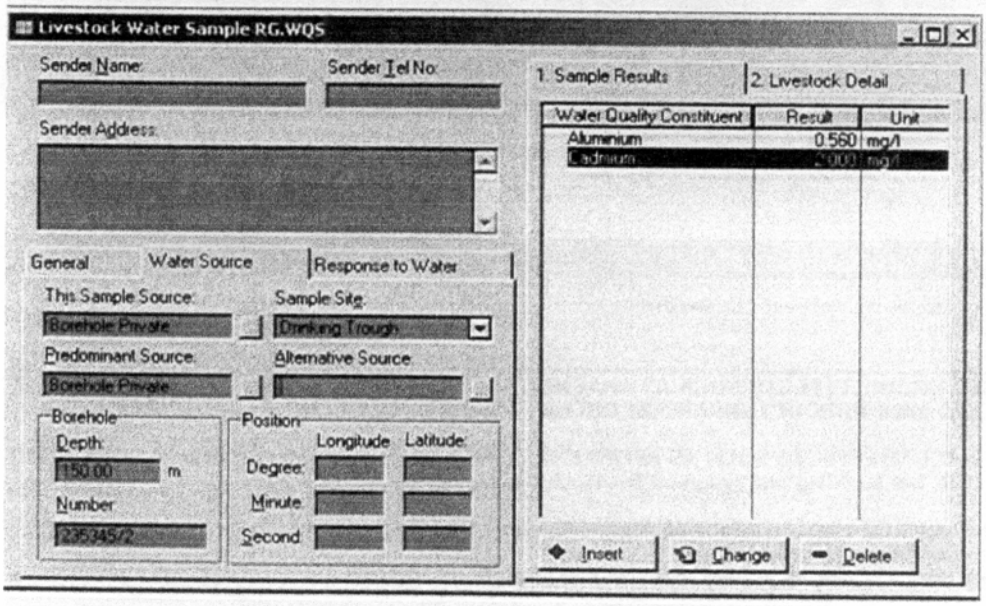


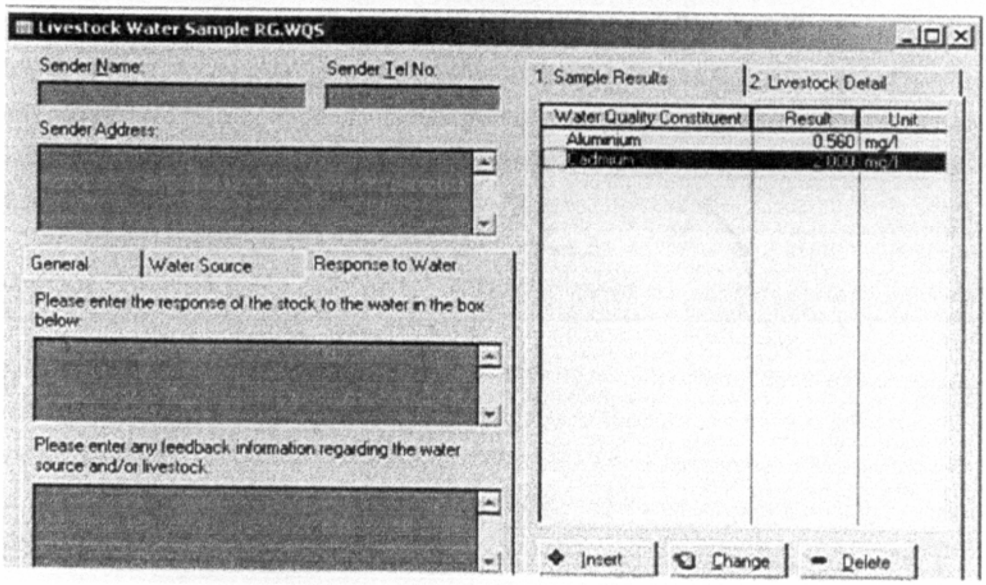


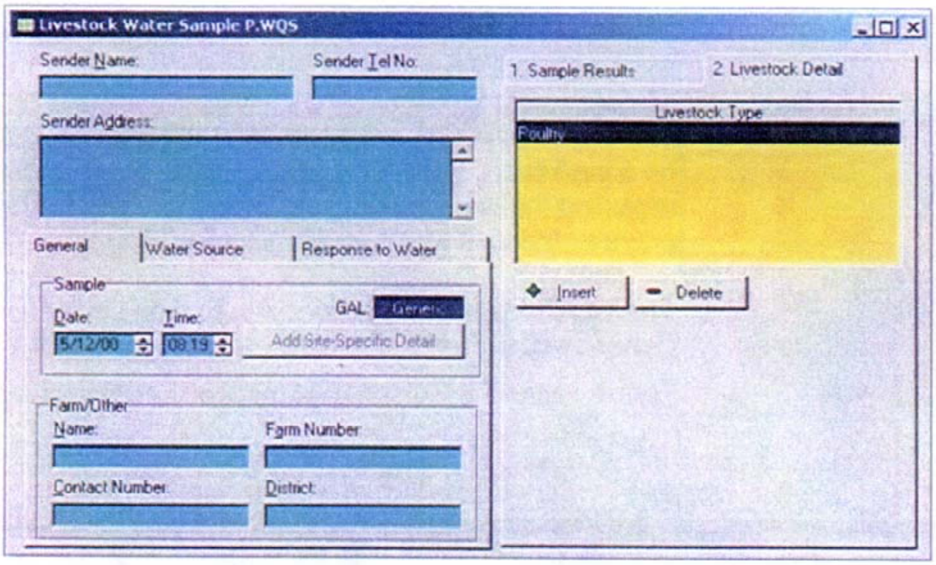

Generic Results for C:\C5PROJ\WQGIS\P.WQS
Affected Livestock
Poultry
Potentially Hazardous Constituents
Arsenic
Calcium
Cadmium
Constituents of Concern
General Comments
Report Back
Print Results
Help
Close

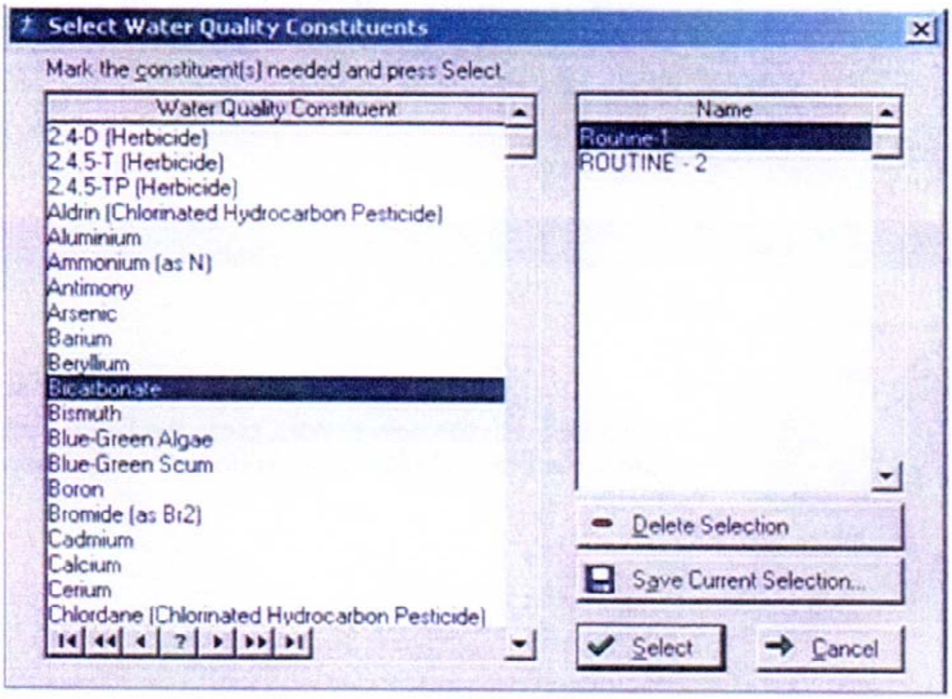

Display Types of Constituent Effects
A Potentially Hazardous Constituent indicates that the constuent (Cadmium) is LIKELY to result in adverse effects
ADVERSE CHRONIC EFFECTS SUCH AS ANAEMIA, TESTICULAR DEGENERATION, REDUCED FEED INTAKE AND MILK PRODUCTION AND REDUCED GROWTH MAY OCCUR.
ADVERSE ACUTE EFFECTS SUCH AS ABORTIONS, STILL BIRTHS, HEPATO- AND NEPHROTOXICITY MAY OCCUR, but suckling and pregnant livestock are principally at risk.
Short-term exposure could be tolerated depending on:
- feed concentrations of cadmium
- adequate intake of dietary protein, calcium and phosphorus.
Help
Close

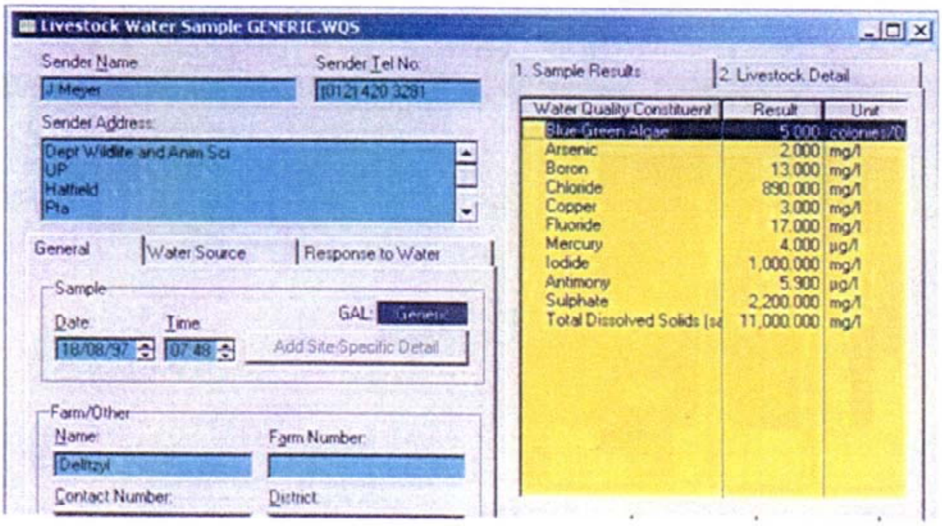

Livestock Water Sample RG.WQS
Sender Name:
Sender Tel No:
Sender Address:
General
Water Source
Response to Water
Sample
Date:
Time:
GAL:
Add Site-Specific Detail
Farm/Other
Name:
Farm Number:
Contact Number:
District:
1. Sample Results
2. Livestock Detail
Water Quality Constituent
Result
Unit
Aluminium
0.560
mg/l
Insert
Change
Delete


Livestock Water Sample RG.WQS
Sender Name:
Sender Tel No:
Sender Address:
General
Water Source
Response to Water
This Sample Source:
Sample Site:
Predominant Source:
Alternative Source:
Borehole
Depth:
m
Number:
Position
Longitude
Latitude:
Degree:
Minute:
Second:
1. Sample Results
2. Livestock Detail
Water Quality Constituent
Result
Unit
Aluminium
0.560
mg/l
Insert
Change
Delete


Livestock Water Sample RG.WQS
Sender Name:
Sender Tel No:
Sender Address:
General
Water Source
Response to Water
Please enter the response of the stock to the water in the box below:
Please enter any feedback information regarding the water source and/or livestock:
1. Sample Results
2. Livestock Detail
Water Quality Constituent
Result
Unit
Aluminium
0.560
mg/l
Insert
Change
Delete


Livestock Water Sample P.WQS
Sender Name:
Sender Tel No:
Sender Address:
1. Sample Results
2. Livestock Detail
Livestock Type
Poultry
Insert
Delete
General
Water Source
Response to Water
Sample
Date:
Time:
GAL:
Generic
5/12/00
08:19
Add Site-Specific Detail
Farm/Other
Name:
Farm Number:
Contact Number:
District:


Select Water Quality Constituents
Mark the constituent(s) needed and press Select.
Water Quality Constituent
2,4-D (Herbicide)
2,4,5-T (Herbicide)
2,4,5-TP (Herbicide)
Aldrin (Chlorinated Hydrocarbon Pesticide)
Aluminium
Ammonium (as N)
Antimony
Arsenic
Barium
Beryllium
Bicarbonate
Bismuth
Blue-Green Algae
Blue-Green Scum
Boron
Bromide (as Br2)
Cadmium
Calcium
Cerium
Chlordane (Chlorinated Hydrocarbon Pesticide)
Name
Routine-1
ROUTINE - 2
Delete Selection
Save Current Selection...
Select
Cancel


Livestock Water Sample GENERIC.WQS
Sender Name
J Meyer
Sender Tel No:
(012) 420 3281
Sender Address:
Dept Wildlife and Anim Sci
UP
Hatfield
Pta
1. Sample Results
2. Livestock Detail
Water Quality Constituent
Result
Unit
Blue-Green Algae 5.000 colonies/0
Arsenic 2.000 mg/l
Boron 13.000 mg/l
Chloride 890.000 mg/l
Copper 3.000 mg/l
Fluoride 17.000 mg/l
Mercury 4.000 µg/l
Iodide 1,000.000 mg/l
Antimony 5.900 µg/l
Sulphate 2,200.000 mg/l
Total Dissolved Solids (s 11,000.000 mg/l
General
Water Source
Response to Water
Sample
Date
Time
GAL:
Generic
18/08/97
07:48
Add Site-Specific Detail
Farm/Other
Name:
Deltzyl
Farm Number:
Contact Number:
District:

Specific WQGIS

The specific Guideline Application Level (GAL) incorporates the site-specific influences on water ingestion as well. This is achieved by making use of simulation modelling

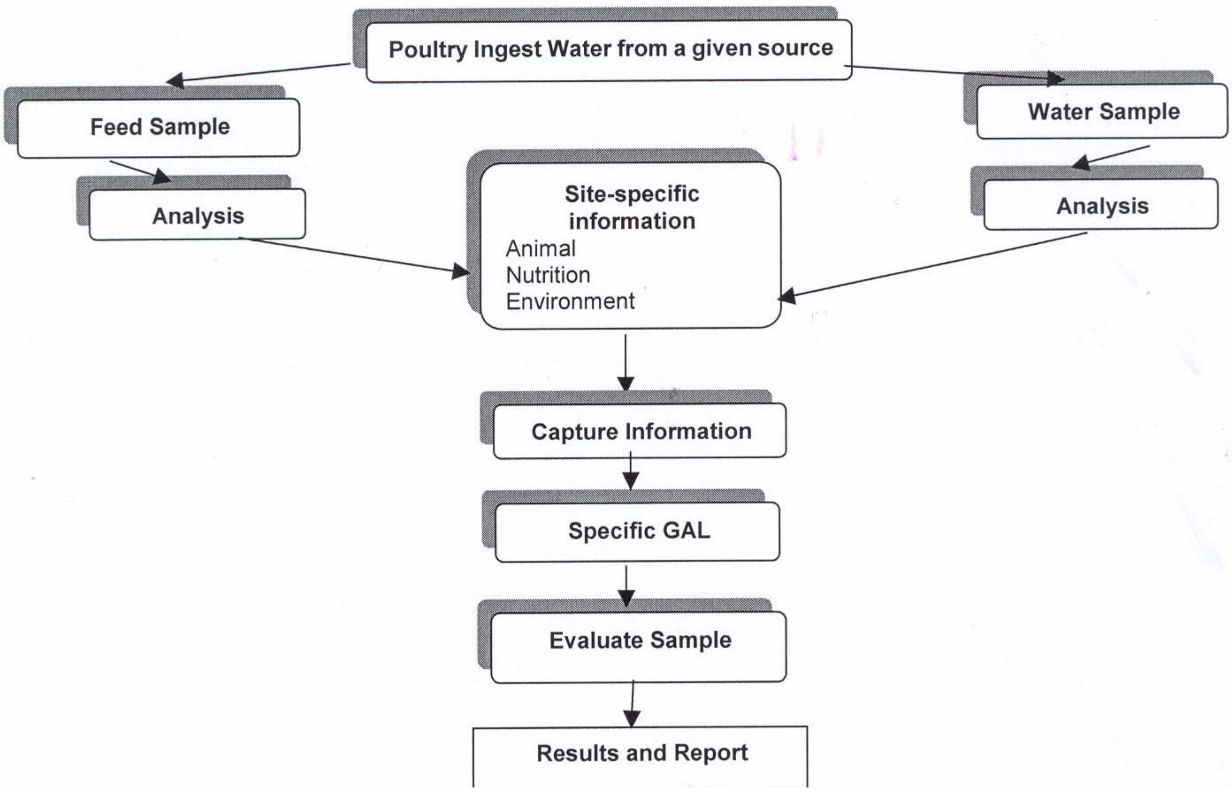
The specific GAL can:

- Establish the ingestion rate of a specific water quality constituent;
- Take system factors into consideration - Animal
  Environment
  Nutrition
- Do a risk assessment
- Make proposed solutions (Casey *et al*. 1998a).

The specific Guideline Application Level (GAL) incorporates the site-specific influences on water ingestion as well. This is achieved by making use of simulation modelling.

Figure 5.2. represents a brief schematic outline of the primary procedures applied in the Specific WQGIS for poultry.

Figure 5.2. Schematic demonstration of the specific model.



Basis of the Specific Water Quality Application Level:

The basis of the Specific WQG application is a water ingestion rate reference document, or WIRRD (Casey *et al*. 1998, Meyer 1998). The reader is referred to Casey *et al*. 1998 for a detailed description and supporting information on the WIRRD concept. This section describes the modifications made to the WIRRD used for modelling of risk assessment for cattle, sheep, goats, horses and pigs, as employed by the software program CIRRA (Constituent Ingestion Rate Risk Assessment) (Meyer 1998). These modifications allow for the inclusion of poultry production systems to the list of potential user groups.

This reference document consists of

- Categories per production system (NRC), which addresses different production systems and ages;
- Body weights (broilers) (BW);
- Feed intakes (FI);
- Egg production (layers);
- Moisture content of the feed;
- Total water intakes (TWI) and
- Constituent ingestion rates (IR).

After all the above information has been incorporated into the WIRRD, the end result is a water quality ingestion rate guideline. The water ingestion of a bird can either be predicted, using regression formulae, or it can be provided by the user. The Water intake (WI) derived from the formulae or the input is then converted to a total water intake (TWI) (Casey *et al*. 1998a).

TWI = WI + % moisture in the feed

The TWI is then converted to a Water Ingestion Rate (WIR) per day in l/kg metabolic mass using the exponent 0.75.

An example of a typical WIRRD will then look as follows:
Arsenic:

Category	Body weight	Age	Feed intake	% Moisture	Range A	Range B
Broiler (3-6weeks)	1.237 kg	4	0.119	11	0.0088	0.0352

WI = 0,1928
TWI = 0.1928 + 0.0131
= 0.206
Metabolic water intake:
= $0.206/BW^{0.75}$
= 0.176
Ingestion Rate of Arsenic:

Range A = 0.176 * 0.05
COC = 0.0088

Range B = 0.176 * 0.2
PHC = 0.0352

Modifying system factors:
Each of the site-specific factors will affect the WIR and consequently the results of the risk assessment. Site-specific factors alter the water concentration at which a given constituent will cause an adverse effect (Casey *et al*. 1998a). A risk assessment cannot be made on a water concentration analysis alone, but requires all variables altering the intake or ingestion rate of a constituent to be taken into account.

The model includes an option of including site-specific factors or excluding them.
The WIRRD is modified according to the effect of the variable on the TWI and WIR.

For example: A broiler in a back yard venture, will not have the same production capability in terms of live-weight gain as a broiler in a commercial venture with environment controlled housing, the correct lighting schedule, stocking densities and feeder and drinker space. Some variables will therefore benefit the WIR and some will penalize the WIR (Casey *et al*. 1998a).

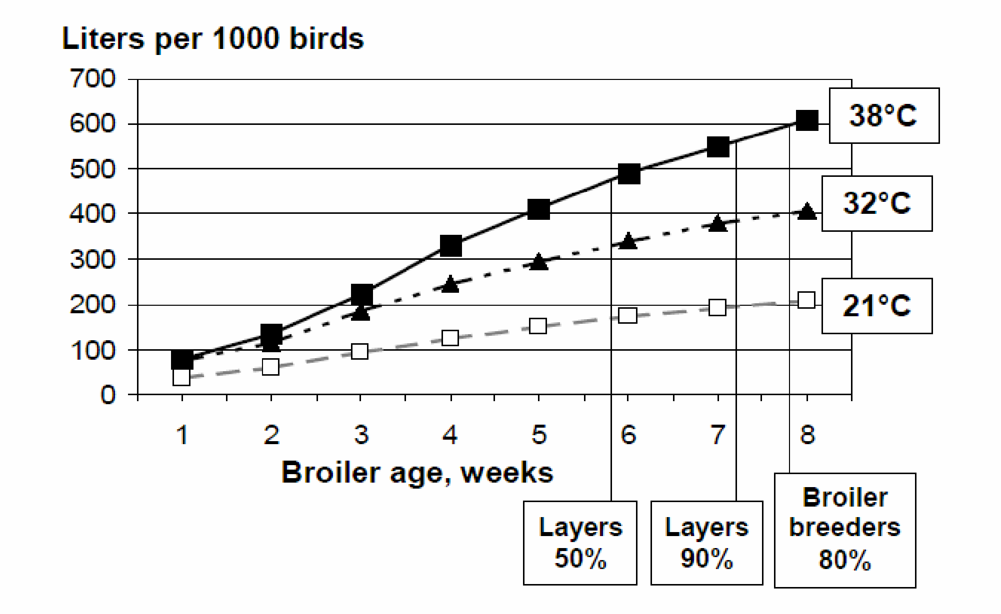
The "factor" system (Casey *et al*. 1998a) is applied by calculating the cumulative effect of all factors either increasing or decreasing the WIR. Factor values assigned to the relevant variables depend on whether they increase or decrease the WIR. The reason for using factor values is that many livestock, livestock production and site-specific factors have an effect on water intake and water turnover, but due to their high variability cannot be accommodated in an equation format. However, to exclude them would be to ignore significant effects. Therefore, in the interests of providing a risk assessment that is a managerial decision making tool, these factors are brought in where appropriate and are presented to the user in two result formats, namely, with and without system factors (Casey *et al*. 1998a). The factors attributing to the modification of the WIR are presented in Appendix 1 and 2 to Chapter 5.

The factors influencing broiler breeder performance, as well as broiler progeny performance, may be divided into two main categories : 1) genetics or inheritance; and 2) environment which includes temperature, humidity, disease, nutrition, feed quality, ventilation, stocking density, beak trimming, and so on. It has been estimated that live performance is determined about 30% by genetics and 70% by non-genetic or environmental factors (Hooge 2002).

Under normal conditions, it is generally assumed that birds will drink around twice as much water by weight as the amount of feed they consume. Water intake increases with age but decreases as a percent of body weight. Water intake varies considerably with air and water temperature. Water consumption increases by approximately 7% for each 1°C above 21°C. This will be greater if the water is cooler than the air and less if the water is warmer than the air. Excess minerals in feed or water above the nutritional requirement will cause increased water consumption and may result in wet manure. Feeds containing more minerals than are anticipated, such as sodium chloride from fishmeal, potassium and ash from molasses or magnesium from calcium or phosphate sources all increase water consumption.

Weight and feed conversion are usually not affected unless water is limiting or if the water contains an excess of the particular mineral that is high in the diet. Average figures for water consumption in broilers and layers are given in Figure 5.3. These should be used as a guideline only. It is recommended that data on water consumption be kept for individual flocks of birds at various points over the course of the year and include both cool and warm weather. The data can then be used later should the need for medication through drinking water arise (Swick 2000).

Figure 5.3 Effect of Temperature on consumption of water in poultry (Swick, 2000)



Site-specific factors addressed.

The site-specific factors affecting water intake and thus the WIRRD of poultry are the following:

Poultry detail:

Production system Breed
Category Application
Age Sex

<u>The production systems addressed are the following:</u>

- Broiler
- Layer
- Breeders

Each of these production systems can be operated at one of the following application levels:

- Commercial
- Semi-intensive
- Back yard
- Free ranging

Animal detail:

General

Feed intake *
Body weight *
Life cycle length
Flock size
Beak trimming
Water intake *
Mortalities
Wet droppings
Gender ratio

Broilers

Target body weight
Feed conversion ratio
Body weight gain

Layers

Egg production *
Egg shell strength
Egg weight
Age at first egg

Breeders

Gender ratio
Egg weight
Age at first egg
Egg production *
Eggshell strength

Dual purpose

All the above

Environment:

Housing
Ventilation rate
Lighting
Stocking density
Air velocity
Feeder space/type
Drinker space/type
Relative humidity
Altitude Temperature *
Floor type

Nutrition:

General

Feeding program *
Watering program
Feed texture/Pellet size *
Phase feeding
Raw materials
Additives
Vaccines/medication
Vitamin and mineral premixes
Nutrient interrelationships
Palatability
NaCl *
Protein
Energy
Lysine
Ca:P

Some of the above factors are attributes to the model, which need to be known, and others are optional or just for record keeping purposes. Attributes that are required are marked with an * and are the minimum information required to run the model.

WIRRD Constituents

The Generic- WQGIS values were used as the trigger values for a PHC in the WIRRD.
A Mineral Reference Document (MINRD) is built into the model. This reference document contains mineral requirements for poultry. The model adds the content of a specific mineral in both the feed and the water, then compares it to the MINRD to see whether requirements are met or not (Casey *et al*. 1998a).

The results of both the comparisons between the WIRRD and MINRD with the sample-information are presented on a result screen, with supporting information and risk assessments. PHC and COC are pointed out and suggestions are made to alleviate problems.

Water quality constituents, which are addressed in the WIRRD for poultry, are presented in Table 5.3 below.

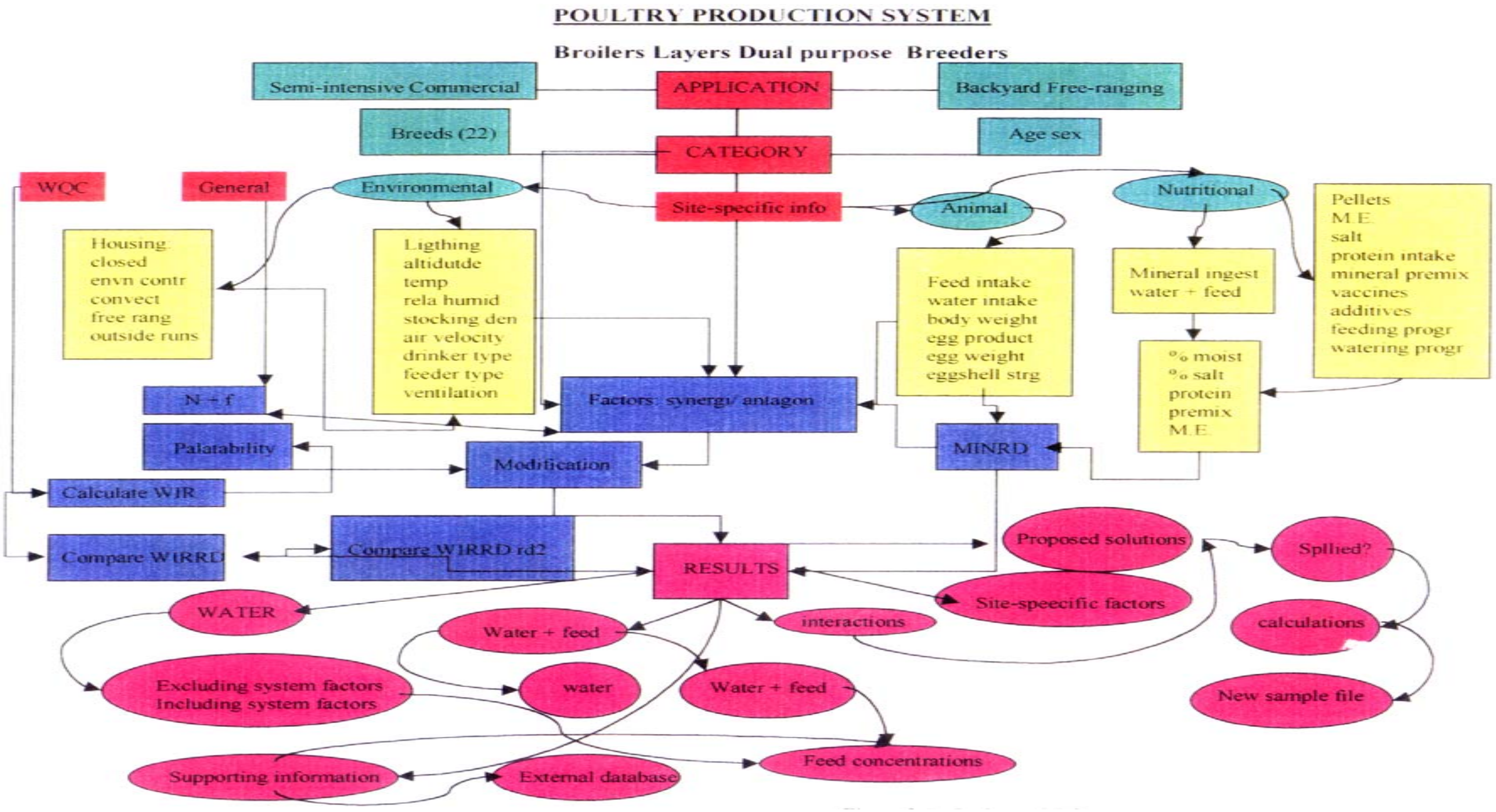
Table 5.3. Water quality constituents with a WIRRD

Arsenic
Bicarbonates
Calcium ,Cadmium, Chloride, Chromium, Copper
Fluoride
Iron
Lead
Magnesium, Manganese, Mercury
Nitrate, Nitrite
Selenium, Sodium, Sulphate
Total Dissolved Solids
Zinc

The specific model:

The basic model used for poultry in the Specific-WQGIS evaluates information concerning the water, the animal, the environment and the nutrition of the animal. This evaluation happens within a category, production system, application, sex and age of the water user group.

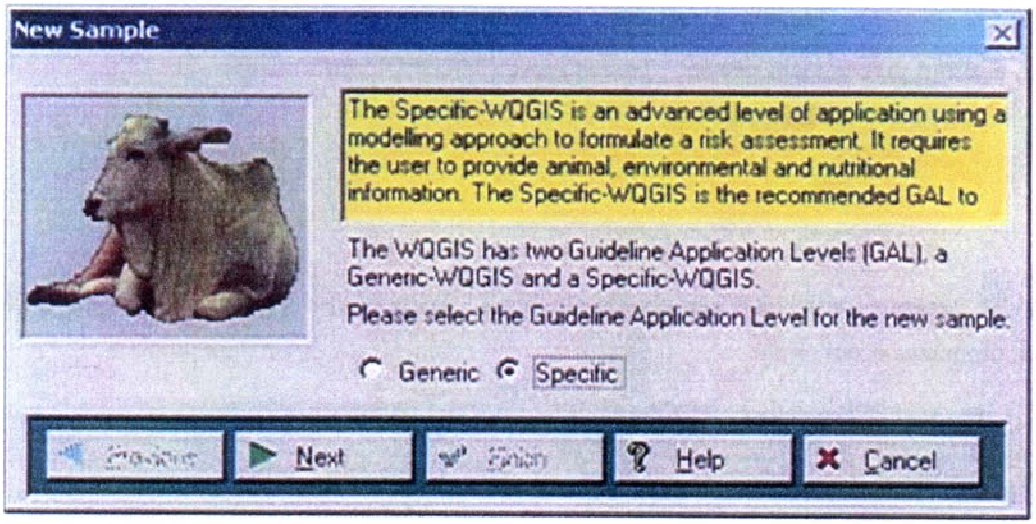
Figure 5.4 Basic model for the Specific application for poultry

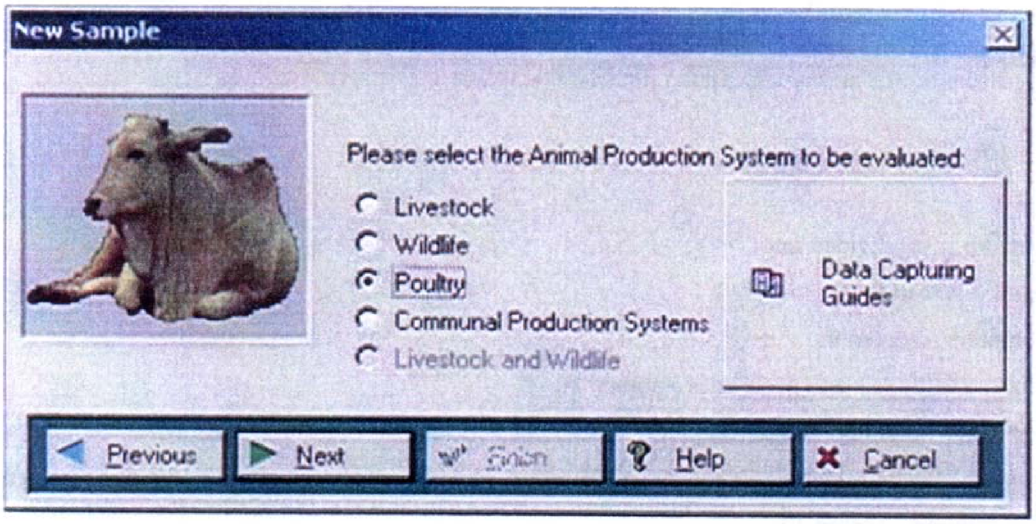


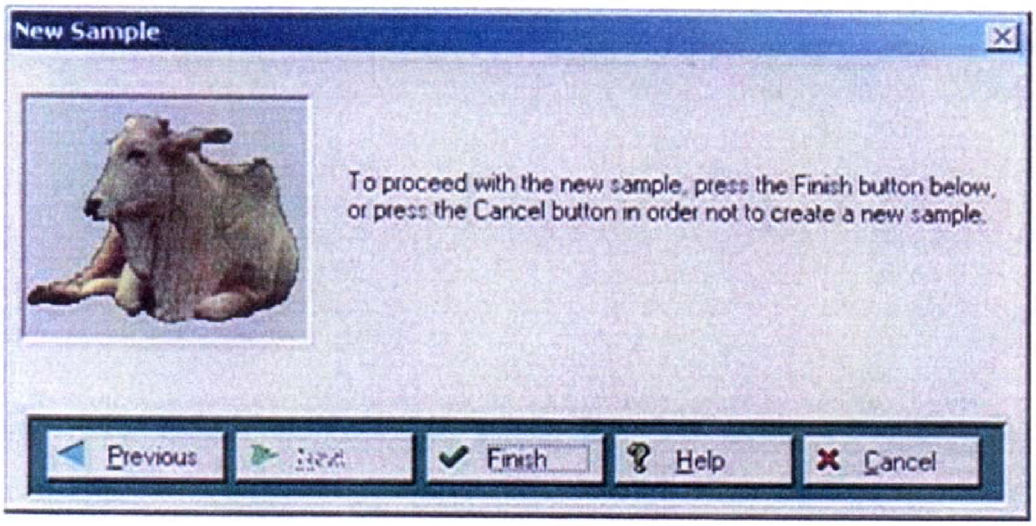
User interface of the Specific WQGIS

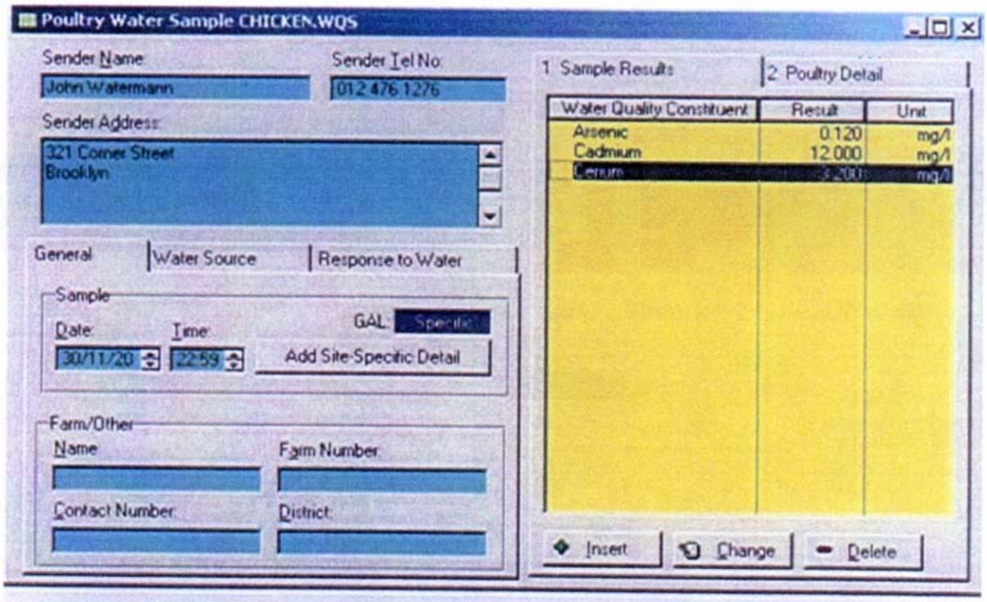
Examples of the general sequence of screens encountered by the user are shown in Screens 5.2

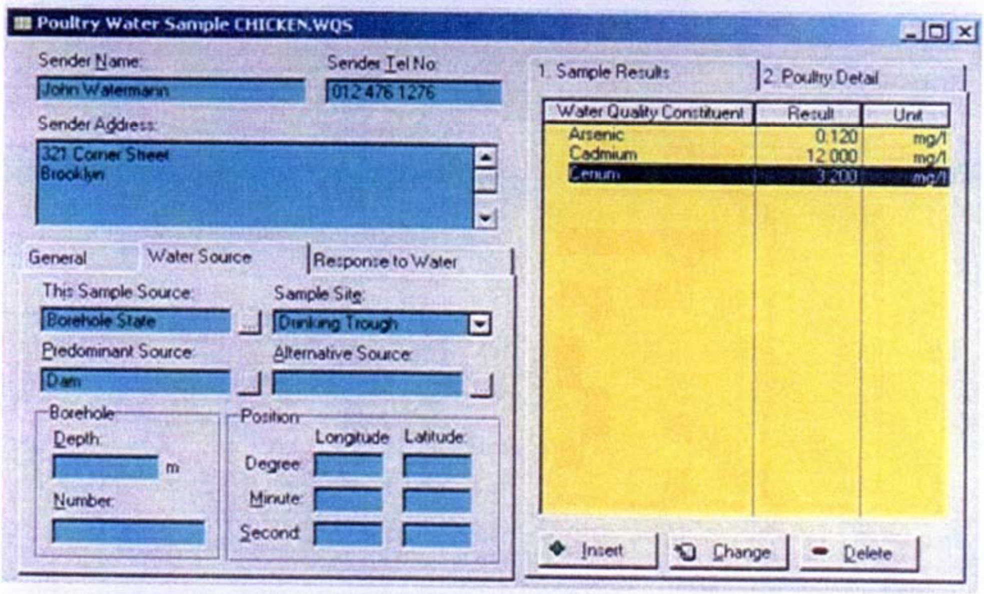
Screens 5.2 Specific WQGIS – software environment

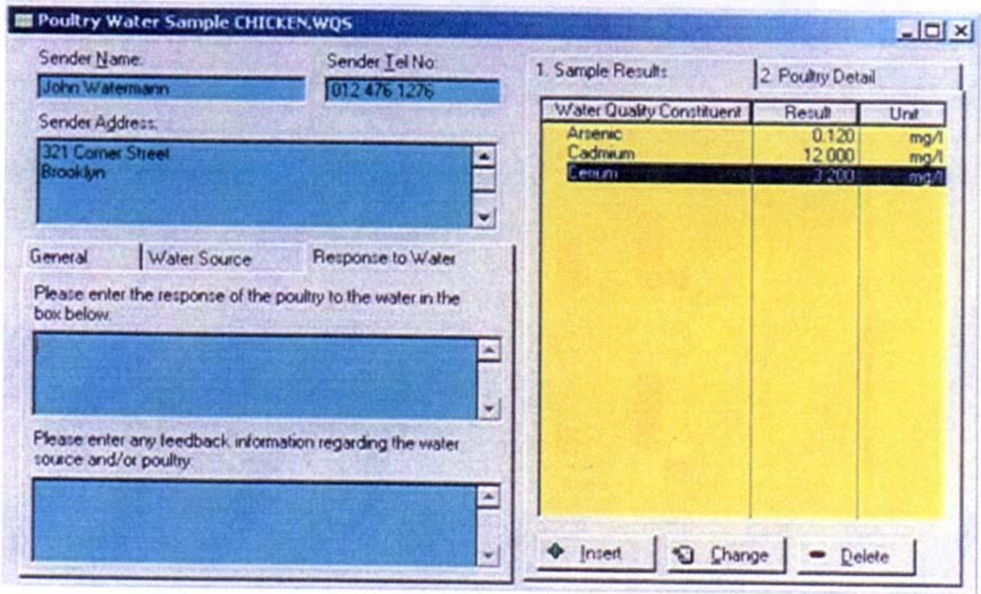


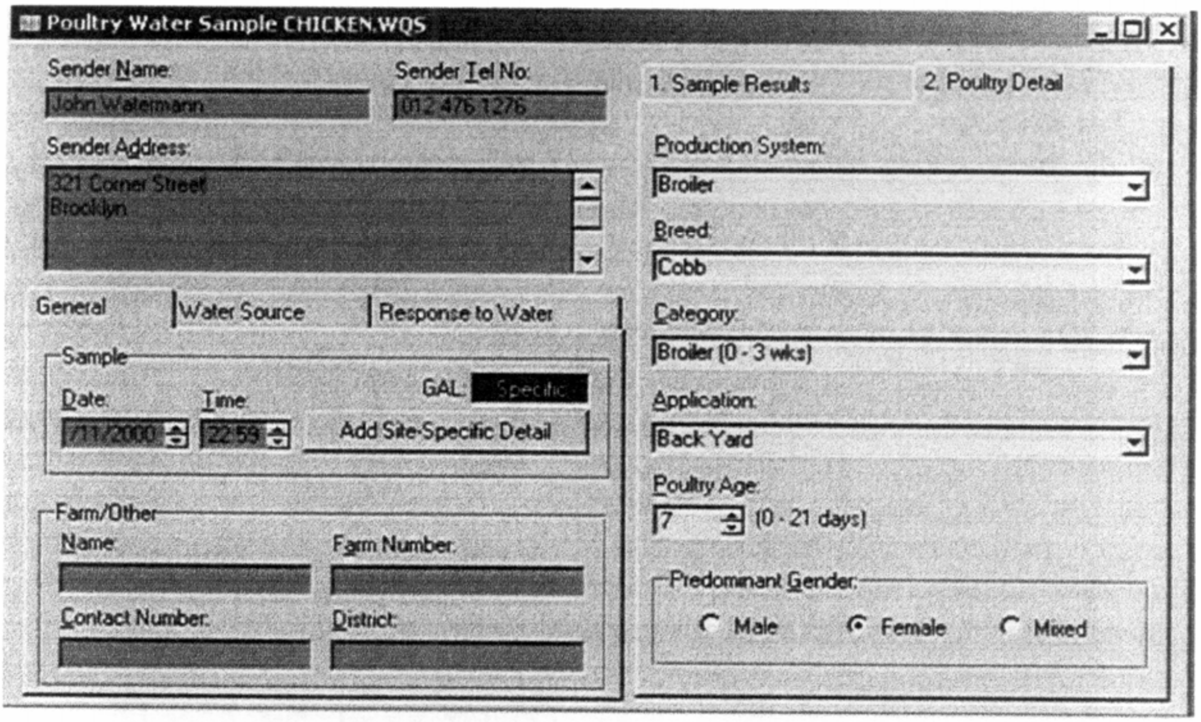


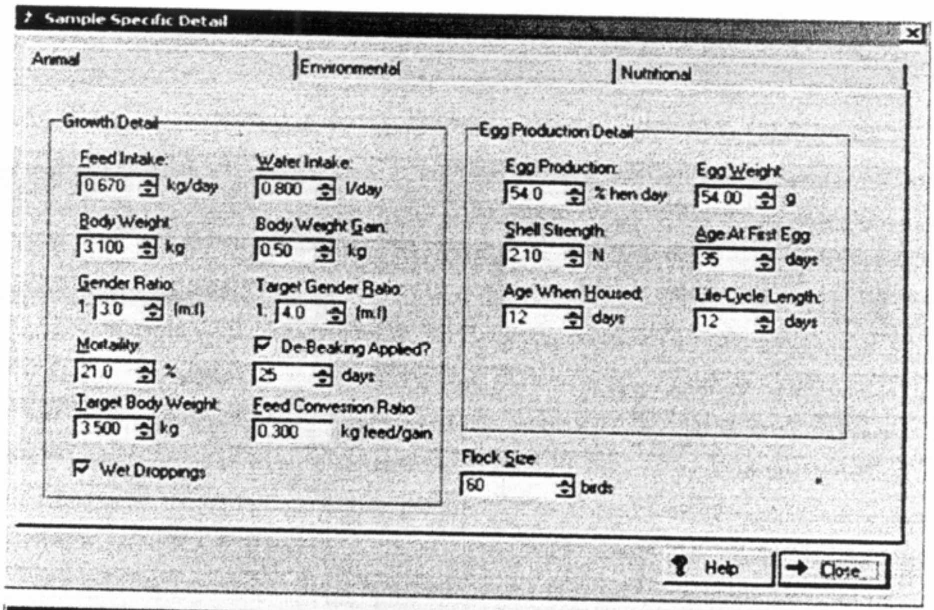


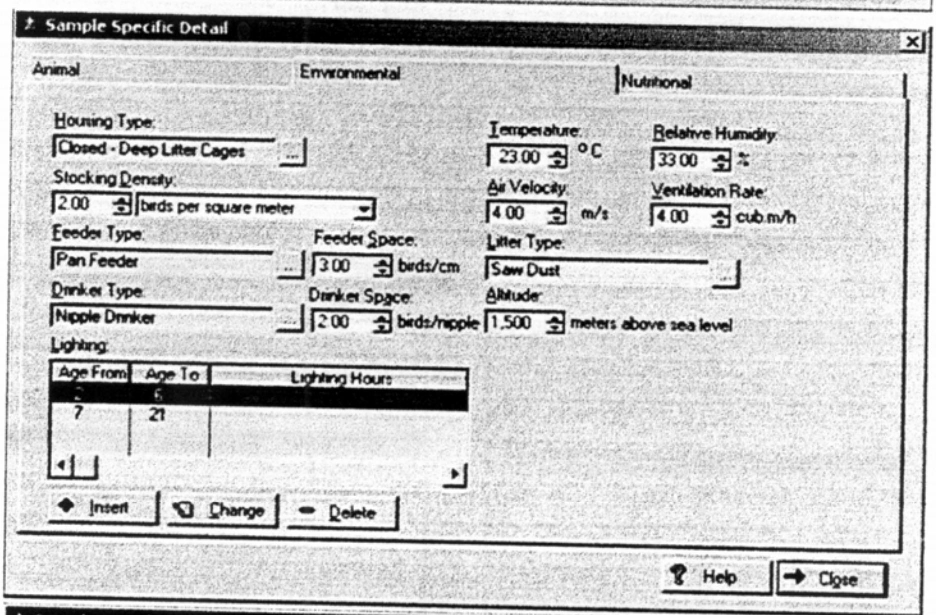

Poultry Water Sample CHICKEN.WQS
Sender Name:
John Watermann
Sender Tel No:
012 476 1276
Sender Address:
321 Corner Street
Brooklyn
General
Water Source
Response to Water
Sample
Date:
30/11/20
Time:
22:59
GAL:
Specific
Add Site-Specific Detail
Farm/Other
Name:
Farm Number:
Contact Number:
District:
1. Sample Results
2. Poultry Detail
Water Quality Constituent
Result
Unit
Arsenic 0.120 mg/l
Cadmium 12.000 mg/l
Cerium 3.200 mg/l
Insert
Change
Delete

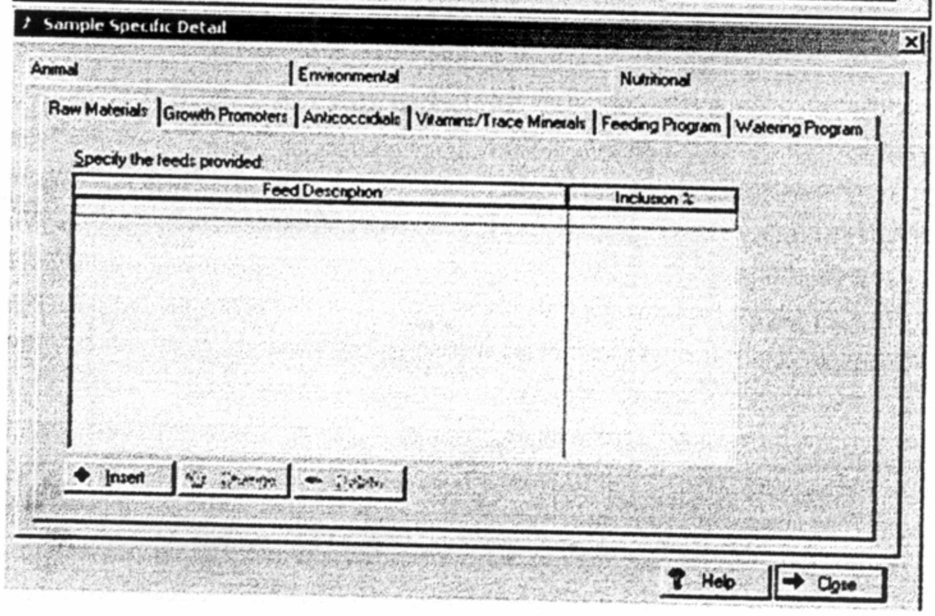

Poultry Water Sample CHICKEN.WQS
Sender Name:
John Watermann
Sender Tel No:
012 476 1276
Sender Address:
321 Corner Street
Brooklyn
General
Water Source
Response to Water
This Sample Source:
Borehole State
Sample Site:
Drinking Trough
Predominant Source:
Dam
Alternative Source:
Borehole
Depth:
m
Number:
Position
Longitude
Latitude
Degree:
Minute:
Second:
1. Sample Results
2. Poultry Detail
Water Quality Constituent
Result
Unit
Arsenic 0.120 mg/l
Cadmium 12.000 mg/l
Cerium 3.200 mg/l
Insert
Change
Delete

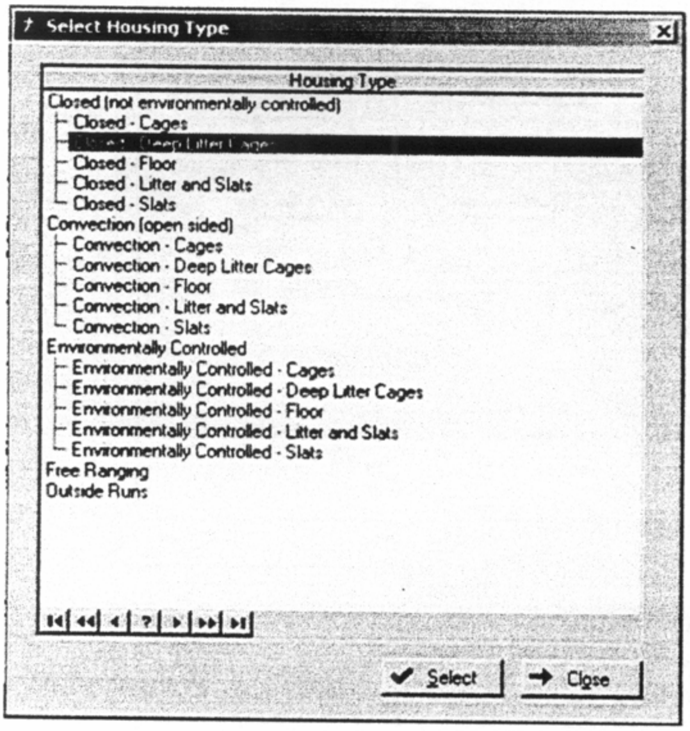

Poultry Water Sample CHICKEN.WQS
Sender Name:
John Watermann
Sender Tel No:
012 476 1276
Sender Address:
321 Corner Street
Brooklyn
General
Water Source
Response to Water
Please enter the response of the poultry to the water in the box below:
Please enter any feedback information regarding the water source and/or poultry:
1. Sample Results
2. Poultry Detail
Water Quality Constituent
Result
Unit
Arsenic 0.120 mg/l
Cadmium 12.000 mg/l
Cerium 3.200 mg/l
Insert
Change
Delete

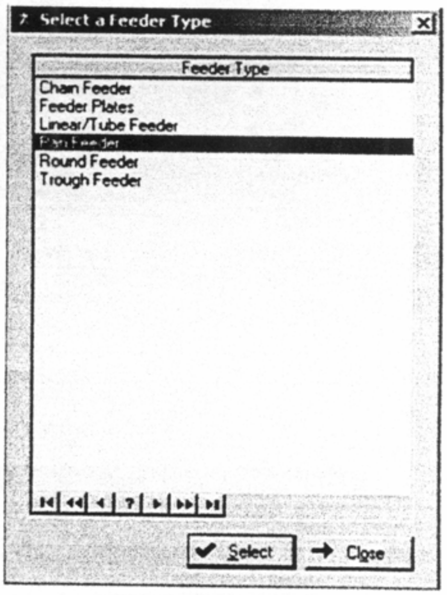

Poultry Water Sample CHICKEN.WQS
Sender Name:
John Watermann
Sender Tel No:
012 476 1276
Sender Address:
321 Corner Street
Brooklyn
General
Water Source
Response to Water
Sample
Date:
7/11/2000
Time:
22:59
GAL:
Specific
Add Site-Specific Detail
Farm/Other
Name:
Farm Number:
Contact Number:
District:
1. Sample Results
2. Poultry Detail
Production System:
Broiler
Breed:
Cobb
Category:
Broiler (0 - 3 wks)
Application:
Back Yard
Poultry Age:
7
(0 - 21 days)
Predominant Gender:
Male
Female
Mixed

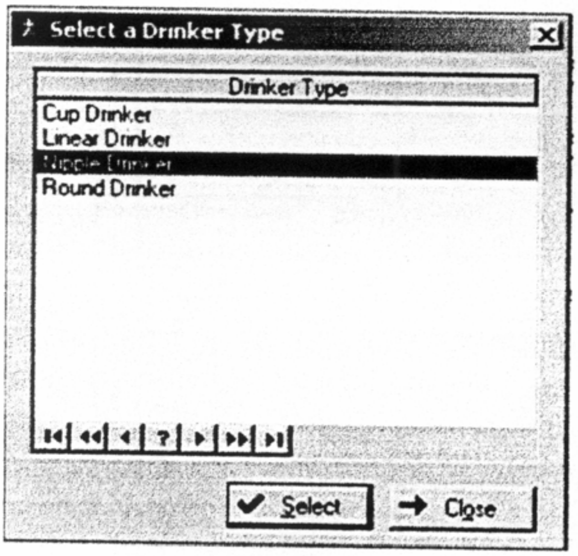

Sample Specific Detail
Animal
Environmental
Nutritional
Growth Detail
Feed Intake:
0.670 kg/day
Water Intake:
0.800 l/day
Body Weight:
3.100 kg
Body Weight Gain:
0.50 kg
Gender Ratio:
1: 3.0 (m:f)
Target Gender Ratio:
1: 4.0 (m:f)
Mortality:
21.0 %
De-Beaking Applied?
25 days
Target Body Weight:
3.500 kg
Feed Conversion Ratio:
0.300 kg feed/gain
Wet Droppings
Egg Production Detail
Egg Production:
54.0 % hen day
Egg Weight:
54.00 g
Shell Strength:
2.10 N
Age At First Egg:
35 days
Age When Housed:
12 days
Life-Cycle Length:
12 days
Flock Size:
60 birds
Help
Close

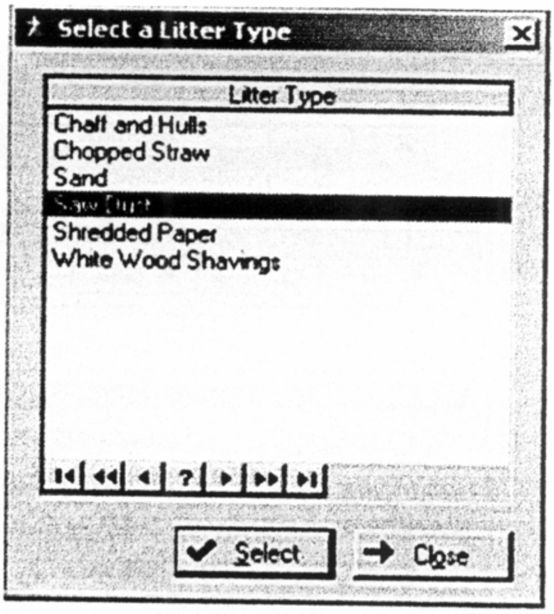

Sample Specific Detail
Animal
Environmental
Nutritional
Housing Type:
Closed - Deep Litter Cages
Stocking Density:
2.00 birds per square meter
Feeder Type:
Pan Feeder
Feeder Space:
3.00 birds/cm
Drinker Type:
Nipple Drinker
Drinker Space:
2.00 birds/nipple
Temperature:
23.00 °C
Relative Humidity:
33.00 %
Air Velocity:
4.00 m/s
Ventilation Rate:
4.00 cub.m/h
Litter Type:
Saw Dust
Altitude:
1,500 meters above sea level
Lighting:
Age From
Age To
Lighting Hours
7
21
Insert
Change
Delete
Help
Close

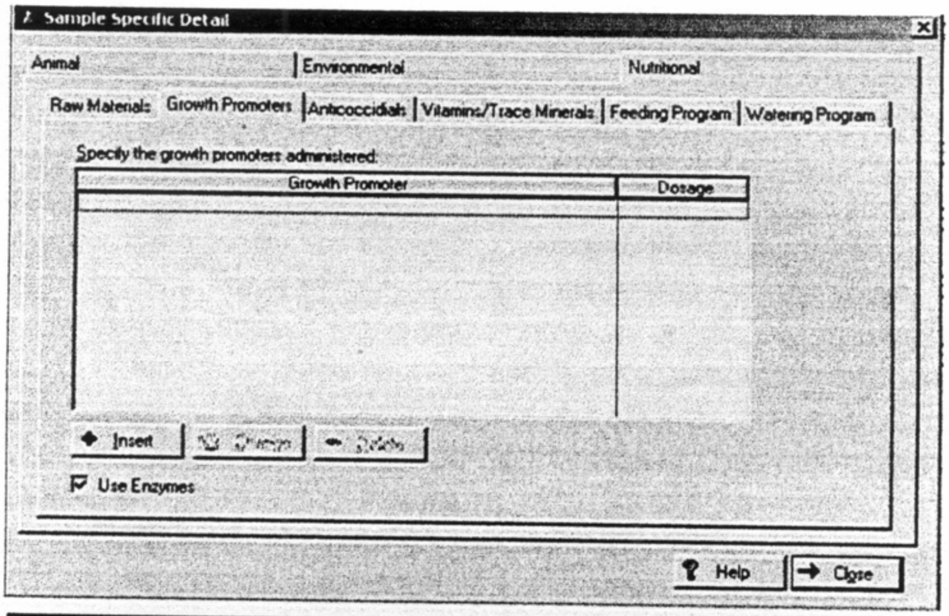

Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Specify the feeds provided:
Feed Description
Inclusion %
Insert
Help
Close

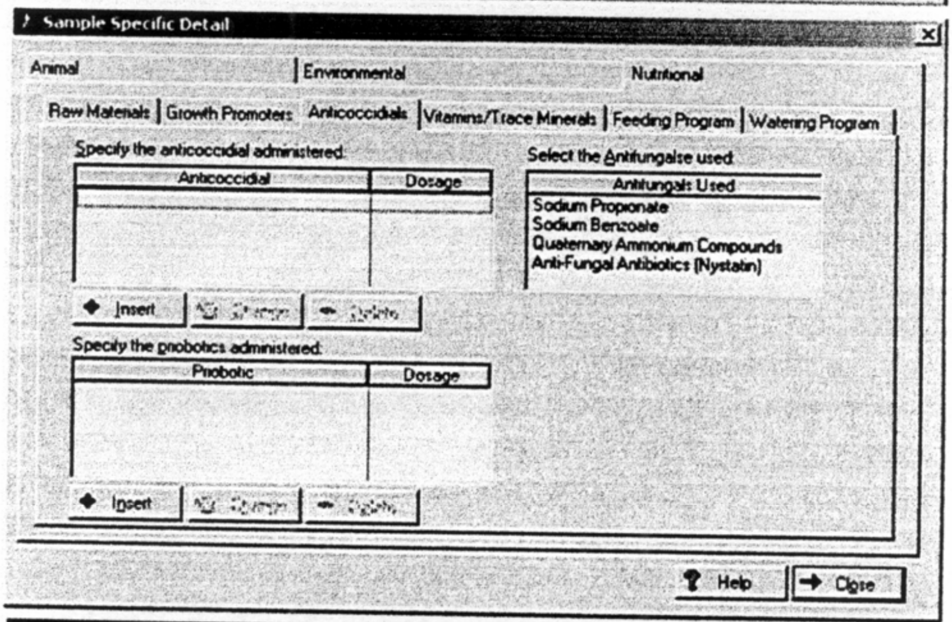

Select Housing Type
Housing Type
Closed (not environmentally controlled)
Closed - Cages
Closed - Deep Litter Cages
Closed - Floor
Closed - Litter and Slats
Closed - Slats
Convection (open sided)
Convection - Cages
Convection - Deep Litter Cages
Convection - Floor
Convection - Litter and Slats
Convection - Slats
Environmentally Controlled
Environmentally Controlled - Cages
Environmentally Controlled - Deep Litter Cages
Environmentally Controlled - Floor
Environmentally Controlled - Litter and Slats
Environmentally Controlled - Slats
Free Ranging
Outside Runs
Select
Close

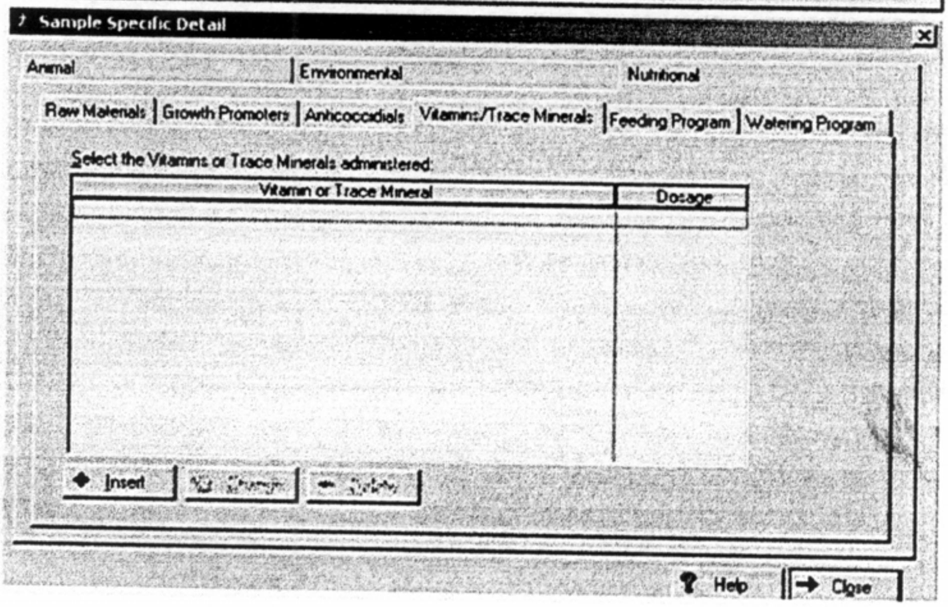

Select a Feeder Type
Feeder Type
Chain Feeder
Feeder Plates
Linear/Tube Feeder
Pan Feeder
Round Feeder
Trough Feeder
Select
Close

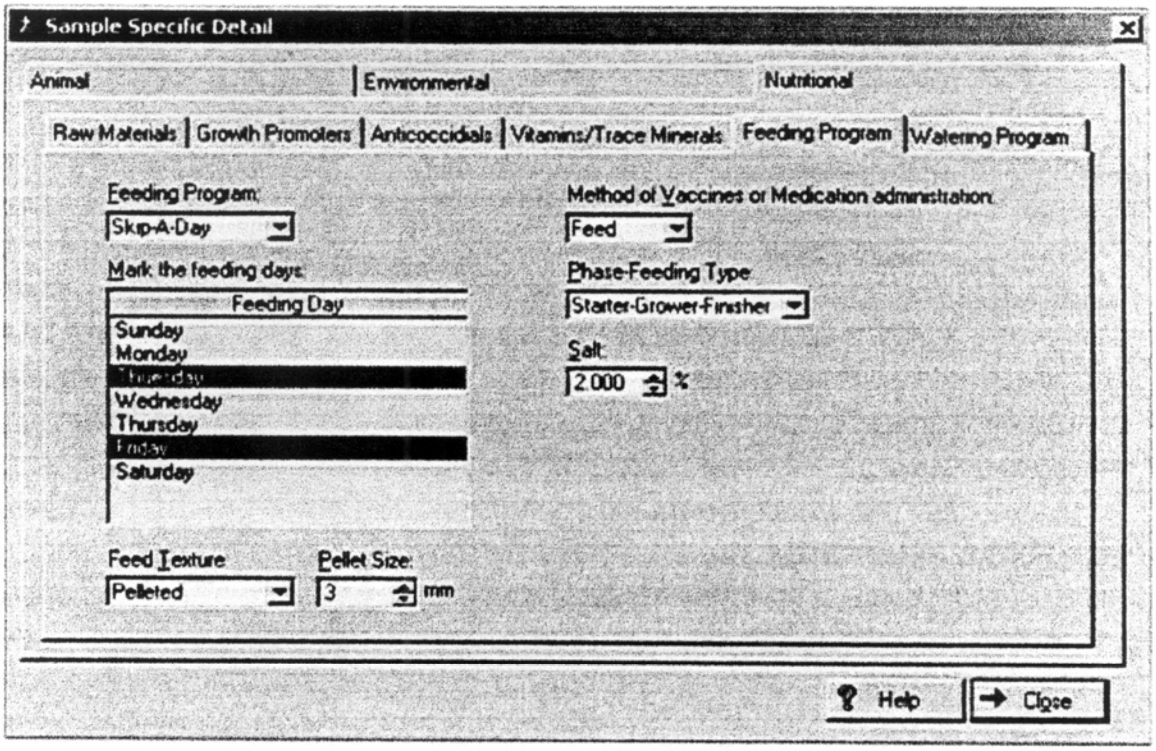

Select a Drinker Type
Drinker Type
Cup Drinker
Linear Drinker
Nipple Drinker
Round Drinker
Select
Close

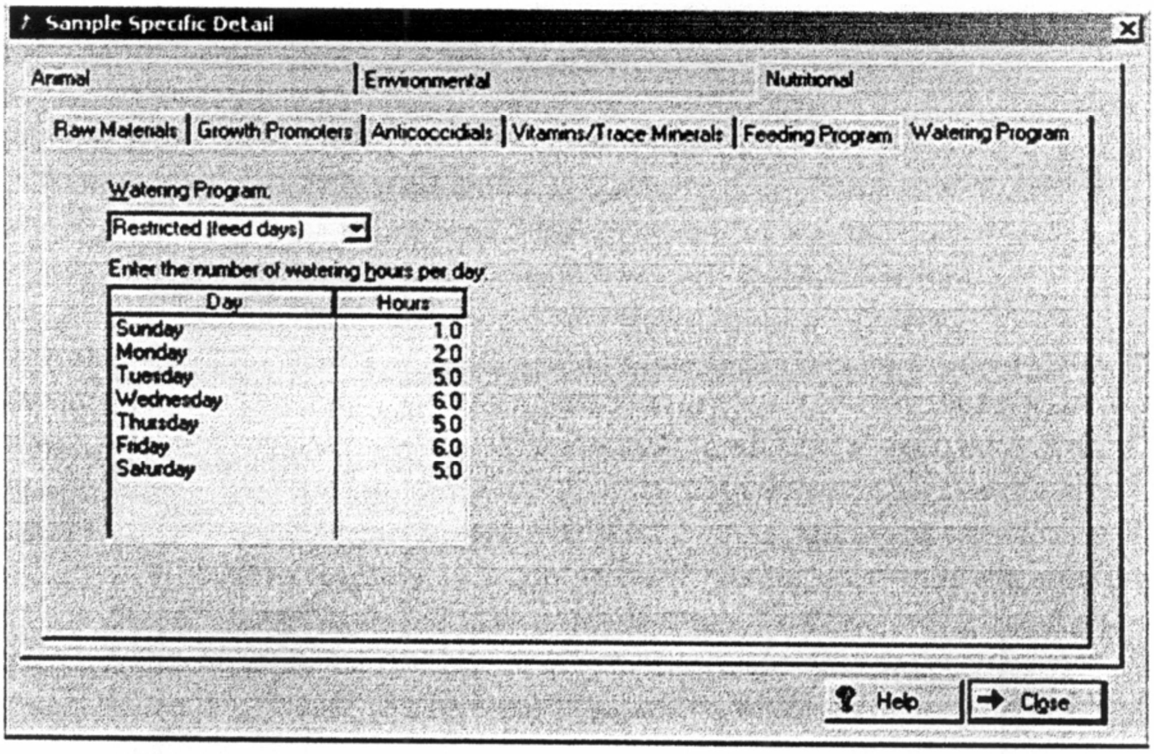

Select a Litter Type
Litter Type
Chaff and Hulls
Chopped Straw
Sand
Saw Dust
Shredded Paper
White Wood Shavings
Select
Close


Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Specify the growth promoters administered:
Growth Promoter
Dosage
Insert
Change
Delete
Use Enzymes
Help
Close


Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Specify the anticoccidial administered:
Anticoccidial
Dosage
Select the Antifungalse used
Antifungals Used
Sodium Propionate
Sodium Benzoate
Quaternary Ammonium Compounds
Anti-Fungal Antibiotics (Nystatin)
Insert
Change
Delete
Specify the probiotics administered:
Probiotic
Dosage
Insert
Change
Delete
Help
Close


Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Select the Vitamins or Trace Minerals administered:
Vitamin or Trace Mineral
Dosage
Insert
Change
Delete
Help
Close


Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Feeding Program:
Skip-A-Day
Mark the feeding days:
Feeding Day
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Method of Vaccines or Medication administration:
Feed
Phase-Feeding Type
Starter-Grower-Finisher
Salt:
2.000 %
Feed Texture:
Pelleted
Pellet Size:
3 mm
Help
Close


Sample Specific Detail
Animal
Environmental
Nutritional
Raw Materials
Growth Promoters
Anticoccidials
Vitamins/Trace Minerals
Feeding Program
Watering Program
Watering Program:
Restricted (feed days)
Enter the number of watering hours per day:
Day
Hours
Sunday 1.0
Monday 2.0
Tuesday 5.0
Wednesday 6.0
Thursday 5.0
Friday 6.0
Saturday 5.0
Help
Close

Help files

A comprehensive help file was incorporated into the system. This gives the user detailed information on each constituent, its effect on poultry, normal tissue levels, toxicity, toxicity signs and interactions (Source: Puls, 1994. Mineral levels in animal health, diagnostic data). A problem solving Reference Document (RD) is also included into the Help file. This document enables the user to do on-the-spot problem solving, provides possible causes for problems and suggests actions to take in case of a specific problem.

Conclusion

Only 10% of South Africa receives an annual rainfall of more than 750 mm. The rainfall pattern is extremely irregular and varies considerably from the average. Water is therefore a valuable commodity in the country and any tool that increases or fine-tunes its use and application holds merit. This thesis highlights the fact that many poultry producers in South Africa have to use water with water quality constituent concentrations way above the norm. The effect of some of these constituents on poultry production has also been addressed. Previously established water quality guidelines recommend much lower maximum levels of water quality constituent concentrations. It is now clear that poultry can tolerate far higher levels without negative effects on production. Developing a water quality assessment tool was therefore a natural progression from the results obtained in the experiments.

For large, intensive commercial production systems a WQC that has a negative influence on nutrient bioavailability or feed intake can have a significant effect on the cost of production. For those production systems operating on large volumes and narrow margins between feed costs and profitability, the contribution that the chemical composition of the water source makes towards mineral requirements, must be taken into account if feed formulation is to be accurate and representative of the true requirements.

The use of both the Generic and Specific GAL should allow for a more accurate observation and assessment of site-specific factors and will also prevent the incorrect classification of water sources as being potentially hazardous based on rudimentary guidelines. It will encourage water users to acknowledge water with a high mineral content as not simply water with poor quality, but rather as a potentially valuable source of minerals for poultry production.

Appendix 1 to Chapter 5

Supporting information for the site specific factors addressed

The following section presents the supporting information for the inclusion of those site-specific factors relevant to poultry production systems in terms of increasing or decreasing risk due to the presence of PHCs in the water source. These factors are based on the literature cited and research conducted. Each of the mentioned factors are incorporated into the model since they all effect water intake, and hence the dose ingestion of a PHC.

ANIMAL

- **Feed intake**

$DFU = -17.7 + 3.45D + 8.11 \times 10^{-2}D^2 - 1.54 \times 10^{-3}D^3$

$(14 < D < 56)$

Where DFU = daily feed use, kilograms per 1000 birds and D = days of age (Xin and Berry, 1994).

- **Water intake:**

Broilers:

$DWU = -2.78 + 4.70D + 0.128D^2 - 2.17 \times 10^{-3}D^3$

$(1 \leq D \leq 56)$

Where DWU = daily water use, litres per 1000 birds (Xin and Berry, 1994).

Layers:

$WI = -0.057\ BW^2 + 0.031\ BW - 0.000002\ EP^2 + 0.0005\ EP - 0.181$

Where WI = Water intake; BW = Body weight; EP = Egg production

The layer equation was developed from local research (Casey *et al*., 1998).

Table 5.4 shows the water intake of different type of poultry at different ages and at moderate and hot temperatures.

Table. 5.4. Daily ad-libitum water consumption of poultry (l/1000 birds) (Leeson and Summers, 1997)

Poultry type	Age	20 °C	32 °C
Leghorn Pullet	4 wk 12 wk 18wk	50 115 140	75 180 200
Laying hen	50% 90%	150 180	250 300
Non-laying hen		120	200
Broiler breeder pullet	4wk 12wk 18wk	75 140 180	120 220 300
Broiler breeder hen	50% 80%	180 210	300 260
Broiler chicken	1wk 3wk 6wk 9wk	24 100 240 300	40 190 500 600
Turkey	1wk 4wk 12wk 18wk	24 110 320 450	50 200 600 850
Turkey breeder hen		500	900
Turkey breeder tom		500	1100
Duck	1wk 4wk 8wk	28 120 300	50 230 600
Duck breeder		240	500
Goose	1wk 4wk 12wk	28 250 350	50 450 600
Goose breeder		350	600

- **Body weight**

Xin, and Berry, 1994, developed the following regression equations for 2 age groups.

$LBW = 48 + 3.64D + 0.636D^2 + 9.63 \times 10^{-3}D^3$

$(1 < D < 28)$

$LBW = -1004 + 65.8D$

$(28 < D < 56)$

- **Mortalities**

$CM = 4.02 \times 10^{-2} - 0.105D + 8.58 \times 10^{-2}D^2 - 5.11 \times 10^{-3}D^{-3}$

$(1 \leq D \leq 10)$

$CM = 1.26 + 0.174D - 5.56 \times 10^{-3}D^2 + 7.53 \times 10^{-5}D^3$

$(11 \leq D \leq 56)$

CM = cumulative mortalities as a percentage of those placed (Xin, and Berry, 1994).

- **Body weight gain and feed conversion:**

$G = -31.797 + 1.2071T + 0.21457BW - 8.852 \times 10^{-5}BW^2 + 1.51 \times 10^{-8}BW^3 - 2.0772 \times 10^{-3}TBW$

Where G = gain per day, grams per day; T = environmental temperature, Celsius and BW = body weight, grams.

$FC = 2.0512 - 2.007 \times 10^{-2}T - 7.226 \times 10^{-4}BW + 1.7361 \times 10^{-7}BW^2 + 2.5564 \times 10^{-5}TBW$

Where FC = feed:gain in grams of feed consumed per grams of BW gain; T = environmental temperature, Celsius and BW = body weight, grams (May *et al.,* 1998).

- **Egg production**

During the period when an egg is formed, a marked increase in water intake is observed. The overall increase in fluid intake is associated with a fall in plasma osmolarity of up to 14% and an increase in urine minute volume. This can be explained as a simple osmotic adjustment.

Plasma osmolarity changes follow alterations in ingestive activity with a phase lag of less than 0.5 h, indicating rapid assimilation of ingested water. Changes in renal output are much slower (1.5 h later) and are quantitatively insufficient to account for the increased fluid intake, which occurs at that time.

Only 8g more urine is produced on a laying than on a non-laying day, and the water content of an egg is approximately 32g, though the extra water ingested amounted to 140g, the accountable fluid loss on a lying day is only 40g. (Howard, B.R., 1975,)

Food intake is greater on days on which ovulation occurred than on days during which there was neither ovulation nor oviposition. Water intake is greater on days during which ovulation occurred than on days with oviposition but no ovulation. On a laying day, food intake is greater than on days without ovulation and oviposition (resting day). Both food and water intakes are depressed for 1 to 2 hours before oviposition, but ingestion increase during the hour of laying and remain high for 1 to 2 hours. (Wood-Gush and Horne, 1970). Approximate water requirements at varying percentages of egg production is shown in Table 5.5 (North and Bell, 1990).

Table 5.5. Egg production and water consumption of layers.

Hen-day Egg production (%)	Water consumption per 1000 birds (l)
10	**151**
30	**159**
50	**174**
70	**201**
90	**239**

- Gender ratio

Too many males in the breeding pen reduces fertility, as do too few. The correct ratio of males to females depends on the type and size of the birds involved and is defined on the basis of the number of cockerels per 100 pullets. Allow a few extra males for early culling and mortalities and provide more males on slats and slats and litter than on all litter floors. The male to female ratio does not affect the frequency of male mating (North and Bell, 1990) (Table 5.6).

Table 5.6. Recommended male female ratios.

Male of mating	Female of mating	Mating Producers	Males per 100 females	
			On Litter	On Slats and litter
Mini-Leghorn	**Standard Leghorn**	**Commercial mini Leghorn Pullet**	**8**	**9**
Standard Leghorn	**Standard Leghorn**	**Commercial standard Leghorn Pullet**	**8**	**9**
Medium size	**Medium Size**	**Commercial medium-size pullet (brown eggs)**	**9**	**10**
Standard meat-type	**Mini-meat-type**	**Commercial broiler**	**9**	**10**
Standard meat-type	**Standard meat-type**	**Commercial broiler**	**10**	**11**

- **Beak trimming**

Beak trimming in adult hens caused a temporary fall in food intake, which was not followed by a compensatory hyperphagia, and body weight was reduced for at least 6 weeks. Removal of half the beak had more effect than removing one-third and the consequences were greater when the hens were fed pellets rather than mash. Beak trimming reduced feeding efficiency (number of pecks per gram of pellets ingested) to only 20% of its pre-operative value. Pecking rate rose sharply after beak trimming, then declined to the pre-operative value after 3 weeks, indicating a decline in feeding motivation. (Gentle *et al* 1982, Table 5.7, 5.8 and 5.9).

Table 5.7. Feed consumption and body weights of pullets on various debeaking treatments.

Debeaking	Feed consumed to 20 weeks of age (g)	Body weight (g) at	
		20 weeks	35 weeks
1 day, precision	**6244.3**	**1285.9**	**1557.4**
6 day, precision	**6407.0**	**1340.6**	**1619.6**
6 week, inside slant	**64616**	**1335.8**	**1612.6**
8 week, non-precision	**6384.6**	**1324.5**	**1625.7**
12 week, non-precision	**6115.2**	**1264.0**	**1565.3**
16 week, non-precision	**6752.1**	**1353.7**	**1552.8**
Non-debeaked	**6719.4**	**1401.6**	**1695.2**

Table 5.8. Effects of age at final beak trimming on age at 50% production, mortality, feed consumption, egg mass and egg production from 140 to 441 days.

Measurement	Beak trimming treatment		
	63 days	84 days	105 days
Age at 50% production (days)	**157.5**	**155.9**	**155.6**
Mortality (%)	**5.4**	**7.6**	**9.2**
Feed consumption (g/hen/day)	**106**	**109**	**108**
Egg mass (g/hen day)	**43.0**	**43.6**	**43.4**
Egg production (hen day %)	**77.0**	**78.4**	**78.1**

Table 5.9. Effects of beak treatment and age on body weight, weight gain, feed intake and the feed to gain ratio of pullets from 4 to 7 weeks of age.

Comparison	Body weight (g)	Weight gain (g)	Feed usage (g/day)	Feed:gain ratio (g/g)
Trimmed	**355**	**83.3**	**37.1**	**3.14**
Intact	**376**	**92.6**	**42.4**	**3.19**
Age				
4 weeks	**329**			
5 weeks	**313**	**73.8**	**30.6**	**2.96**
6 weeks	**407**	**93.9**	**41.2**	**3.07**
7 weeks	**503**	**96.3**	**47.5**	**3.47**

Broilers

After beak trimming, broilers fed firm pellets with essentially no fines experienced feed consumption and weight gain depressions from 50 to 70 days of age, compared with the corresponding values for controls. When birds were changed from mash to pellet diets at 42 days of age, there was a significant initial increase in feed intake and body weight gain in broilers receiving the pelleted diet, compared with broilers receiving the mash diet (Deaton *et al*. 1988, Table 5.10).

Table 5.10. Effect of beak trimming on body weight gain and feed consumption of broilers fed feed in mash and pelleted form

Beak trimming	50 day Beginning weight	50 – 56 days		56 – 70 days	
		Weight gain	Feed consumption	Weight gain	Feed consumption
		(g)			
All mash diet					
None	**2.457**	**443**	**1.110**	**898**	**2.813**
1/3 Top	**2.484**	**402**	**1.010**	**863**	**2.704**
½ Top	**2.487**	**380**	**960**	**845**	**2.693**
½ Block	**2.475**	**287**	**825**	**911**	**2.657**
Pelleted diet					
None	**2.602**	**431**	**1.118**	**850**	**2.633**
1/3 Top	**2.606**	**215**	**766**	**699**	**2.173**
½ Top	**2.593**	**-91**	**428**	**484**	**1.643**
½ Block	**2.598**	**-48**	**462**	**460**	**1.605**

Environmental detail:

Housing

Housing types:

1. Convection (open-sided)
   - Floor with litter
   - Slats
   - Cages
   - Litter and slats
2. Environmentally controlled
   - Floor with litter
   - Slats
   - Cages
   - Litter and slats
3. Closed house (not environmentally controlled)
   - Floor with litter
   - Slats
   - Cages
   - Litter and slats
4. Outside runs
5. Free ranging

2. Ventilation rate

Humidity rises with cooling. Reducing the temperature of the incoming air by 10° will cause humidity to go up 20%. Reducing it by 20° will result in the relative humidity of the incoming air increasing 40%. In a study by Lacy and Czarick (1992) daily temperatures averaged 36°C. Typically, temperatures were reduced by 1 - 2°C in conventional housing and 4 - 7°C in tunnel-ventilated housing. Body weights at 55 days averaged 2.42 kg in the tunnel-ventilated house and 2.33 kg in the conventional house. Feed conversion was 2.03 and 2.05 in the tunnel ventilated and conventional houses, respectively. Livability was essentially the same in both houses. Electricity costs over the entire grow-out in the tunnel-ventilated house were nearly double those of the conventional house. However, these costs were only 20 - 30% higher on hot days.

3. Air velocity

Air speed around each bird greatly influences the comfort of the bird. During marginally cool temperatures, air movements can easily and quickly chill the birds, particularly young birds. During hot weather, birds are kept comfortable, even at high measured temperatures, by the movement of air across their bodies (Krevinghaus 1997).

Male broilers were grown in environmental chambers from 21 to 49 days of age and weighed weekly. The chambers were maintained at 27°C and broilers were exposed to still air (< 15 m/min) or air velocity of 120 m/min. Water usage was calculated as percent of body weight per day. Daily water usage for still air ranged from 23% of body weight at 22 days to 12% at 48 days. Usage was 17% of body weight at 34 days. Air velocities had no effect before 30 days. After 34 days usage was 15.7% at 120 m/min. The average usage from 35 to 49 days was 14.3% in still air and 12.4% at 120 m/min. These results illustrate the relationship between age and tunnel ventilation (May and Lott 2000).

Wind Chill is the term used to describe the combined effect of low temperature and wind rate on heat loss from the body. As air velocity increases, heat is carried away from the body at a faster rate, driving down both skin temperature and eventually internal body temperature.

The following equation is used to determine the Wind Chill Index (K) for poultry but is applicable only at air velocities higher than 1.79 m/s.

K = 41 – ((10.45 + 10 *(√Air velocity) – Air velocity)*(41 – Temperature)/22.04
Where 41 = the body temperature of a chicken.

4. Lighting

The duration of the adaptation period to continuous light is an important factor in determining feeding behaviour. Two important factors must be adhered to when choosing a lighting program for growing and laying pullets (North and Bell 1990): (1) The length of the light day should never increase for growing pullets and (2) the length of the light day should never decrease for laying pullets (Table 5.11).

Table 5.11 Influence of lighting on sexual maturity, laying house mortality and egg production.

Light treatment		Days to reach 10% Egg prod.	Days to reach 50% Egg prod.	Laying house Mortality %	Egg prod. during 47 weeks of lay
Growing period	Laying period				
Gradually decreased from 22hr to 16 hr	**Gradually increased from 16 hr to 22 hr**	**156**	**172**	**3.3**	**225**
Gradually decreased from 22hr to 9 hr	**Gradually increased from 9 hr to 22 hr**	**172**	**186**	**3.3**	**220**
Gradually decreased from 16hr to 9 hr	**Gradually increased from 9 hr to 16 hr**	**171**	**191**	**3.8**	**220**
Gradually decreased from 16hr to 9 hr	**Gradually increased from 9 hr to 16 hr**	**163**	**176**	**5.0**	**230**
Started on constant 16 hr then suddenly decreased to constant 9 hr	**Suddenly increased from 9 hr to 16 hr**	**165**	**176**	**4.6**	**227**
Constant 16 hr	**Constant 16 hr**	**156**	**171**	**5.0**	**224**

It is accepted that when pullets are delayed in the onset of egg production, the first eggs are larger (North and Bell 1990, Table 5.12).

Table 5.12. Age at lighting and egg size.

Trait	Age at lighting (wk)		
	18	20	22
Average egg weight (g/egg)	**57.7**	**58.8**	**59.4**
Percent large and above	**65.8**	**74.2**	**79.5**

Age at sexual maturity and age at light stimulation are correlated (Leeson and Summers 1997).

$Y = 92.6 + 0.44X$

Where Y = Age at first egg

X = Age at light stimulation.

Broiler lighting:

Although the exact reasons for better growth on intermittent light programs are not known, it is thought that by giving chickens a meal (short feeding period), followed by a longer period of time for digesting the meal (no feed available), the efficiency of feed utilization is improved (Tables 5.13, 5.14).

Table 5.13. Improvements with various lighting programs (North and Bell 1990)

Light program	Hours light and dark	Relative growth efficiency
Continuous light in open sided house	**23 hours light, 1 hour darkness**	**100 (base)**
Continuous light in light tight house	**23 hours light, 1 hour darkness**	**104-106 %**
Intermittent light in light tight house	**1 hour light, 3 hours darkness, then repeat.**	**106%**

Table 5.14. Effect of short day length on male broiler performance (Leeson and Summers 1997)

Light schedule	Body weight (g)				0-48d mortality (%)
	7d	21d	35d	48d	
23L:1D	**138**	**738**	**1852**	**2924**	**9.0**
16L:8D	**126**	**684**	**1798**	**2912**	**3.0**
14L:10D	**121**	**641**	**1727**	**2850**	**3.5**
Step down-step up.	**115**	**614**	**1713**	**2884**	**3.5**

5. Stocking density

The health implications of higher density broiler production are significant and must be considered. With increased density, access to feed and water is more difficult, reducing the performance of each normal bird. Furthermore, birds that have only a marginal disability become less able to compete. With increased stocking density the demand for vital oxygen rises, adding to pressure on the bird's pulmonary and cardiovascular systems. Poorer litter conditions, with higher moisture content, result when stocking densities are greater. Coupled with the greater likelihood of a bird being scratched, this promotes the incidence of type II cellulitis.

The ability to vaccinate birds via the drinking water will be compromised by increasing the stocking density. Poorly vaccinated flocks are more prone to vaccine "rolling" reactions and to disease.

Increased stocking densities and stress go hand in hand. Increased stress will manifest itself in many ways, most commonly as a reduction in overall performance. Greater stress increases susceptibility to the common broiler diseases of a given geographical area and may open the door for new and re-emerging diseases (Ritchie 1999, Table 5.15).

Table 5.15. Stocking densities for broilers

Liveweight (kg)	**Birds/m^2**
1	34.2
1.2	28.5
1.25	27.2
1.4	24.4
1.5	22.7
1.6	21.4
1.75	19.4
1.8	19.0
2	17.1
2.2	15.6
2.25	15.1
2.4	14.3
2.5	13.6
2.6	13.2
2.75	12.4
2.8	12.2
3	11.4
3.2	10.7
3.4	10.0
3.5	9.7
3.6	9.5

Broilers:

Open side houses:	25 kg/m^2
Environmentally controlled houses:	30-35 kg/m^2

Breeders:

	week 1 – 7	**week 8 – 20**	**week 21 - 65**
Female birds/m^2	10 - 12	5 – 7	4 - 6
Male birds/m^2	10 – 12	3 – 4	-

Layers:

Cage system	*Week 0 – 5*	*Week 5 – 18*	*Week18 - 72*
	200 cm^2/bird	300 cm^2/bird	450 cm^2
Floor System	25 – 30 birds/m^2	12 birds/m^2	

6. Feeder space/type

Production per hen day and food intake was higher, but return on estimated capital outlay was lower, with 102 mm than with 76 mm feeding space/bird, at a constant Colony size and floor area/bird. (Robinson 1979). The following space requirements are advised.

Feeder Type		**Feeder Space**
Manually filled:		
Feeder plates		1 plate/70 – 100 chicks
Metal pen troughs (2cm)		4 cm space/chicken
Round suspended feeders (tube 38cm)		1 tube/70 birds
Automatically filled:		
Chain feeders (troughs) single chain		2.5 cm/bird
Overhead tube feeders		1 tube/70 birds
Pan feeders (33 cm)		1 pan for 50 – 100 birds
Broilers:		
Troughs		2.5 cm/bird
Pan or tube feeders		2 – 3/100 birds
Broiler breeders:		
Hand-Fed Trough		20 cm/bird
Mechanical chain		15 - 20 cm/bird
Hanging 45 cm diameter tube		12 birds/tube (80 feeders/1000 birds)
Automatic centerless auger		10 - 12 birds per pan on restricted and controlled feed
Layer brooders:		
Cage: feeder space	2.5 cm/bird (0 - 5 weeks)	5 cm/bird (5 - 18 weeks)
Floor: feeder space	2.5 cm/bird (0 - 5 weeks)	2 tubes /100 birds (0 - 5 weeks)
		8 cm/bird (5 - 18 weeks) or 1 pan/20 birds
		3 tubes /100 birds (5 - 18 weeks)
Layers:		
Cage: feeder space	5 cm/bird	
Floor: feeder space	7.5 cm/bird	
Trough	4 cm/bird (18 - 72 weeks)	
Round	4 per 100 birds (18 - 72 weeks)	

7. Drinker space/type

In a study by Gernat and Adams (1992) hens/nipple had no effect on age at sexual maturity, egg production, mortality and egg weight, but efficiency of feed usage for egg production decreased with 3.5:1 and 7:1 hens per nipple.

Body weight and water intake was significantly influenced by the number of nipples per hen. Body weight decreased with increased hens per nipple and water intake increased with decreased hens per nipple.

When hens per nipple were increased from 2:1 to 14:1, water consumption and feed consumption decreased but feed efficiency increased, so performance of all strains was not adversely affected. A decrease in hens per nipple would increase equipment cost and could increase feed cost.

Waterer Type		Waterer Space
Bell drinkers	- hot climate	1 drinker/65 birds
Bell drinkers	- cool climates	1 drinker/100 birds)
Nipples		12 – 15 birds/nipple
Cup drinkers		30 – 35 birds per cup
Broilers:		
Auto drinkers – 400mm while brooding		1.6/100 birds
Auto drinkers – 400mm		1/100 birds
Broiler breeders:		
Plastic cone type		2/200 birds
8-foot trough waterers		1/200 birds (80 birds/m)
Nipple		1/15 pullets
Layer brooders:		
Cage: waterer space		1 cup or nipple per 16 birds (0 - 8 weeks)
		1 cup or nipple per 8 birds (8 - 18 weeks)
Floor: waterer space		2 cm/bird (0 - 8 weeks)
		4 cm/bird (8 - 18 weeks) (average 3 cm over growing period)
Trough: waterer space		2 cm/bird (0 - 8 weeks)
		4 cm/bird (8 - 18 weeks)
		(average 3 cm over growing period)
Layers:		
Cage: drinker space		8 birds per nipple
		12 hens per cup
		2.5 cm of space per bird
Floor: drinker space		2.5 cm of space per bird
		50 hens per fountain drinker
Nipples		4 - 6 birds/nipple (18 - 72 weeks)
Linear		2 cm/bird (18 - 72 weeks)
Round		1/125 birds (18 - 72 weeks)

Note: 2.5 cm of edge space of a round feeder or waterer is equivalent to 3.17 cm of straight trough. For trough waterers and feeders, count total usable edge space exposed to the birds.

1. Relative humidity

The higher the temperature, the lower the RH and the lower the outside temperature, the higher the RH. The reason for this inverse relationship between temperature and RH is that as air temperature rises, its ability to hold moisture is increased. In fact for every 20 degree rise in temperature the moisture holding ability of air doubles. The hotter the day the drier the air (Lacy 1995). The relative humidity is presented **by the line XM/PM in Figure**

Figure 5.5. The relationship between dry bulb temperature, wet bulb temperature, equivalent temperature, vapour pressure and dew point.

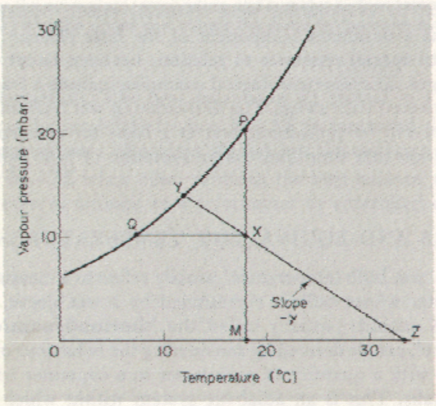


Fig. 11.1 The relation between dry bulb temperature, wet bulb temperature, equivalent temperature, vapour pressure and dew point. The point X represents air at 18°C and 10 mbar vapour pressure. The line YXZ with a slope of −γ gives the wet bulb temperature from Y (12°C) and the equivalent temperature from Z (33·3°C). The line QX gives the dew point temperature from Q (7·1°C). The line XP gives the saturation vapour pressure from P (20·6 mbar).

The heat index (HI) gives a measure of how hot it actually feels due to the combined effect of the air temperature and the relative humidity. Hot, humid air actually feels hotter than hot, dry air.

Table 5.16 gives the optimum temperature and relative humidity for broilers.

Table 5.16. Relation between temperature (°C) and relative humidity (Avian Farms Broiler Manual).

Age in days	Relative Humidity				
	80%	70%	60%	50%	40%
1	**33**	**33**	**33**	33	**35**
2	**32**	**32**	**32**	32	**34**
3	**31**	**31**	**31**	31	**33**
4	**30**	**30**	**30**	30	**32**
5	**30**	**30**	**30**	30	**32**
6	**29**	**29**	**29**	29	**31**
7	**29**	**29**	**29**	29	**31**
8	**28**	**29**	29	29	**31**
9-12	**27**	**28**	28	**29**	**31**
13-16	**26**	**27**	27	**29**	**31**
17-20	**25**	**26**	26	**28**	**30**
21-24	**24**	25	**26**	**27**	**29**
25-30	**23**	24	**25**	**27**	**29**
31-35	**22**	23	**25**	**26**	**28**
>35	**21**	22	**24**	**25**	**27**

The areas in bold numbers are considered ideal conditions for the chicks and birds.

With high relative humidity (80%) the temperature should drop rapidly after 16 days of age in order not to affect the growth rate of the birds. With low relative humidity (40%) the temperatures can stay higher without affecting the growth rate and feed conversion.

9. Temperature

May *et al*. (1998) reported on the effect of high environmental temperatures on the growth and feed:gain ratio in broilers. The body weight at the maximum rate of gain was inversely related to temperature. Feed:gain increased as body weight increased. Feed:gain was directly related to temperature at weights above 800 g and the effect of temperature increased as body weight increased.

The following regression equations were developed in this study.

$G = -31.797 + 1.2071T + 0.21457BW - 8.852 \times 10^{-5} BW^2 + 1.51 \times 10^{-8} BW^3 - 2.0772 \times 10^{-3} TBW$

$FC = 2.0512 - 2.007 \times 10^{-2}T - 7.226 \times 10^{-4}BW + 1.7361 \times 10^{-7}BW^2 + 2.5564 \times 10^{-5} TBW$

At moderate temperatures animals will consume, by weight, twice as much water as food. Environmental temperature is perhaps the major factor influencing fluctuation in water intake. For every increase in environmental temperature of 1°C, there usually is an appropriate 7-9% increase in water consumption (Spesfeed 1999, Table 5.17, 5.18).

Table 5.17. % Increase in feed consumption between two temperatures as temperatures increase.

From °C	To °C					
	10.0	15.6	21.1	26.7	32.2	37.8
4.4	**3**	**8**	**16**	**27**	**42**	**60**
10.0		**6**	**14**	**25**	**40**	**59**
15.6			**9**	**21**	**37**	**56**
21.1				**13**	**31**	**52**
26.7					**20**	**45**
32.2						**31**

Table 5.18. % Increase in feed consumption between two temperatures as temperatures decrease.

From °C	To °C					
	32.2	26.7	21.1	15.6	10.0	4.4
37.8	**46**	**82**	**110**	**130**	**143**	**151**
32.2		**25**	**44**	**58**	**67**	**72**
26.7			**10**	**26**	**34**	**38**
21.1				**10**	**16**	**20**
15.6					**6**	**9**
10.0						**3**

- **Floor type**

Poor litter conditions reduce access to feed and water. An increased demand for fresh air may increase the incidence of pulmonary/cardiovascular disease (Table 5.19).

Table 5.19. Effect of floor type on feed consumption.

Floor type	Average body weight (g)	Average feed consumption/bird (g)	Feed:gain
Litter floor	**1.663**	**6.922**	**4.26**
Wire floor	**1.746**	**7.584**	**4.44**

NUTRITION

1. Feeding program

Types:

- *Ad libitum*
- Skip a day feeding
- 4 – 3 feeding
- 3 – 1 – 2 – 1 feeding

Significantly higher water intakes were measured in chicks selected for high body weights, when fed a restricted diet. (Marks, 1980, Tables 5.20, 5.21, 5.22)

Table 5.20. Water intake (g/bird/day) of broilers by line to 49 days of age.

Period (day)	Selected	Non-selected	Selected –feed restricted
2	**16.0**	**3.1**	**12.8**
3-4	**21.5**	**12.9**	**17.4**
5-6	**37.0**	**20.6**	**29.7**
7-8	**46.3**	**25.0**	**36.9**
9-10	**58.0**	**29.0**	**46.6**
11-12	**70.3**	**31.6**	**56.7**
13-14	**78.8**	**36.0**	**56.6**
15-16	**87.3**	**39.0**	**57.6**
17-18	**95.5**	**43.1**	**64.8**
19-20	**113.4**	**48.2**	**74.8**
21-22	**157.5**	**57.5**	**102.9**
23-34	**178.1**	**62.8**	**119.4**
25-26	**166.0**	**58.0**	**112.2**
27-28	**203.1**	**68.0**	**127.9**
29-36	**362.1**	**110.6**	**233.5**
37-42	**297.6**	**97.7**	**225.2**
43-49	**396.0**	**128.9**	**273.1**

Watering program

Table 5.21. Mean feed and water consumption and egg production of hens during and after a 6-week period with water supply restricted to 90% of *ad libitum* intake.

21d with *ad lib*. food and water supply, before restriction, Mean ambient temperature = 16.6°C				42 d with each bird's daily water supply restricted to 90% of *ad lib*. intake, Mean ambient temperature = 18.1°C					21d with *ad lib*. Food and water supply, after restriction. Mean temperature = 20.9 °C		
Daily food intake (g)	Daily water intake (g)	Egg prod. (egg/hen day)	R between food intake and water intake	Predicted daily food intake (g)	Actual daily food intake (g)	Daily water intake (ml)	Egg prod. (egg/hen/d)	Change in body weight (g)	Daily food intake (g)	Daily water intake (ml)	Egg prod. (egg/hen d)
157.2	**339.8**	**0.62**	**0.22**	**152.6**	**136.3**	**292.7**	**0.52**	**-66**	**156.8**	**328.6**	**0.62**
113.0	**234.7**	**0.48**	**0.61**	**103.3**	**98.8**	**208.2**	**0.40**	**-30**	**92.0**	**217.1**	**0.29**
101.1	**246.4**	**0.14**	**0.16**	**98.0**	**134.5**	**217.6**	**0.38**	**+92**	**149.8**	**275.1**	**0.43**
101.8	**178.1**	**0.52**	**0.08**	**102.7**	**104.9**	**158.2**	**0.55**	**-7**	**107.8**	**239.9**	**0.57**
119.6	**201.5**	**0.38**	**0.69**	**109.5**	**80.1**	**165.7**	**0.45**	**-99**	**96.5**	**159.8**	**0.19**
120.4	**207.6**	**0.62**	**0.46**	**113.5**	**124.7**	**184.8**	**0.40**	**+106**	**103.8**	**279.2**	**0.29**
112.1	**229.8**	**0.48**	**0.37**	**106.7**	**107.8**	**201.6**	**0.38**	**+92**	**87.6**	**230.9**	**0.43**
126.4	**211.5**	**0.43**	**0.44**	**123.9**	**115.8**	**187.9**	**0.45**	**+86**	**118.3**	**197.6**	**0.52**
96.2	**213.0**	**0.48**	**0.78**	**85.0**	**103.0**	**188.9**	**0.57**	**+58**	**112.1**	**208.5**	**0.43**
126.2	**293.1**	**0.24**	**0.23**	**123.1**	**105.2**	**260.6**	**0.21**	**+89**	**105.4**	**244.5**	**0.43**
Mean 117.4	**235.6**	**0.44**	**0.40**	**111.8**	**111.1**	**206.6**	**0.43**	**+32.1**	**113.0**	**238.1**	**0.42**

Table 5.22. Effect of water restriction on weekly feed consumption of broilers (Leeson and Summers 1997).

	Water restricted each day	Water restricted only on feed days	Ad-lib water
Water consumed on a feed day	**175 ml**	**182 ml**	**270 ml**
Water consumed on off-feed day	**108 ml**	**109 ml**	**36 ml**
Average	**141 ml**	**145 ml**	**153 ml**

2. Feed texture/Pellet size

The form of the feedstuffs plays a role in the consumption of water, although it is largely due to the relationship between feed and water rather than the actual physical form of the feed (Table 5.23).

Table 5.23 Mean body weights, feed intake and water intake by dietary treatment and age. (Marks and Pesti 1984)

Age (days)	Body weight (g)			Age (days)	Feed intake (g/bird/day)			Water intake (g/bird/day)		
	Mash	Crumbles	Ratio C/M		Mash	Crumbles	Ratio C/M	Mash	Crumbles	Ratio C/M
0	**42.8**	**43.1**								
2	**57.5**	**63.2**	**110**	**0-2**	**7.29**	**9.53**	**131**	**14.49**	**19.08**	**132**
4	**77.4**	**89.2**	**115**	**2-4**	**14.90**	**15.36**	**103**	**22.77**	**27.23**	**120**
5	**104.2**	**125.1**	**120**	**4-6**	**20.01**	**26.92**	**135**	**33.72**	**40.93**	**122**
8	**135.0**	**167.9**	**124**	**6-8**	**22.88**	**31.08**	**136**	**37.70**	**49.13**	**131**
10	**169.8**	**214.1**	**126**	**8-10**	**27.24**	**34.66**	**128**	**42.51**	**53.07**	**125**
12	**226.0**	**286.2**	**127**	**10-12**	**40.01**	**50.59**	**127**	**63.43**	**82.75**	**131**
14	**287.7**	**358.1**	**125**	**12-14**	**44.70**	**54.52**	**122**	**71.63**	**89.42**	**125**
16	**352.3**	**436.6**	**124**	**14-16**	**51.98**	**62.98**	**122**	**75.98**	**94.86**	**125**
18	**426.3**	**522.2**	**123**	**16-18**	**60.77**	**72.54**	**120**	**93.62**	**117.77**	**126**
20	**504.1**	**619.8**	**123**	**18-20**	**66.91**	**82.16**	**123**	**109.77**	**140.22**	**128**

4. Phase feeding

Different levels of daily nutrient intake are usually employed in different phases of feeding. The water intake will be affected, because the protein or ME inclusions of the diet varies (See section on protein and ME).

5. Additives

Feed additives affect water and feed intake in the following way:

Growth and production promoters

A. Antibiotics cause a 1% increase in feed intake

1. Penicillin
2. Chlortetracycline
3. Oxytetracycline
4. Bacitracin
5. Streptomycin

B. Arsenic compounds cause <5% decrease in feed intake

1. Arsanilic acid (para – amino – hydroxyphenylarsonic acid)
2. Sodium arsanilate
3. 3 – nitro – 4 – hydroxyphenylarsonic

C. Hormonal preparations

1. Thyro – active have no effect on feed intake
   a) Iodinated casein
   b) Desiccated thyroid glands
   c) Thyroxine
2. Estrogenics cause 2% increase in feed intake
   a) Diethylstilbestrol (DES)
   b) Dienestrol diacetate

Enzyme preparations

No effect on feed intake

Pellet binders

No effect on feed intake

1. Sodium Bentonite
2. Paper and pulp by – products (hemicelluloses and lignins)
3. Guar meal

Anticoccidials

5% decrease in feed intake

1. Coccidiostats
2. Coccidiocides
   a) Ionophores – Monensin

Antifungals

1% increase in feed intake

1. Sodium propionate
2. Sodium benzoate
3. Quaternary ammonium compounds
4. Anti-fungal antibiotics (Nystatin)

Chapter 5 Antioxidants

Chapter 6 No effect on feed intake

1. Butylated hydroxy - anisode (BHA)
2. Diphenylparaphenylediamine (DPPD)
3. Ethoxyquin
4. Butylated hydroxytoluene (BHT)
5. Tocopherols (Vit E)
6. Phospholipids

Pigmentation compounds

No effect on feed intake

Insecticides (to kill flies)

No effect on feed intake

Deworming drugs (Anthelminicts)
No effect on feed intake

1. Hygromycin – round worm
2. Niclosmide – tape worm

Probiotics

0.5 - 1% increase in feed intake

1. Lactobacilli

Vitamin and trace mineral premixes

Recommended vitamin and mineral specifications are presented in Table 5.24.

Table 5.24 Recommended Vitamin and Trace Mineral levels

		Layer	Breeder Layer	Broiler Starter	Broiler Grower	Chick Starter	Chick Grower
Vit A	IU	8000	13000	12000	10000	10000	7500
Vit D_3	IU	2000	2500	2500	2000	2000	2000
Chapter 7 it E	mg	10	40-80	40-80	30	20	10
Vit K	mg	3	4	4	2	2	2
Vit B_1	mg	0.5	3	2	2	2	2
Vit B_2	mg	3	8	6	5	5	5
Vit B_6	mg	2	4	4	3	3	3
Vit B_{12}	mg	0.02	0.03	0.02	0.01	0.015	0.01
Folic Acid	mg	0.5	2	2.5	2	0.8	0.5
Niacin	mg	20	40	40	30	20	20
Pantothenic	mg	4	12	15	12	10	10
Choline Cl	mg	200	600	300	300	200	200
Biotin	mg	0.05	0.25	0.075	0.05	0.05	0.05
Vit C	mg	0	100	0	0	0	0
Mn	mg	120	120	100	100	100	100
Zn	mg	100	100	100	100	100	100
Cu	mg	8	8	8	8	8	6
Fe	mg	70	70	70	70	70	70
I	mg	1	1	1	1	1	1
Se	mg	0.25	0.35	0.35	0.25	0.25	0.25
Co	mg	0.5	0.5	0.5	0.5	0.5	0.5

7. Interrelationships

Numerous feeding trials conducted with chickens during the past eighty years have resulted in a wealth of information on their nutrient requirements. At least forty-one specific nutrients are recognized as essential. It is said that more is known about the nutrition of chickens than about any other species including man. Precise requirements for various amino acids, vitamins, minerals, energy and fatty acids have been worked out.

Generally, a standard methodology has been followed for the determination of the requirements of a specific nutrient. Graded amounts of the nutrient under study are added to a purified diet containing all the nutrients with the exception of the one being investigated. The minimum amount of a nutrient which produces the maximum benefit to, for example, growth, development, egg production or feed efficiency in a normal healthy flock, was tabled as the requirement for that function.

Although is was imperative to determine the specific contribution of individual nutrients in maintaining the health and production of chickens, this led to an obviously mistaken idea : that the requirements and functions were independent and isolated. During the last thirty years the concept of interdependence and interrelationships of various nutrients has been recognized and given due emphasis.

The following interrelationships are well known and alter the nutrient requirements of chickens under practical conditions.

- The energy-protein relationship.
- The interrelationship between calcium, phosphorus and Vitamin D_{3}.
- Nicotinic acid and tryptophan.
- Choline, methionine, folic acid and Vitamin B_{12}.
- Vitamin E, Selenium and Cystine.
- Copper and zinc, zinc and cadmium, molybdenum and tungsten, selenium and arsenic.
- Interrelationships between arginine and lysine, between leucine, isoleucine and valine.

ME:P

This interrelationship is the only one of the above mentioned, which may affect water intake (Table 5.25).

Table 5.25. ME/P ratios for varying caloric and protein content of the diet.

ME	Protein %													
Kcal per0.45 kg	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1200	**100**	**92**	**86**	**80**	**75**	**71**	**67**	**63**	**60**	**57**	**55**	**52**	**50**	**48**
1250	**104**	**96**	**89**	**83**	**78**	**74**	**69**	**66**	**63**	**60**	**57**	**54**	**52**	**50**
1300	**108**	**100**	**93**	**87**	**81**	**76**	**72**	**68**	**65**	**62**	**59**	**56**	**54**	**52**
1350	**113**	**104**	**96**	**90**	**84**	**79**	**75**	**71**	**68**	**64**	**61**	**59**	**56**	**54**
1400	**117**	**108**	**100**	**93**	**88**	**82**	**78**	**74**	**70**	**67**	**64**	**61**	**58**	**56**
1450	**121**	**112**	**104**	**97**	**91**	**85**	**81**	**76**	**73**	**69**	**66**	**63**	**60**	**58**
1500	**125**	**115**	**107**	**100**	**94**	**88**	**83**	**79**	**75**	**71**	**68**	**65**	**63**	**60**
1550	**129**	**119**	**111**	**103**	**97**	**91**	**86**	**82**	**78**	**74**	**71**	**67**	**65**	**62**
1600	**133**	**123**	**114**	**107**	**100**	**94**	**89**	**84**	**80**	**76**	**73**	**69**	**67**	**64**

Sodium Chloride

The addition of increasing amounts of salt to the ration causes a progressive increase in water intake per gram of feed consumed. High levels of salt in the diet will lead to increased water intake and wet litter (Tables 5.26, 5.27).

Table 5.26 Diet salt and litter moisture (Leeson and Summers 1995).

Dietary salt (%)	**Nipple drinker**		**Bell drinker**	
	Litter moisture (%)			
	21 days	**49 days**	**21 days**	**49 days**
0.25	16	18	17	21
0.50	17	20	21	33
0.75	22	23	28	49

Table 5.27. Mean feed and water intake and water/feed ratios from 0 to 16 days of age by dietary treatments

Line	Days	Feed intake (g/bird/day)			Water intake (g/bird/day)			Water/Feed ratio		
		0.4% NaCl	0.8% NaCl	1.6% NaCl	0.4% NaCl	0.8% NaCl	1.6% NaCl	0.4% NaCl	0.8% NaCl	1.6% NaCl
1	0 – 2	9.9	10.0	9.7	26.5	30.1	31.4	2.69	3.02	3.24
	2 – 4	16.0	16.7	16.1	38.9	42.5	48.4	2.43	2.55	3.01
	4 – 8	24.9	25.9	26.1	54.0	61.3	74.8	2.16	2.37	2.87
	8 – 12	35.0	37.6	37.7	73.3	84.7	107.5	2.09	2.26	2.85
	12 – 16	48.3	49.4	50.8	100.8	110.5	144.0	2.09	2.24	2.83
2	0 - 2	8.1	9.0	8.1	17.6	22.1	21.2	2.17	2.46	2.63
	2 – 4	14.2	15.1	14.3	30.7	36.8	40.3	2.15	2.44	2.83
	4 – 8	24.9	25.3	24.2	48.9	57.6	69.1	1.96	2.28	2.85
	8 – 12	36.0	36.7	36.8	68.3	78.4	103.0	1.89	2.14	2.80
	12 – 16	49.7	50.8	49.8	94.6	110.4	137.9	1.90	2.17	2.77

9. Protein

Protein sources such as soybean and meat and bone meal tend to increase water consumption compared to other protein sources. Certain fish meals contain higher sodium concentrations, depending on the age and type of fish used and the time of the year it was processed, which increases water consumption. Any nutrient that increases mineral excretion by the kidney will influence water intake (Table 5.28).

A comparison of the amount of oxidative water produced with the amount of water lost through evaporation and other routes allows for an estimate of the general importance of metabolic water in avian physiology. The maximum and minimum amounts of oxidative water which a bird of a given size will produce at rest can be calculated if the following assumptions are made.

1. The relation of body weight to basal metabolism is expressed by Brody's (1945) formula :
   kcal/day = 89(wt. in kg) to the power of 0.64
2. The oxidation of 1g of fat yields 1.07g of water and 9.2 kcal.
3. The oxidation of 1g of carbohydrate yields 0.56 g of water and 4.10 kcal
4. The oxidation of 1g of protein yields 0.40g of water and 4.10 kcal.

(Bartholomew and Cade 1963).

Table 5.28. Growth, feed and water consumption of birds on different levels of soybean oil meal (44%) in the diet over 8 weeks. (Glista and Scott, 1949)

Average/chick	% Inclusion of soybean oil meal			
	0	**7.5**	**15**	**30**
Water consumption (ml)	3646	3781	3898	4604
Feed consumption (g)	1868	1901	1939	2053
Ml water: g feed	1.95	1.99	2.01	2.24
8 week weight (g)	868	861	863	828
8 week feed efficiency	0.403	0.414	0.399	0.378

10. Energy

High-energy diets tend to decrease water consumption compared to low energy diets (Table 5.29).

Table 5.29. Performance of broilers fed diets of variable energy content (Leeson and Summers 1997)

Diet ME (kcal/kg)	Body weight (g)		Feed intake (g/bird)		
	25 days	**49 days**	**0 – 25 days**	**25 – 49 days**	**0 – 49 days**
3300	1025	2812	1468	3003	4471
3100	1039	2780	1481	3620	5101
2900	977	2740	1497	3709	5206
2700	989	2752	1658	3927	5586

Table 5.30 Effect of energy dilution of finisher diet on growth of broilers. (Leeson and Summers 1997)

Diet energy ME (kcal/kg)	Body weight (g)		Feed intake (g/bird)		Energy intake (Mcal)
	42d	**49d**	**35 – 42d**	**42 - 29d**	**35 – 49d**
3200	2370	2982	1250	1373	8.43
2950	2395	2998	1301	1401	8.00
2700	2371	2970	1377	1456	7.66
2450	2331	2913	1371	1585	7.24
2200	2323	3022	1444	1677	6.85
1950	2277	2946	1482	1946	6.65

APPENDIX 2 to Chapter 5

Site Specific Factors used in the model:

As explained in the section on modifying the WIRRD the following section deals with the modifying factors used to accommodate changes from the factors mentioned in APPENDIX 1.

Animal Factors

1. Water intake

If the water intake is not known, then the following equations are used to predict the water intake. This is then used to establish the WIR in the reference document.

Broilers:

$DWU = -2.78 + 4.70D + 0.128D^2 – 2.17 \times 10^{-3}D^3$

$(1 \leq D \leq 56)$

Where DWU = daily water use, litres per 1000 birds (Xin and Berry, 1994).

Layers:

$WI = -0.057\ BW^2 + 0.031\ BW - 0.000002\ EP^2 + 0.0005\ EP – 0.181$

Where WI = Water intake; BW = Body weight; EP = Egg production

1. Egg production

The following factors apply to layers. If hen-day egg production (%) is the following and water intakes exceeds the reference value, then apply the factor 1.025

Hen-day Egg production (%)	Water consumption per 1000 birds (l)
10	**151**
30	**159**
50	**174**
70	**201**
90	**239**

2. Gender Ratio

If the recommendations for gender ratio are not adhered to, the following rule applies:

Gender ratio > recommendation, then apply factor 0.9

Gender ratio < recommendation, then apply factor 1.1

3. Beak trimming

Layers:

If the following beak trimming methods are used, then the following factors apply:

Debeaking	Factor applied
1 day, precision	0.9
6 day, precision	0.95
6 week, inside plant	0.95
8 week, non-precision	0.95
12 week, non-precision	0.9
16 week, non-precision	1.1
Non-debeaked	1

Broilers:

If the following beak trimming methods are used, then the following factors apply:

Beak trimming	50 day Beginning weight
Chapter 8	**All mash diet**
None	1.1
1/3 top	1
½ top	9.5
½ block	8
Chapter 9	**Pelleted Feed**
None	1.1
1/3 top	7.5
½ top	4.5
½ block	4.5

Environmental factors

1. Housing factors

The following housing water turnover rate factors apply:

Housing type	Broilers	Layers	Breeders	Dual purpose
Convection with floor with litter	0.9	0.9	1	1
Convection with slats	0.9	1	0.9	1
Convection with cages	0.9	1	0.9	1
Environmentally controlled with floor with litter	1	0.9	1	1.1
Environmentally controlled house with slats	1	0.9	1	1.1
Environmentally controlled house with cages	0.9	1	0.9	1.1
Closed house (not environmentally controlled) with slats	0.9	1	1	1
Closed house (not environmentally controlled) with cages	0.9	0.9	0.9	1
Closed house (not environmentally controlled) with floor with litter	0.9	0.9	0.9	1
Outside runs	0.8	0.9	0.9	1
Free ranging	0.7	0.8	0.8	1

2. Air velocity

If the air velocity is > 1.79 m/s, then the following equation determines the wind chill index. Air velocity is measured in m/s and temperature in degrees Celcius.

K = 41 – ((10.4 + 10*(√Air velocity) – Air velocity)*(41 – Temperature)/22.04

Where 41 = the body temperature of a chicken.

Chapter 10 Air velocity	Temperature	K
2	12	11.47392
4	12	7.798094
6	12	5.420924
8	12	3.715985
10	12	2.440639
12	12	1.470447
14	12	0.731486
16	12	0.17559
18	12	-0.2307
20	12	-0.51173

3. Lighting

Layers: If the following lighting regimens are not adhered to, a factor 1.025 applies

Light treatment	
Growing period	Laying period
Gradually decreased from 22hr to 16 hr	**Gradually increased from 16 hr to 22 hr**
Gradually decreased from 22hr to 9 hr	**Gradually increased from 9 hr to 22 hr**
Gradually decreased from 16hr to 9 hr	**Gradually increased from 9 hr to 16 hr**
Gradually decreased from 16hr to 9 hr	**Gradually increased from 9 hr to 16 hr**
Started on constant 16 hr then suddenly decreased to constant 9 hr	**Suddenly increased from 9 hr to 16 hr**
Constant 16 hr	**Constant 16 hr**

Broilers: The following factors apply if the corresponding recommendations are not met.

Light program	Hours light and dark	Factor
Continuous light in open sided house	**23 hours light, 1 hour darkness**	**1**
Continuous light in light tight house	**23 hours light, 1 hour darkness**	**1.5**
Intermittent light in light tight house	**1 hour light, 3 hours darkness, then repeat.**	**1.6**

4. Stocking density for broilers: If stocking densities are exceeded, apply the factor 0.9.

Liveweight (kg)	Birds/m^2
1.0	34.2
1.2	28.5
1.25	27.2
1.4	24.4

Liveweight (kg)	Birds/m^2
1.50	22.7
1.6	21.4
1.75	19.4
1.8	19.0
2.0	17.1
2.2	15.6
2.25	15.1
2.4	14.3
2.50	13.6
2.6	13.2
2.75	12.4
2.8	12.2
3.0	11.4
3.2	10.7
3.4	10.0
3.50	9.7
3.6	9.5

Open side houses for broilers: 25 kg/m^2

Environmentally controlled houses: 30-35 kg/m^2

Stocking density for breeders:

	week 1 – 7	**week 8 – 20**	**week 21 - 65**
Female birds/m^2	10 - 12	5 – 7	4 - 6
Male birds/m^2	10 – 12	3 – 4	-

Stocking density for layers:

Cage system	*Week 0 – 5* 200 cm^2/bird	*Week 5 – 18* 300 cm^2/bird	*Week18 - 72* 450 cm^2
Floor System	25 – 30 birds/m^2	2 birds/m^2	

5. Feeder space/type

If feeder space is smaller than prescribed, apply the factor 0.9.

Feeder Type	**Feeder Space**
<u>Manually filled:</u>	
Feeder plates	1 plate/70 – 100 chicks
Metal pen troughs (2cm)	4 cm space/chicken
Round suspended feeders (tube 38cm)	1 tube/70 birds
<u>Automatically filled:</u>	
Chain feeders (troughs) single chain	2.5 cm/bird
Overhead tube feeders	1 tube/70 birds
Pan feeders (33 cm)	1 pan for 50 – 100 birds

Broilers:

Troughs	2.5 cm/bird
Pan or tube feeders	2 – 3/100 birds

Broiler breeders:

Hand-Fed Trough	20 cm/bird
Mechanical chain	15 - 20 cm/bird
Hanging 45 cm diameter tube	12 birds/tube (80 feeders/1000 birds)
Automatic centerless auger	10 - 12 birds per pan on restricted and controlled feed

Layer brooders:

Cage: feeder space	2.5 cm/bird (0 - 5 weeks)	5 cm/bird (5 - 18 weeks)
Floor: feeder space	2.5 cm/bird (0 - 5 weeks)	2 tubes /100 birds (0 - 5 weeks)
		8 cm/bird (5 - 18 weeks) or 1 pan/20 birds
		3 tubes /100 birds (5 - 18 weeks)

Layers:

Cage: feeder space	5 cm/bird
Floor: feeder space	7.5 cm/bird
Trough	4 cm/bird (18 - 72 weeks)
Round	4 per 100 birds (18 - 72 weeks)

6. Drinker space/type

If drinker space is smaller than prescribed, apply the factor 0.9.

Waterer Type	**Waterer Space**
Bell drinkers - hot climate	1 drinker/65 birds
Bell drinkers - cool climates	1 drinker/100 birds)
Nipples	12 – 15 birds/nipple
Cup drinkers	30 – 35 birds per cup
Broilers:	
Auto drinkers – 400mm while brooding	1.6/100 birds
Auto drinkers – 400mm	1/100 birds
Broiler breeders:	
Plastic cone type	2/200 birds
8-foot trough waterers	1/200 birds (80 birds/m)
Nipple	1/15 pullets
Layer brooders:	
Cage: waterer space	1 cup or nipple per 16 birds (0 - 8 weeks)
	1 cup or nipple per 8 birds (8 - 18 weeks)
Floor: waterer space	2 cm/bird (0 - 8 weeks)
	4 cm/bird (8 - 18 weeks) (average 3 cm over growing period)

Trough: waterer space	2 cm/bird (0 - 8 weeks)
	4 cm/bird (8 - 18 weeks)
	(average 3 cm over growing period)
Layers:	
Cage: drinker space	8 birds per nipple
	12 hens per cup
	2.5 cm of space per bird
Floor: drinker space	2.5 cm of space per bird
	50 hens per fountain drinker
Nipples	4 - 6 birds/nipple (18 - 72 weeks)
Linear	2 cm/bird (18 - 72 weeks)
Round	1/125 birds (18 - 72 weeks)

Note: 2.5 cm of edge space of a round feeder or waterer is equivalent to 3.17 cm of straight trough. For trough waterers and feeders, count total usable edge space exposed to the birds.

7. Relative humidity

If the RH exceeds the standards provided apply factor 1.1.

If the RH is less than the standards, then apply the factor 0.8.

Age in days	Relative Humidity				
	80%	70%	60%	50%	40%
1	**33**	**33**	**33**	33	**35**
2	**32**	**32**	**32**	32	**34**
3	**31**	**31**	**31**	31	**33**
4	**30**	**30**	**30**	30	**32**
5	**30**	**30**	**30**	30	**32**
6	**29**	**29**	**29**	29	**31**
7	**29**	**29**	**29**	29	**31**
8	**28**	**29**	29	29	**31**
9-12	**27**	**28**	28	**29**	**31**
13-16	**26**	**27**	27	**29**	**31**
17-20	**25**	**26**	26	**28**	**30**
21-24	**24**	25	**26**	**27**	**29**
25-30	**23**	24	**25**	**27**	**29**
31-35	**22**	23	**25**	**26**	**28**
>35	**21**	22	**24**	**25**	**27**

The areas in bold numbers are considered ideal conditions for the chicks and birds.

With a relative humidity (80%) the temperature should drop rapidly after 16 days of age in order not to affect the growth rate of the birds. With low relative humidity (40%) the temperatures can stay higher without affecting the growth rate and feed conversion.

8. Temperature

The following regression equations are used to determine the effect of temperature on gain and feed conversion.

G = -31.797+ 1.2071T + 0.21457BW - 8.852 X 10 -5 BW2 + 1.51 X 10 -8 BW3 - 2.0772 X 10 -3 TBW

FC = 2.0512 - 2.007 X 10 -2T - 7.226 X 10 -4BW + 1.7361 X 10-7BW2 + 2.5564 X 10 -5 TBW

9. Floor type

Apply the following factors:

Floor type	Factor
Litter floor	**1.1**
Wire floor	**1**

Nutrition factors:

1. Feeding programme

Apply the following water intakes (g/bird/day) if feed is restricted, or *ad libitum*

Period (day)	Selected	Non-selected	Selected –feed restricted
2	**16.0**	**3.1**	**12.8**
3-4	**21.5**	**12.9**	**17.4**
5-6	**37.0**	**20.6**	**29.7**
7-8	**46.3**	**25.0**	**36.9**
9-10	**58.0**	**29.0**	**46.6**
11-12	**70.3**	**31.6**	**56.7**
13-14	**78.8**	**36.0**	**56.6**
15-16	**87.3**	**39.0**	**57.6**
17-18	**95.5**	**43.1**	**64.8**
19-20	**113.4**	**48.2**	**74.8**
21-22	**157.5**	**57.5**	**102.9**
23-34	**178.1**	**62.8**	**119.4**
25-26	**166.0**	**58.0**	**112.2**
27-28	**203.1**	**68.0**	**127.9**
29-36	**362.1**	**110.6**	**233.5**
37-42	**297.6**	**97.7**	**225.2**
43-49	**396.0**	**128.9**	**273.1**

2. Watering program

The water intakes are adjusted by the watering programme detail stipulated below.

	Water restricted each day	Water restricted only on feed days	Ad-lib water
Water consumed on a feed day	**175 ml**	**182 ml**	**270 ml**
Water consumed on off-feed day	**108 ml**	**109 ml**	**36 ml**
Average	**141 ml**	**145 ml**	**153 ml**

3. Feed texture/Pellet size

Water intake (g/bird/day)

Water intake (g/bird/day)		
Mash	Crumbles	Ratio C/M
14.49	**19.08**	**132**
22.77	**27.23**	**120**
33.72	**40.93**	**122**
37.70	**49.13**	**131**
42.51	**53.07**	**125**
63.43	**82.75**	**131**
71.63	**89.42**	**125**
75.98	**94.86**	**125**
93.62	**117.77**	**126**
109.77	**140.22**	**128**

4. Additives

Chapter 11 If the following additives are present in the diet, apply the following factors :

Chapter 12 **Growth and production promoters**

Chapter 13 A Antibiotics cause a 1% increase in feed intake

- Penicillin
- Chlortetracycline
- Oxytetracycline
- Bacitracin
- Streptomycin

B. Arsenic compounds cause <5% decrease in feed intake

- Arsanilic acid (para – amino – hydroxyphenylarsonic acid)
- Sodium arsanilate
- 3 – nitro – 4 – hydroxyphenylarsonic

C. Hormonal preparations

Thyro – active No effect on feed intake

- Iodinated casein
- Desiccated thyroid glands
- Thyroxine

Estrogenic - 2% increase in feed intake

- Diethylstilbestrol (DES)
- Dienestrol diacetate

Enzyme preparations **Factor 1**

Pellet binders **Factor 1**

- Sodium Bentonite
- Paper and pulp by – products (hemicelluloses and lignins)
- Guar meal

Anticoccidials **Factor 9.995**

- Coccidiostats
- Coccidiocides
- Ionophores – Monensin

Antifungals **Factor 1.001**

- Sodium propionate
- Sodium benzoate
- Quaternary ammonium compounds
- Anti-fungal antibiotics (Nystatin)

Antioxidants **Factor 1**

- Butylated hydroxy - anisode (BHA)
- Diphenylparaphenylediamine (DPPD)
- Ethoxyquin
- Butylated hydroxytoluene (BHT)
- Tocopherols (Vit E)
- Phospholipids

Pigmentation compounds **Factor 1**

Insecticides (to kill flies) **Factor 1**

Deworming drugs (Anthelminicts) **Factor 1**

- Hygromycin – round worm
- Niclosmide – tape worm

Probiotics **Factor 1.0005**

- *Lactobacilli*

5. Vitamin and trace mineral premixes

The recommended allowances are compared with the user input data and used to assess total trace mineral intake.

6. ME:P

User defined ME/P ratios for varying caloric and protein content of the diet are compared to the reference material provided.

7. NaCl

Salt in the diet affects water intake as follows:

Line	Days	Water intake (g/bird/day)			Water/Feed ratio		
		0.4% NaCl	0.8% NaCl	1.6% NaCl	0.4% NaCl	0.8% NaCl	1.6% NaCl
1	0 – 2	26.5	30.1	31.4	2.69	3.02	3.24
	2 – 4	38.9	42.5	48.4	2.43	2.55	3.01
	4 – 8	54.0	61.3	74.8	2.16	2.37	2.87
	8 – 12	73.3	84.7	107.5	2.09	2.26	2.85
	12 – 16	100.8	110.5	144.0	2.09	2.24	2.83
2	0 - 2	17.6	22.1	21.2	2.17	2.46	2.63
	2 – 4	30.7	36.8	40.3	2.15	2.44	2.83
	4 – 8	48.9	57.6	69.1	1.96	2.28	2.85
	8 – 12	68.3	78.4	103.0	1.89	2.14	2.80
	12 – 16	94.6	110.4	137.9	1.90	2.17	2.77

8. Protein

Apply the following values if the protein levels are below 0, 7.5, 15 or 30%

Average/chick	% Inclusion of soybean oil meal			
	0	7.5	15	30
Water consumption (ml)	3646	3781	3898	4604
Feed consumption (g)	1868	1901	1939	2053
Ml water: g feed	1.95	1.99	2.01	2.24
8 week weight (g)	868	861	863	828
8 week feed efficiency	0.403	0.414	0.399	0.378

9. Energy

Apply the following factors for water intake if the ME values are:

Diet energy **ME (kcal/kg)**	Factor	
	42d	49d
3200	1.250	1.373
2950	1.301	1.401
2700	1.377	1.456
2450	1.371	1.585
2200	1.444	1.677
1950	1.482	1.946