DRAFT

Manual for Evaluation of Wetlands in Florida*

Howard T.Odum
Center for Environmental Policy &
Environmental Engineering Sciences
University of Florida, Gainesville, Fl.,32611

ABSTRACT

This is the first draft of a manual for evaluation of wetlands in Florida for purposes of judging their contribution to public welfare, for mitigation, and for planning. It is not for estimating market values nor rights due businesses and individuals. The manual provides procedures and spread sheets for evaluating the accumulated and annual works of nature in generating wetland values. Values of the several kinds of work are expressed in units of EMERGY, defined as the energy of one kind utilized. In this manual ***solar*** EMERGY is used with values expressed as solar emjoules. The wetland contribution to public welfare is also given in EMERGY-estimated dollars of gross economic product due to the work of the wetland (macroeconomic $). The dollars of the gross state product is estimated as that proportion that the wetland EMERGY is of the total state EMERGY.

Three levels of precision are provided for evaluating the wetland work. Quick calculations using level (1) and level (2) can provide preliminary evaluations and determine if the more detailed effort of level (3) evaluation is desirable. The 3 stages in environmental evaluation are:

(1) Value based on area and time of accumulated work assuming an average EMERGY for any land. This coarse measure can be applied to any land area on earth;

(2) Value based on typical EMERGY budgets for the wetland type, area, and time of accumulated work. This value is based on preliminary estimates of EMERGY for wetland types in Florida, using a classification of wetlands based on the energy signature of the wetland. The manual can be extended to other states and nations by adding an EMERGY table for the types of wetlands found there.

(3) Value based on scientific data for a particular site, area, and time of accumulated work. This value is calculated for a particular site where there are estimates or data for the set of energy inputs for the site.

The procedure allows the contributions to the wetland that come from the economy with human work and economic investments to be measured on the same basis as the contributions from environmental systems work. In addition, the part that a particular wetland site plays in the larger regional system is also evaluated in EMERGY units. For example, a particular wetland may have special value because of its position in the hydrologic cycle, in wildlife corridors, or in its spatial position in human developments.

A sample calculation is provided for a cypress pond in north Florida. Calculations are aided by five spreadsheet templates for Macintosh EXCEL.

*Included with Plenary Presentation at the IV International Wetlands Conference, Columbus Ohio, Sept. 18, 1992.

Introduction

The processes in a wetland include the work of nature based on sun, wind, rain, rivers, tides, genetic information in species, etc. plus the work that may be done by humans involving fuels, goods, and human services purchased from the economic system or supplied by human initiatives without payment. Figure 1 shows some of the inputs to the wetland work.

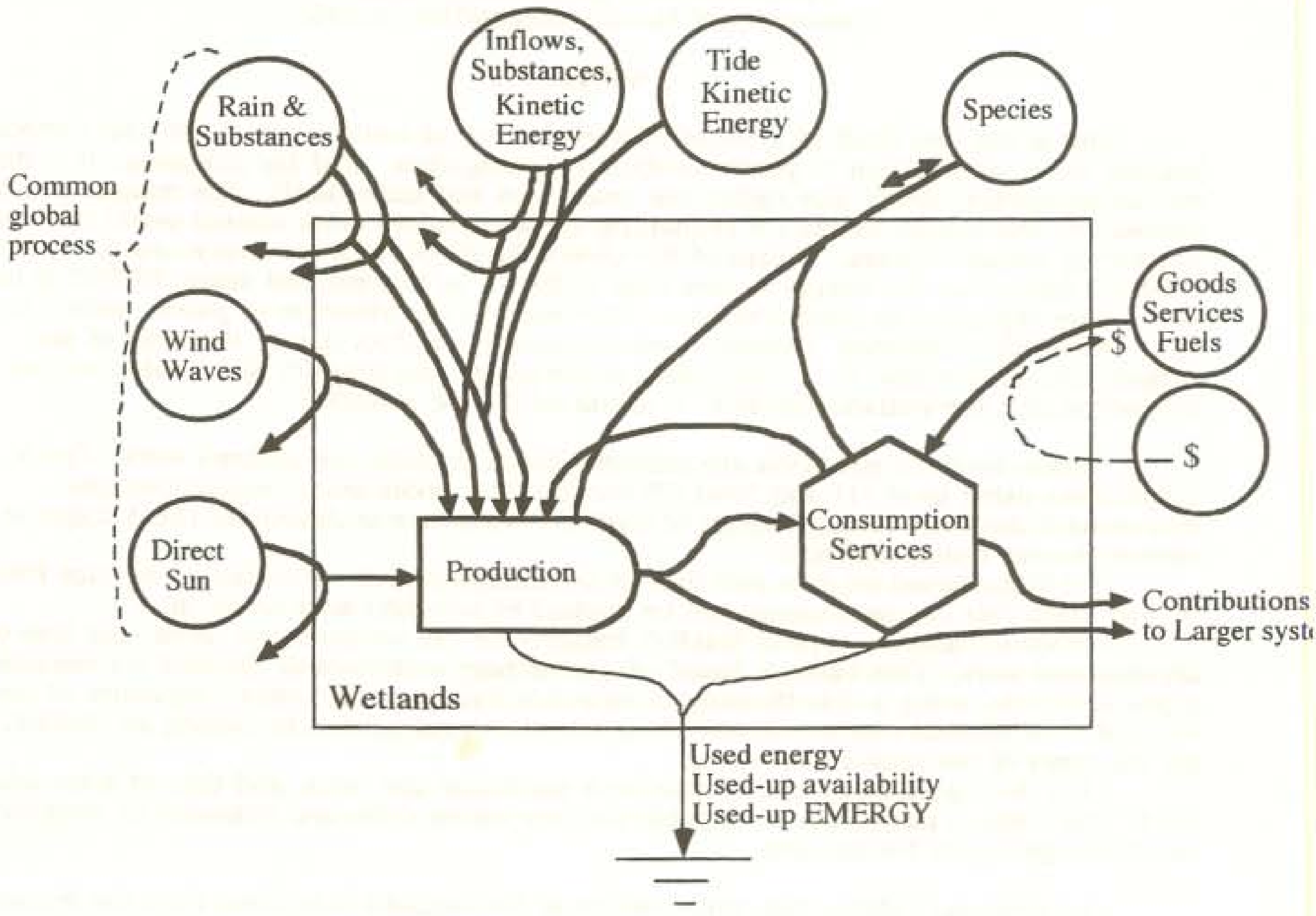

Figure 1. Energy systems diagram of a wetland showing many of the external energy inflows of various kind which need to be evaluated.

EMERGY is defined as the energy of one kind directly and indirectly required in transformations to generate a product or service. EMERGY is the available energy previously used up, all expressed as energy of one kind. If all flows are expressed in solar EMERGY, the units are solar emjoules. The many kinds of work within a wetland are evaluated in this manual as **solar emjoules.** The solar EMERGY required for wetland processes for a year can be multiplied by the number of years of growth to determine the solar EMERGY of stored products such as biomass, wood, diversity, and wetland geomorphology. Both work by natural process and those by humans and economic process are expressed on a common basis using solar EMERGY.

From previous evaluation of the annual solar EMERGY basis for all of Florida, we can indicate the average solar EMERGY required to generate the wealth represented by a dollar of buying power. The annual solar EMERGY of Florida was divided by the gross economic product to obtain the EMERGY/$ ratio (2 E12 solar emjoules per 1991 dollar). EMERGY values of wetlands can be expressed in dollar equivalents using the EMERGY/$ ratio. The share of the Florida's economy which is attributed to a wetland using EMERGY evaluation is called its **macroeconomic value,** not to be confused with or substituted for market value.

By evaluating the EMERGY inputs of various kinds to a wetland, a bar graph can be prepared showing which inputs are largest. By classifying systems according to the largest EMERGY inputs, classification reflects what is important. In self organization those inputs that are largest are expected to develop more structure, adapted species, etc. We used this principle to classify Florida Wetlands earlier (Wharton et al.,1976). In this draft the level 2 evaluation includes only the highest EMERGY inputs of the EMERGY signature of each wetland type. Level 3 evaluation evaluates all the inputs believed to be appreciable.

To evaluate a wetland site, follow the procedures that follow. Tables 1-4 are print-outs of spread-sheets written for the Macintosh program EXCEL. By entering a few numbers in the spaces provided in these tables, the calculations of solar EMERGY and macroeconomic dollars are made automatically.

For evaluating wetland work, Level 1 evaluation takes a minute; Level 2 evaluation takes 10 minutes; and Level 3 evaluation will take whatever time is required to assemble data for the site. Evaluating the site's participation in the regional system may require more knowledge and time (Table 4).

CALCULATION PROCEDURES

I. EVALUATION OF WETLAND WORK

AREA-TIME VALUE: First, using suggestions of Pimentel and Giampetro (1990) determine the product of area in hectares and time in years. The result would be a measure of work if every area of the earth accomplished the same amount of work per unit area per time. **Determine the area-time value in hectare-years by filling in items 1-5 in Table 1.**

LEVEL 1 EVALUATION OF WETLAND WORK: Next, make an approximation of solar EMERGY stored in the wetland by multiplying the area-time value by an average value of solar EMERGY use per hectare per year for land, calculated from global EMERGY and World land area. This simple measure assumes all areas of the world do similar work per unit time. **Make the level 1 evaluation by filling in items in the top box in Table 1. Macroeconomic $ value is included as item 10.**

LEVEL 2 EVALUATION OF WETLAND WORK: Next, make a more accurate evaluation of the solar EMERGY stored in the wetland by determining what type of wetland it is. Then multiply the area-time values by the typical annual solar EMERGY production and use for that type of wetland. **Select a wetland type from the list in Table 2. Copy the total annual solar EMERGY use from the last column (sej/ha/yr) to line 12 in the SECOND BOX in Table 1. The solar EMERGY that results is in line 13 and its macroeconomic value in line 16.**

In this first draft the calculations of annual solar EMERGY for wetland types in Florida is incomplete and tentative, pending introduction of more data and perhaps some additional research on energy uses in wetlands. Even with these reservations, this second level evaluation may be good enough for many purposes.

LEVEL 3 EVALUATION OF WETLAND WORK If large area and important controversies are involved that justify the most careful site evaluations that are possible, then Table 3 provides an initial outline. **Using scientific and economic data, evaluate the footnotes in Table 3, so that the spread sheet generates the annual solar EMERGY production-use in solar emjoules per hectare per year (sej/ha/yr). Copy the total from line 18, Table 3 to line 17 in the THIRD BOX of Table 1. The solar EMERGY that results is in line 18 and its macroeconomic value in line 21.**

Table 1. EMERGY Evaluation of Wetlands						
	Note:	Items to enter:	Site #1	Site #2	Site #3	Site #4
	1	Name of site:	Odum Cypress			
	2	Area in hectares:	4			
	3	Year of evaluation:	1992			
	4	Years of work	100			
	5	Hectare-years of work	400	0	0	0
Level (1)	6	Unit Emergy: sej/ha/yr	6.30E+14	6.30E+14	6.30E+14	6.30E+14
Evaluation:	7	Stored Emergy: sej	2.52E+17	0	0	0
(Average land)	8	Emergy/$ sej/$	1.46E+12	1.46E+12	1.46E+12	1.46E+12
	9	Year of Macroec. $ next	1990			
	10	Macroeconomic $	172602.74	0	0	0
Level (2)	11	Name of Wetland tupe:	Cypress pond			
Evaluation:	12	Unit Emergy: sej/ha/yr	9.00E+14			
(Wetland type)	13	Stored Emergy: sej	3.6E+17			
	14	Emergy/$ in sej/$:	1.46E+12	1.46E+12	1.46E+12	1.46E+12
	15	Year of Macroec. $ next	1990			
	16	Macroeconomic $	246575.342	0	0	0
Level (3)	17	Unit Emergy: sej/ha/yr	1.04E+15			
Evaluation:	18	Stored Emergy: sej	4.144E+17	0	0	0
(Site analysis)	19	Emergy/$ in sej/$:	1.46E+12	1.46E+12	1.46E+12	1.46E+12
	20	Year of Macroec. $ next	1990			
	21	Macroeconomic $	283835.616	0	0	0
	Footnote:					
	1	Enter name of site.				
	2	Enter number of hectares in site (1 hectare = 2.5 acres).				
	3	Enter year of the evaluation (usually current year).				
	4	Enter number of years environment has required to develop the current structures.				
	5	Spread sheet multiplies area times years of work.				
	6	9.44 E24 sej/yr earth renewable energy divided by 1.5 E10 hectares of land on earth				
	7	Spread sheet multiplies hectare years by average world emergy/yr/hectare of land.				
	8	Annual EMERGY use for the state divided by the gross state product for that year				
		Florida Example, 1990:(3.51 E 23 solar emjoules/yr divided by 240 E9 $ /yr				
	9	Enter year for which EMERGY/$ ratio was calculated.				
	10	Spread sheet divides stored EMERGY by the Emergy/$				
	11	Select wetland type; for Florida see Table 2.				
	12	Enter typical annual solar EMERGY use for this type from Table 2.				
	13	Spread sheet multiplies hectare-years by the annual solar EMERGY use.				
	14	Enter EMERGY/$ ratio such as that calculated in footnote 8				
	15	Enter year for which EMERGY/$ ratio was calculated.				
	16	Spread sheet divides stored EMERGY by the Emergy/$				

Table 2. **Florida Wetlands and Annual Emergy Uses**

Wetland Type	Note	Name of Inflow	Units	Flux used Units/ha/yr	Solar Emergy/Unit sej/unit	Solar Emergy Use sej/Ha/yr
Cypress, gum pond	1a	Water transpired				
		(Gibbs Energy)	Joules:	5.00E+10	1.80E+04	9E+14
Bays, bogs	1b	Water transpired				
		(Gibbs Energy)	Joules	1.70E+10	1.80E+04	3.06E+14
Dwarf cypress	1c	Water transpired				
		(Gibbs Energy)	Joules	1.70E+10	1.80E+04	3.06E+14
Cypress strand	1d	Water transpired				
		(Gibbs Energy)	Joules	7.50E+10	1.80E+04	1.35E+15
	2a	Water motion energy	Joules	1.96E+07	2.79E+04	5.4684E+11
		Total solar Emergy:				1.35055E+15
Lake Margin Swamp	1e	Water transpired				
		(Gibbs Energy)	Joules	1.00E+11	1.80E+04	1.8E+15
	4a	Wave motion energy	Joules	1.96E+07	3.04E+04	5.9584E+11
		Total solar Emergy:				1.8006E+15
Seepage Swamp	1f	Water transpired				
		(Gibbs Energy)	Joules	7.65E+11	1.80E+04	1.377E+16
Floodplain	1g	Water transpired				
		(Gibbs Energy)	Joules	9.50E+10	1.80E+04	1.71E+15
	2b	Water motion energy	Joules	1.96E+07	2.79E+04	5.4684E+11
		Total solar Emergy:				1.71055E+15
Eutrophic Marsh	1h	Water transpired				
		(Gibbs Energy)	Joules	1.00E+11	1.80E+04	1.8E+15
	2c	Water motion energy	Joules	1.96E+07	2.79E+04	5.4684E+11
	5a	Phosphorus import	grams	1.69E+08	3.80E+07	6.422E+15
		Total solar Emergy:				8.22255E+15
River Marsh	1i	Water transpired		9.00E+10		
		(Gibbs Energy)	Joules	5.00E+10	1.80E+04	9E+14
	2d	Water motion energy	Joules	1.96E+07	2.79E+04	5.4684E+11
		Total solar Emergy:				9.00547E+14
Sawgrass prairie	1j	Water transpired				
		(Gibbs Energy)	Joules	2.50E+10	1.80E+04	4.5E+14
	2e	Water motion energy	Joules	1.96E+07	2.79E+04	5.4684E+11
		Total solar Emergy:				4.50547E+14

Spartina saltmarsh	1k	Water transpired				
		(Gibbs Energy)	Joules	3.50E+10	1.80E+04	6.3E+14
	3a	Tidal energy	Joules	3.54E+10	1.64E+04	5.8056E+14
		Total solar Emergy:				1.21056E+15
Juncus saltmarsh	1l	Water transpired				
		(Gibbs Energy)	Joules	2.50E+10	1.80E+04	4.5E+14
	3b	Tidal energy	Joules	3.54E+10	1.64E+04	5.8056E+14
		Total solar Emergy:				1.03056E+15
Salina	1m	Water transpired				
		(Gibbs Energy)	Joules	5.00E+09	1.80E+04	9E+13
Black Mangroves	1n	Water transpired				
		(Gibbs Energy)	Joules	2.50E+10	1.80E+04	4.5E+14
	3c	Tidal energy	Joules	3.54E+10	1.64E+04	5.8056E+14
		Total solar Emergy:				1.03056E+15
Dwarf Mangroves	1o	Water transpired				
		(Gibbs Energy)	Joules	1.00E+10	1.80E+04	1.8E+14
	3d	Tidal energy	Joules	3.54E+10	1.64E+04	5.8056E+14
		Total solar Emergy:				7.6056E+14
Red mangroves	1p	Water transpired		3.00E+10		
		(Gibbs Energy)	Joules	5.00E+10	1.80E+04	9E+14
	3e	Tidal energy	Joules	3.54E+10	1.64E+04	5.8056E+14
		Total solar Emergy:				1.48056E+15
Melaleuca	1q	Water transpired				
		(Gibbs Energy)	Joules	1.00E+11	1.80E+04	1.8E+15
Lake Marsh	1r	Water transpired				
		(Gibbs Energy)	Joules	5.00E+10	1.80E+04	9E+14
	4b	Wave motion energy	Joules	3.10E+09	3.04E+04	9.424E+13
		Total solar Emergy:				9.9424E+14

Footnotes to Table 2:					Flux of energy use:	
1	Gibbs Free energy in Transpired water =					
	(______m3/ha/yr water used)(1 E6 g/m3)(5 J/g freshwater relative to salt)					
1a	Enter m3/ha/yr:	1.00E+04	Flux of Gibbs Free energy =		5E+10	J/ha/yr
1b	Enter m3/ha/yr:	3.40E+03	Flux of Gibbs Free energy =		1.7E+10	J/ha/yr
1c	Enter m3/ha/yr:	3.40E+03	Flux of Gibbs Free energy =		1.7E+10	J/ha/yr
1d	Enter m3/ha/yr:	1.50E+04	Flux of Gibbs Free energy =		7.5E+10	J/ha/yr
1e	Enter m3/ha/yr:	2.00E+04	Flux of Gibbs Free energy =		1E+11	J/ha/yr
1f	Enter m3/ha/yr:	1.50E+04	Flux of Gibbs Free energy =		7.5E+10	J/ha/yr
1g	Enter m3/ha/yr:	1.90E+04	Flux of Gibbs Free energy =		9.5E+10	J/ha/yr
1h	Enter m3/ha/yr:	2.00E+04	Flux of Gibbs Free energy =		1E+11	J/ha/yr
1i	Enter m3/ha/yr:	1.80E+04	Flux of Gibbs Free energy =		9E+10	J/ha/yr
1j	Enter m3/ha/yr:	5.00E+03	Flux of Gibbs Free energy =		2.5E+10	J/ha/yr
1k	Enter m3/ha/yr:	7.00E+03	Flux of Gibbs Free energy =		3.5E+10	J/ha/yr
1l	Enter m3/ha/yr:	5.00E+03	Flux of Gibbs Free energy =		2.5E+10	J/ha/yr
1m	Enter m3/ha/yr:	1.00E+03	Flux of Gibbs Free energy =		5E+09	J/ha/yr
1n	Enter m3/ha/yr:	5.00E+03	Flux of Gibbs Free energy =		2.5E+10	J/ha/yr
1o	Enter m3/ha/yr:	2.00E+03	Flux of Gibbs Free energy =		1E+10	J/ha/yr
1p	Enter m3/ha/yr:	6.00E+03	Flux of Gibbs Free energy =		3E+10	J/ha/yr
1q	Enter m3/ha/yr:	2.00E+04	Flux of Gibbs Free energy =		1E+11	J/ha/yr
1r	Enter m3/ha/yr:	1.00E+04	Flux of Gibbs Free energy =		5E+10	J/ha/yr
2	Energy of moving water based on head loss per 10 m:					
	(m3/yr)(density, 1E3 kg/m3)(Height change, m)(gravity, 9.8m2/sec2)					
2a	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2b	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2c	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2d	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2e	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2f	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
2g	Enter m3/ha/yr:	1.00E+05	Enter change m:	0.02	19600000	J/ha/yr
3	Tidal energy absorbed per hectare based on m tidal range * 0.5 as center of gravity					
	(area,1E4 m2)(0.5)(range squared)(706 tides/yr)(density, 1.023 E3 kg/m3)(gravity)					
3a	Enter range in m:	1	Tidal energy absorbed =		3.54E+10	J/ha/yr
3b	Enter range in m:	1	Tidal energy absorbed =		3.54E+10	J/ha/yr
3c	Enter range in m:	1	Tidal energy absorbed =		3.54E+10	J/ha/yr
3d	Enter range in m:	1	Tidal energy absorbed =		3.54E+10	J/ha/yr
3e	Enter range in m:	1	Tidal energy absorbed =		3.54E+10	J/ha/yr

Wetland Table 2 types notes

4	Water wave energy absorbed per square hectare based on wave height					
	(100 m size)(.125)(density, 1.023 E3 kg/m3)(gravity)(m squared)(velocity)(sec/yr)					
	Velocity = square root of product of gravity and depth of wave measurement					
4a	Enter m of wave:	0.5	Enter m of depth	1	3.1E+09	J/ha/yr
5	Nutrient phosphorus evaluated as Gibbs energy of its concentration compared to background					
	(m3/ha/yr)(____g/m3 P)(Joules Gibbs energy/g)					
	Gibbs energy = (gas cnostant)(Kelvin T.)((log base e of ppm ratio)/(atomic weight)					
	Enter input ppm:	5	Background ppm:	0.05		
5a	input m3/Ha/yr:	1.00E+05	Gibbs free energy in nutrient P::		1.69E+08	J/ha/yr

Wetland Value Table 3

Table 3. Evaluation of Annual Emergy Use in Florida Wetlands

Enter Name of Wetland here: Odum Cypress dome

Note	Name of Inflow	Units	Flux used Units/ha/yr	Solar Em./unit sej/unit	Solar Emergy use: sej/ha/yr
Environmental Inputs:					
1	Water transpired (Gibbs Free Energy)	Joules	5.00E+10	1.80E+04	9E+14
2	Fresh-water motion energy absorbed	Joules	0.00E+00	2.79E+04	0
3	Tidal energy absorbed	Joules	0.00E+00	1.64E+04	0
4	Wave motion energy	Joules	0.00E+00	3.04E+04	0
5	Phosphorus influx used	grams	0.00E+00	3.80E+07	0
6	Nitrogen influx used	grams	0.00E+00	2.60E+06	0
7	Physical energy of wind absorbed	Joules		1496	0
8	Clay sediments received	grams	1.00E+04	2.00E+09	2E+13
9	Organic matter imported	Joules	5.40E+06	7.40E+04	3.996E+11
10	Influx of Species	#			0
11	Direct sunlight	Joules	5.90E+09	1	5900000000
12	Total of independent environmental inputs				9.204E+14
Human Inputs:					
13	Human Goods and Services used	$	0	1.60E+12	0
14	Taxes paid per year	$	84	1.60E+12	1.344E+14
15	Fuels Used	Joules	0	53000	0
16	Interest paid	$	0	1.60E+12	0
17	Total of Human & economic inputs			4.8E+12	1.344E+14
18	Sum of Environmental and Human inputs				1.0548E+15

Footnotes to Table 3:						
Environmental Inputs:						
1	Gibbs Free energy in Transpired water =					
	(_____m3/ha/yr water used)(1 E6 g/m3)(5 J/g freshwater relative to salt)					
	Enter m3/ha/yr:	1.00E+04	Flux of Gibbs Free energy =		5E+10	J/ha/yr
	Water through-flows that are not used on site are evaluated in Table 4.					
2	Energy of moving water based on head loss per 10 m:					
	(m3/yr)(density, 1E3 kg/m3)(Height change, m)(gravity, 9.8 m2/sec2)					
	Enter m3/ha/yr:	1.00E+05	Enter change m	0.02	19600000	J/ha/yr
3	Tidal energy absorbed per hectare based on m tidal range * 0.5 as center of gravity					
	(area,1E4 m2)(0.5)(range squared)(706 tides/yr)(density, 1.023 E3 kg/m3)(gravity)					
	Enter range in m:	1	Tidal energy absorbed =		3.539E+10	J/ha/yr
4	Water wave energy absorbed per square hectare based on wave height					
	(100 m size)(.125)(density, 1.023 E3 kg/m3)(gravity)(m squared)(velocity)(sec/yr)					
	Velocity = square root of product of gravity and depth of wave measurement					
	Enter m of wave:	0.5	Enter m of dep	1	3099379025	J/ha/yr
5	Nutrient phosphorus evaluated as Gibbs energy of its concentration compared to background					
	(m3/ha/yr)(___g/m3 P)(Joules Gibbs energy/g)					
	Gibbs energy = (gas cnostant)(Kelvin T.)((log base e of ppm ratio)/(atomic weight)					
	Enter input ppm:	5	Background pp	0.05		
	input m3/Ha/yr:	1.00E+05	Gibbs free energy in nutrient P		169240004	J/ha/yr
6	Nutrient nitrogen evaluated as Gibbs energy of its concentration compared to background					
	(m3/ha/yr)(___g/m3 N)(Joules Gibbs energy/g)					
	Gibbs energy = (gas cnostant)(Kelvin T.)((log base e of ppm ratio)/(atomic weight)					
	Enter input ppm:	5	Background pp	0.05		
	input m3/Ha/yr:	1.00E+05	Gibbs free energy in nutrient P		411011439	J/ha/yr
7	Wind at 1000 m multiplied by height, density, eddy diffusion coef., vertical gradient and area					
	(___m/sec)(1000m)(1.23kg/m3)(___m3/m/sec)(3.154 E7 sec/y)(__m/sec/m)2(1E4m2)					
	Enter wind,m/sec:	10		diffusion coef:	2	
	Enter Vert. grad:	2.00E-03	Wind absorbed downward:		3.1035E+10	J/ha/yr
8	Clay sediments deposited from wind or water					
9	Organic matter brought from outside, stored and/or used on site					
	(waters, m3/ha/yr)(organics, g/m3)(5 kcal/g)(4186 J/kcal)					
	Enter water inflow:	3				
	and organics ppm:	100	Flux of organic energy added =		6279000	J/ha/yr
10	Input of seeds and other propagules evaluated by number of individuals of each kind					
	Use transformities for each species as the solar emergy required to copy each species of propagu					
11	Solar insolation from climatological data;					
	Direct sunlight is not added into total since it is already included in the transformity of rain					
12	Sum of independent inputs; Direct sunlight and wind omitted--climatic by-products of rain used					
Human Inputs:						
13	Human goods and services in expenditures of a particular year					
14	Taxes in expenditures in a particular year					
15	Fuels used in work on site multiplied by energy per unit fuel					
16	Interest in dollars of a particular year paid on debt on the site					
17	Sum of solar EMERGY contributed through human and economic inputs					
18	Sum of enviromental contributions and human-economic contributions (Item 12 & item 17)					

II. EVALUATION OF REGIONAL ROLE:

Whereas the calculations in levels 1-3 evaluate the work done on site using the main energy sources from nature and humanity, Judgments about a particular wetland site may depend on the role it plays in the larger system. Table 4 provides a calculation table for estimating EMERGY and macroeconomic dollar values of work in the regional system for which the wetland site may be essential because of its contributions to the outside, position in water cycles, wildlife corridors, city proximity's, etc. Table 4 evaluates the EMERGY production and use outside of the site in question that might be at risk if its role in the larger system were changed. Mitigation has to be based not only on the EMERGY wealth generated by the work of the wetland site, but the change in EMERGY production and use in the surrounding system caused by the change.

For evaluation of regional role, draw a systems diagram of the regional system showing the role the site in question plays in the surroundings (Figure 2). Using the spreadsheet for Table 4, evaluate the main processes affected by the wetland site. If the diagramming indicates processes not already covered in Table 4, add appropriate line items. Use the solar EMERGY values and their macroeconomic $ equivalents to consider any changes proposed in the use of the wetland. Specific proposals for changed use of a wetland should be accompanied by evaluation of Table 4 before and after the proposed change.

EXAMPLE: FLORIDA CYPRESS POND

Tables 1,2, 3, and 4 include an example, a cypress pond in north Florida where tree growths have accumulated 100 years. The procedure generated the following results (Table 5). Data on the cypress pond wetland type are given by Ewel and Odum (1985).

Table 5 Solar EMERGY Evaluation of a Cypress Pond

	Solar Emergy sej/ha	Macroeconomic 1990 $
Evaluation of Storage/ha, Table 1:		
Level 1(constant land EMERGY)	2.5 E1	172,603.
Level 2(based on wetland type	3.6 E17	246,757.
Level 3(detailed evaluation)	4.4 E17	275,000.
Annual value, Table 3, Line 18	1.1 E15	688.
Annual role in surroundings(Table 4)	7.9 E15	4,971.

Table 4. Emergy Evaluation of the Outside Role of a Florida Wetland						
	See Table 3 for evaluation of Emergy uses on site					
	Enter Name of Wetland here:		Odum Cypress Pond			
Note	Name of flow	Units	Flux used Units/ha/yr	Solar Em./unit sej/unit	Solar Emergy use: sej/ha/yr	Macroeconomic $/ha/yr
Unabsorbed flows through the site affecting other areas:						
1	Chem. energy, fresh water	Joules	2.50E+11	1.80E+04	4.50E+15	1730.76923
2	Phys. energy, fresh water	Joules	4.90E+07	2.79E+04	1.37E+12	0.52580769
3	Saltwater currents	Joules	0	1.64E+04	0.00E+00	0
4	Phosphorus flux	grams	1.01E+06	3.80E+07	3.84E+13	14.7615385
5	Nitrogen flux	grams	1.02E+07	2.60E+06	2.65E+13	10.2
6	Sediment transport	grams	0	2.00E+09	0.00E+00	0
7	Organic transport	Joules	1.05E+11	7.40E+04	7.74E+15	2977.07692
8	Species refuge	#	2.00E+07	1.00E+07	2.00E+14	76.9230769
9	Harvested products	$	0	4.00E+03	0.00E+00	0
10	Human experiences	Joules	2.10E+07	2.00E+07	4.20E+14	161.538462
11	Sum of separate items of outside effect (#1-#10)				1.2927E+16	4971.79504
12	Potential oftypical outside EMERGY matching				6.44E+15	2476.92308
Footnotes for Table 4:						
*	Solar Emergy/ha/yr divided by EMERGY/$ ratio =			2.60E+12	sej/$	
1	Gibbs Free energy in Transpired water =					
	(_____m3/ha/yr water used)(1 E6 g/m3)(5 J/g freshwater relative to salt)					
	Enter m3/ha/yr:	5.00E+04	Flux of Gibbs Free energy =		2.5E+11	J/ha/yr
	Water through-flows that are not used on site are evaluated in Table 4.					
2	Energy of moving water based on head loss per 10 m:					
	(m3/yr)(density, 1E3 kg/m3)(Height change, m)(gravity, 9.8 m2/sec2)					
	Enter m3/ha/yr:	5.00E+04	Enter change n	0.1	49000000	J/ha/yr
3	Tidal energy absorbed per hectare based on m tidal range * 0.5 as center of gravity					
	(area,1E4 m2)(0.5)(range squared)(706 tides/yr)(density, 1.023 E3 kg/m3)(gravity)					
	Enter range in m:	0	Tidal energy absorbed =		0	J/ha/yr
4	Nutrient phosphorus evaluated as Gibbs energy of its concentration compared to background					
	(m3/ha/yr)(___g/m3 P)(Joules Gibbs energy/g)					
	Gibbs energy = (gas cnostant)(Kelvin T.)((log base e of ppm ratio)/(atomic weight)					
	Enter input ppm:	0.2	Background ppı	0.05		
	input m3/Ha/yr:	5.00E+04	Gibbs free energy in nutrient P		1018926.36	J/ha/yr
5	Nutrient nitrogen evaluated as Gibbs energy of its concentration compared to background					
	(m3/ha/yr)(___g/m3 N)(Joules Gibbs energy/g)					
	Gibbs energy = (gas cnostant)(Kelvin T.)((log base e of ppm ratio)/(atomic weight)					
	Enter input ppm:	0.5	Background ppı	0.05		
	input m3/Ha/yr:	5.00E+04	Gibbs free energy in nutrient P		10275286	J/ha/yr

6	Sediment flow passing, Water Flux multiplied by clay sediment concentration					
	Enter water flux:	5.00E+04	g/m3 clay:	0	0	J/ha/yr
7	Organic filtering in Joules, times ppm organic content and 5 kcal/g & 4186 J/kcal					
	Enter water flux:	5.00E+04	ppm organics:	100	1.0465E+11	J/ha/yr
8	Wildlife sanctuary,hectare contribution based on wildlife biomass/area					
	Enter grams dry biomass/ha:	1.00E+03			20930000	J/ha/yr
9	Yield to outside, dry g/ha/yr times energy content					
	Enter yield dry g/ha/yr:	0			0	J/ha/yr
10	Multiply person-days of human contact/y by metabolism per hour(2500 kcal/day*4186 J/kcal)					
	Enter person-days	2			20930000	J/ha/yr
11	Sum of solar EMERGY/ha/yr in the last column.					
12	Economic activity in surroundings based on mataching EMERGY of wetland ;					
	Multiply annual solar EMERGY from Environment (Table 3) by Investment ratio for Florida(7.0).					
	Enter Wetland sej/ha/yr:	9.20E+14			6.44E+15	seJ/ha/yr

In the example, the higher value in Level 3 analysis was due to the tax included as measure of one of the human controls. Large items of wetland contribution to the surrounding systems included the EMERGY of the water recharged to the ground and the contained organic matter processing that was a measure of the filtering and metabolic action in the process.

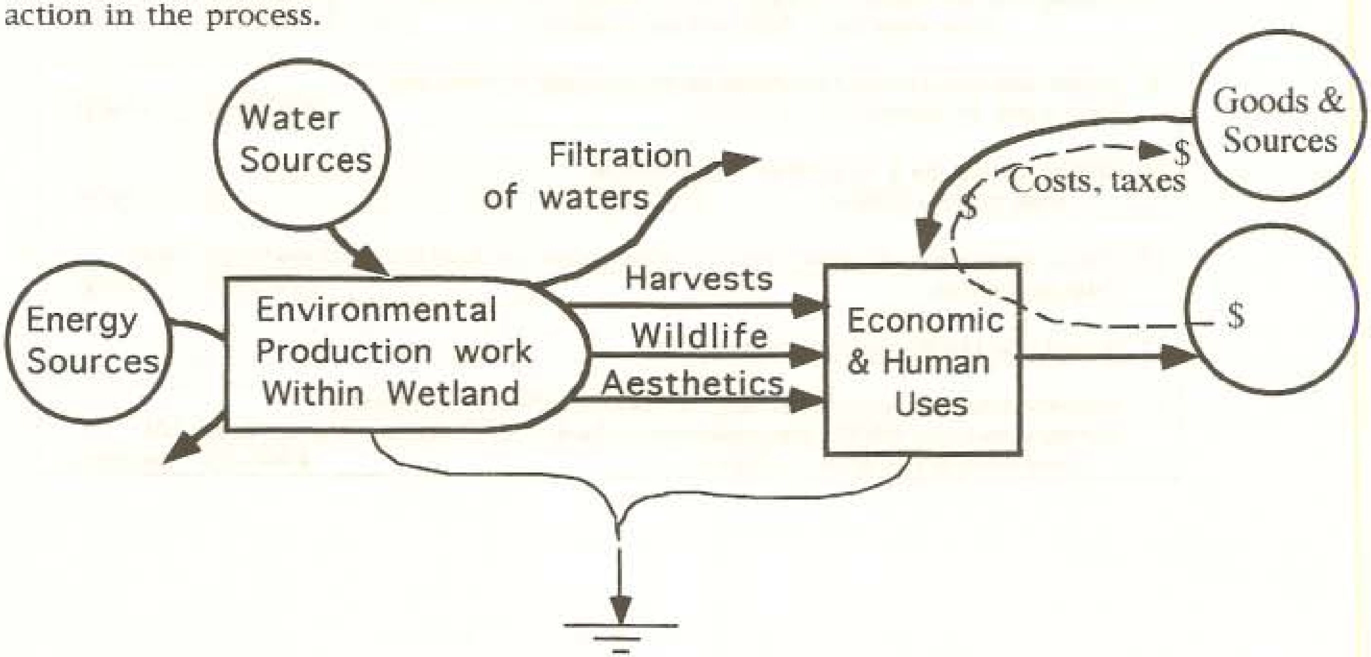

Figure 2. Some of the ways wetlands participate in larger system

This preliminary draft is assembled to elicit interest and test feasibility of this approach. With funding and participation of those with local knowledge, this manual could be completed for Florida and similar manuals adapted for other states and nations.

For more background on EMERGY, copies of the report by Odum and Arding (1991) are available which includes a glossary and an appendix introducing concepts. That report includes EMERGY analysis on several scales: international,national, regional, ecosystem, and mircoeconomic systems with EMERGY-based policy recommendations .

References Cited

Ewel, K. and H.T. Odum, eds. 1985. Cypress Swamps. University of Florida Press, Gainesville. 472 pp.

Giampietro, M and D. Pimentel 1991 Energy efficiency: assessing the interaction between humans and their environment. Ecological Economics, 4(2):117-144.

Odum, H.T. and J.E. Arding. 1991. EMERGY Analysis of Shrimp Mariculture in Ecuador. Working Paper prepared for the Coastal Resources Center, University of Rhode Island, Narragansett, RI. 114 pp.

Wharton, C. and H.T. Odum, eds. 1976. Wetlands Use Manual. Florida Division of State Planning, 380 pp.