A Case Study: Systemic Evaluation of Compensatory Mitigation Sites Within the Carlsbad Hydrological Unit

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Abstract

This study took place over the course of four months within the Carlsbad Hydrologic Unit (CHU). The cities (Carlsbad, Encinitas, Vista, Escondido, Oceanside, Solano Beach, and San Marcos) of the CHU are in northern San Diego County, California, USA. The sites under study were complied into a database for the Regional Water Quality Control Board (RWQCB) permit records (from Section 401 of the Clean Water Act (CWA)) and individual Environmental Impact Reports (EIRs) requested from various federal, city, and trustee agencies. The database contained project information such as state clearinghouse number, lead agency, project description, location, affected body of water and watershed, the type of habitat impacted, and the extent of the impact (in acres). Location of the mitigation sites was made using GPS information. For on-site evaluation a systemic, qualitative bioassessment process was created and performed. These mitigation sites were then given a "score" based on the site's internal and external health. A root cause mapping process was employed to identify the systemic relationships among the multiple factors of the bioassessment. The lack of a distinct regulatory mechanism was identified as a key root cause driver.

A cybernetic model was used to model the regulatory relationships within the system and evaluate the effectiveness of current regulatory practices. The CHU is a system with widely varied inputs, complex set of dynamic states, and divided stakeholders. Comparison between an idealized cybernetic regulatory system and the observed system of regulation in CHU allowed me to identify information transfer and feedback-loop break-downs. Recommendations were made to close feedback loops, eliminate delays and lags in the regulatory process, and foster collaborative, unbiased information transfer in an effort to create an evolving regulation system.

Keywords: cybernetic regulation, feedback-loop, root-cause mapping, bioassessment.

Introduction to the Problem Situation

The Carlsbad Hydrologic Unit lies in central and northern San Diego County. The CHU encompasses multiple watersheds from their headwaters to the lagoons that spill into the ocean. Accordingly, each watershed has a conservancy, "friends of" program, and/or various non-profit organizations that are associated with its water. They take-on tasks such as regular clean-ups, watershed health monitoring, and public outreach and education. However, these organizations are typically small, resource-limited, and localized. In other words, each organization is consumed with the business of their own watershed, and inter-watershed collaboration is not a regular process. The necessity of a CHU-wide study, or at the very least accounting, was obvious, but outside the agenda for any watershed-specific groups.

The Natural Reserve System (NRS) provided the appropriate vehicle for an inter-watershed study of the CHU. The Natural Reserve System is a non-profit, research- and conservation-minded organization that maintains several natural reserves inside and around the CHU. The organization plays the role of a "trustee agency" who is involved in the public review and consultation portion of the permitting process. It also acts as a "watchdog", which has the technical and financial abilities to bring specific cases to court. This creates accountability on the part of the cities, developers, and public. NRS's provided the ecological knowledge and tools to approach a multiple watershed problem.

Initial findings showed an up-to-date accounting of the CHU's mitigation status was missing. Environmental impacts were continuously occurring within the watershed (as reported by permit records), but records of their mitigation were not extensive nor reliable. Even central groups within the CHU-- the conservancies and the Carlsbad Watershed Network-- were uninformed about the current impact to mitigation ratio. The extent and location of cumulative impacts was unknown. Therefore, there was no way to evaluate the effectiveness of the "No Net Loss" policy. The foundation of California conservation policy is "No Net Loss", which depends on the amount of mitigated habitat to be quantitatively equal to or greater than what was impacted. The need for a comprehensive study was clear.

Thus, the primary goal of this study was to compile a database of the reported impacts to wetlands and associated habitats (riparian, streambed, lake, and ocean) within the CHU, and their compensatory mitigation measures. Most entries came from the Regional Water Quality Control Board (RWQCB) database. Their records of 401 permits (Clean Water Act) were obtained for the past twenty years. The records were sorted to sites within the jurisdiction of the CHU. The Individual Environmental Impact Reports (EIRs) were obtained by contacting individual agencies such as the Army Corp of Engineers, California Department of Fish and Game and Department of Wildlife, the regional EPA office, and other local regulatory agencies.

A second goal was to articulate the regulatory processes that shape the CHU. There are a complex set of influences and an extensive cast of stakeholders that affect the CHU. Economic development by expanding cities threatens natural habitat. Political struggles for land use, such as the recent proposition addressing urban sprawl, increase the stress on remaining habitat. The rapidly expanding populations within the CHU fuel increasing congestion, air and water pollution, and habitat destruction. There is a wide range of stakeholders often with conflicting agendas. Stakeholders include: the cities of the CHU, the watershed conservancies, contractors and developers, special consultants (biologists, ecologists, etc.), federal, state, and local regulatory agencies, private landowners, non-profit, special interest environmental groups, and the public. When all of these components must coexist, the situation becomes bogged-down in complexity, and a systemic approach must be used to understand their many interactions.

A third goal was recording and evaluating compensatory mitigation sites of the CHU. The reported Global Positioning System (GPS) information was only adequate for about ten percent of the total records. The mitigation sites had to be located in order to determine the distribution of impacted habitat throughout the CHU. It became evident which watersheds had the most impacts and corresponding mitigation. The differences in the impact to mitigation ratios between watersheds distinguished one from another in their regulatory effectiveness and rigor. An on-site evaluation of a given mitigation site provided insight not only into the quantitative extent, but also the quality of mitigation. A specific evaluation process called bioassessment was created for this task. The use of this evaluator in the field was vital to understanding the quantitative and qualitative status of mitigation within the CHU.

Finally, recommendations will be made to revitalize conservation efforts within the system. As it stands now, there are fundamental flaws in the regulatory process that need to be addressed systemically to move toward sustainable success.

Systemic Bioassessment

After the location data was sorted and verified, the study turned towards field work. Armed with viable GPS locations and topographic/road maps, the sites were fairly easy to find. Once there, the site was thoroughly explored and a photographic record taken of the described mitigation. With the bioassessment worksheet (Fig. 1), the site was evaluated based on ecological and functional criteria.

The bioassessment used in this study featured a rating system that ranged from 0 (extreme degradation) to 20 (near pristine/ healthy). The site receives a score for each category based the criteria listed under “Habitat Parameters”. The parameters are then divided again into three classifications for “Habitat Dimensions”, “Productivity”, and “Resiliency”. The scoring criteria included:

	HABITAT PARAMETER	CONDITION CATEGORY			
		HEALTHY		UNHEALTHY	
		NEAR PRISTINE/ HEALTHY	SOME DEGRADATION	UNHEALTHY/ OBVIOUS DEGRADATION	EXTREME DEGRADATION
HABITAT DIMENSIONS	QUALITY OF VEGETATIVE COVER*	Diverse and statified canopy that offers excellent habitat for wildlife.	Inconsistent stratification, but canopy is sufficiently heterogenous to offer wildlife habitat.	One or more levels of trees, woody shrubs, or hebacious plants is absent. Wildlife cover is limited.	Homogenous habitat which offers no cover for willife
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	PLANT AND ANIMAL SPECIES DOMINANCE	100-75% native species present.	75-50% native species present.	50-25% native species present.	<25% native species present.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	VISIBLE BIODIVERSITY**	High family and/or species diversity. High divergence between families with proportional representaiton of each.	Moderate family and/or species diversity. Diversity displays suficent family divergence. Representation may be unbalanced, but no taxa is overly dominate.	Limited family and/or species diversity. Family divergence is reduced and taxa dominaiton is emerging.	Habitat dominated by one or a few species from closely related families.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	GROUND COVER (Compared to a control)	Ground cover is heterogeneous and protects against erosion (> 90% protective cover).	Ground cover heterogeny less than prisitne but still diverse. Slight erosion evident (70-90% protective cover).	Ground cover is dominated by several species and significant erosion is evident (50-70% protective cover).	Ground cover consists of one or a few species, and extensive erosion has resulted (<50% protective cover).
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	FRAGMENTATION	No significant barriers to wildlife and habitat is continuous.	A few barriers to wildlife movement, but not restrictive. Slight fragmentation of habitat.	Significant restrictions of wildlife movement and habitat fragmentation.	Wildlife movement has been disrupted, and habitat exists in islands.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
PRODUCTIVITY	COMPATIBILITY#	Site flora and fauna, terrain, and hydrology compatible/ complementary with surrounding habitat.	Site flora and fauna, terrain, and hydrology mostly compatible/ complementary with surrounding habitat.	Site flora and fauna, terrain, and hydrology inconsistent with surrounding habitat.	Site flora and fauna, terrain, and hydrology dramatically inconsistent with surrounding habitat.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	RIPARIAN FUNCTION	Riparian areas effectively filter run-off, regulate temperature, and provide organic input into the ecosystem.	Riparian areas for the most part filter run-off, regulate temperature, and provide organic input into the ecosystem.	Riparian areas do not filter run-off, regulate temperature, and/or provide organic input into the ecosystem.	Riparian areas absent.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	ECONOMIC PURPOSE	Human interaction with site is negligeble. A symbiosis is achieved.	Human interaction with site is passive, but present.	Human interaction with site is temporarily detremental.	Human interaction with site is permenantly detremental.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
RESILENCY	CUMULATIVE EFFECTS##	Stress(es) to site have little negative synergy.	Stress(es) to site display some negative synergy.	Stress(es) to site display significant negative synergy.	Stress(es) to site display extensive negative synergy.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
	REVERSABILTY***	Negative impacts are superfical and can be reversed with little effort.	Negative impacts are significant, but with moderate effort can be reversed.	Negative impacts are extensive and can only be reversed by large-scale efforts.	Negative impacts are irreversible.
	SCORE	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
*** Are the mitigation measures helping to reerse the impacts? Examine the habitat's overall degradation.		*Layers of vegetation are considered here. Examine the stratification of trees, woody shrubs, and herbacious plants. Is there heirarchy or canopy stratificaiton?		#Consider factors such as continuous terrain (topography and composition), compatible hydrology, and consistent flora and fauna. Compare with surrounding habitat.	
		**Pay attention to higher taxa diversity. Count the numbers of families and species present		##Stresses can be independent or connected. If the effect of multiple stresses could not have been achieved without the combination of those stresses, then negative synergy has occurred.	

Figure 1: The Bioassessment Evaluation Worksheet

- *Visible Biodiversity*: the visible biodiversity is evaluated by family, as opposed to species, divergence that requires less specific species knowledge;
- *Plant and Animal Species Dominance*: the ratio of native to non-native/invasive species;
- *Quality of Vegetative Cover*: the stratification canopy that contains a diversity of vegetation that provides multiple niches for wildlife to occupy;
- *Ground Cover*: the site's susceptibility to erosion-- sufficient ground cover, present in vegetation's root systems, will prevent erosion;
- *Fragmentation*: the site must exhibit no significant barriers to wildlife movement and be continuous;
- *Compatibility*: the natural hydrology must be maintained and the flora compatible with surrounding natural vegetation;
- *Riparian Function*: habitat's ability to filter run-off, regulate temperature, and provide organic input into the system;
- *Economic Purpose*: does the site's extent and nature of human interaction promote sustainable development;
- *Resiliency*: the site's capacity to rebound after cumulative effects of multiple stresses; and
- *Cumulative effects*: did the mitigation measures help reverse impacts to the site, or are the impacts irreversible.

Results

A database containing 208 records was compiled for impact and mitigation sites. It included the type and extent of impacts, compensatory mitigation, the lead agency involved, and the watershed that was affected. Not only was the database a first step towards creating accountability, it also revealed the extent to which the CHU's habitat is being degraded.

From the database, two summary tables were created to make the database's information more accessible (Table 1 and 2). The summary tables give the extent of impacts and mitigation based on totals from individual permits. Both the impacts and mitigation tables divide the CHU into its constituent watersheds, then further into the type of habitat affected. The overall ratio of acres impacted to acres mitigated was 1,392 to 561. The watersheds that effectively implemented mitigation (according to impacts:mitigation ratios) are Agua Hedionda HA(47.77: 57.8), Escondido HSA (5.64: 11.81), Loma Alta HA (32.23: 41.80), Los Manos HSA (10.36: 29.39), and San Elijo HSA (64.44: 71.68). The most effective watershed was Buena Vista Creek HA with a ratio of 18.53: 45.40. On the other end of the spectrum, the watersheds with the least effective implementation were Batiquitos HA (68.63: 33.81) and San Marcos HA. San Marcos had they most unequal ratio of 1,010.05: 126.76, which exceeded the ratio of the entire CHU. The other watersheds (Buena HSA, El Salto HSA, Escondido Creek HA, Richland HSA, Twin Oaks HSA, and Vista HSA) had a ratio near 1:1. Cottonwood HA and Encinas HA had no information reported in their project summaries.

IMPACTS (ACRES)	TYPE OF HABITAT IMPACTED												
	TEMPORARY IMPACTS					TOTAL FOR INDIVIDUAL WATERSHED	PERMANENT IMPACTS					TOTAL FOR INDIVIDUAL WATERSHED	OVERALL IMPACTS TO INDVIDUAL WATERSHED
	WETLANDS	RIPARIAN/ WOODLANDS	STREAMBED	LAKE	OCEAN		WETLANDS	RIPARIAN/ WOODLANDS	STREAMBED	LAKE	OCEAN		
AGUA HEDIONDA HA (904.30)	4.87	0.79	0.11	0	2mil cy	5.77	18	13.22	6.38	4.48	0	42	47.77
BATIQUITOS HA (904.51)	1.133	0	0.17	0	2mil cy	1.303	14.196	5.1302	3.46	44.54	0	67.3262	68.6292
BUENA HSA (904.32)	0.66	0	0.01	0	0	0.67	5.2	0.12	2.12	0	0	7.44	8.01
BUENA VISTA CREEK HA (904.20)	1.653	0	0.178	0	0	1.831	9	0.68	6.672	0.35	40,000 CY	16.702	18.533
COTTONWOOD HA (904.51) **(NO INFORMATION)**	0	0	0	0	0	0	0	0	0	0	0	0	0
EL SALTO HSA (904.21)	0.06	0	0	0	0	0.06	0	0	0	0	0	0	0.06
ENCINAS HA (904.40) **(NO INFORMATION)**	0	0	0	0	0	0	0	0	0	0	0	0	0
ESCONDIDO CREEK HA (904.60)	2.227	0.176	2.523	45.1	0	50.026	36.355	4.874	7.953	9.62	1.5	60.302	110.328
ESCONDIDO HSA (904.62)	1.734	0.15	2.426	0	0	4.31	1.017	0.105	0.203	0	0	1.325	5.635
LOMA ALTA HA (904.10)	2.95	4.5	0.021	0	0	7.471	8.957	10.53	3.002	2.27	0	24.759	32.23
LOS MANOS HSA (904.31)	0	0	0.04	0	0	0.04	8.34	0	1.98	0	0	10.32	10.36
RICHLAND HSA (904.52)	0.04	0	0	0	0	0.04	0.28	0	0.199	0	0	0.479	0.519
SAN ELIJO HSA (904.61)	0.14	0	0.9	45.1	2mil cy	46.14	17.5744	0	0.724	0	0	18.2984	64.4384
SAN MARCOS HA (904.50)	3.77	0	350.435	0	1.6	355.805	27.674	8.706	605.809	10.63	1.43	654.249	1010.054
TWIN OAKS HSA (904.53)	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2
VISTA HSA (904.22)	0.012	14.46	0	0	0	14.472	0.162	0.222	0.08	0	0	0.464	14.936
TOTALS FOR CARLSBAD HYDROLOGIC UNIT	19.249	20.076	356.813	90.2	1.6	487.938	147	43.5872	638.782	71.89	2.93	904	1391.7026

Table 1: Extent of impacts within the CHU divided by watershed and type

MITIGATION (ACRES)	TYPE OF HABITAT MITIGATION									TOTAL FOR INDIVIDUAL WATERSHED
	WETLANDS			RIPARIAN/WOODLANDS			WATERS			
	CREATE	PRESERVE	RESTORE	CREATE	PRESERVE	RESTORE	CREATE	PRESERVE	RESTORE	
AGUA HEDIONDA HA (904.30)	25.996	0.53	7.393	7.798	0.42	11.63	2.51	0.02	1.5	57.797
BATIQUITOS HA (904.51)	22.06	8.34	0.404	0.5	0	0.3	2.12	0	0.09	33.814
BUENA HSA (904.32)	6.02	0	5.43	0	0	0	1.38	0	0.01	12.84
BUENA VISTA CREEK HA (904.20)	17.621	0	16.64	5.832	0	0.72	4.45	0	0.138	45.401
COTTONWOOD HA (904.51) **(NO INFORMATION)**	0	0	0	0	0	0	0	0	0	0
EL SALTO HSA (904.21)	0	0	0.12	0	0	0	0	0	0	0.12
ENCINAS HA (904.40) **(NO INFORMATION)**	0	0	0	0	0	0	0	0	0	0
ESCONDIDO CREEK HA (904.60)	37.184	1.45	12.575	4.991	0	0.291	3.99	0.67	50.744	111.895
ESCONDIDO HSA (904.62)	1.351	0.56	6.29	0	0.835	0.35	0.709	0	1.71	11.805
LOMA ALTA HA (904.10)	10.89	0.78	5.36	21.88	1.41	0	1.38	0	0.1	41.8
LOS MANOS HSA (904.31)	2.84	0	11.9	0	0	6.1	8.518	0	0.025	29.383
RICHLAND HSA (904.52)	0.524	0	0.14	0	0	0	0	0	0.135	0.799
SAN ELIJO HSA (904.61)	20.544	0	0.32	0.9	0	0.21	0.9	0	48.81	71.684
SAN MARCOS HA (904.50)	16.44	70.88	20.27	10.14	0.16	0	3.6	3.23	2.04	126.76
TWIN OAKS HSA (904.53)	0	0	0	0	0	0	0.26	0	0	0.26
VISTA HSA (904.22)	1.458	0	0.04	0.16	0	14.72	0	0	0	16.378
TOTALS FOR CARLSBAD HYDROLOGIC UNIT	162.928	82.54	86.882	52.201	2.825	34.321	29.817	3.92	105.302	560.736

Table 2: Extent of compensatory mitigation within the CHU organized by watershed and type

The tables tell us which habitats were impacted most frequently throughout the CHU, and whether that impact was temporary or permanent. The results show that the most frequently impacted habitat, regardless of the impact's permanence, was streambed. Streambed habitat had 356.81 acres temporarily impacted and 638.78 acres permanently impacted. This suggests that streambed regulation may be currently ineffective. Wetlands were the second-most impacted habitat, but with much more permanent impacts. Wetlands sustained 19.25 acres of temporary impacts and 147 acres of permanent impacts. Lakes were the third most-impacted with 90.2 acres of temporary impacts and 71.89 acres of permanent impacts. Riparian/ Woodlands were fourth most-impacted with 20.10 acres of temporary impacts and 43.59 acres of permanent impacts. Finally, marine habitat was last with 1.6 acres of temporary impacts and 2.93 acres of permanent impacts. These rankings may be important indicators of the level of protection each habitat is receiving. However, it is important to keep in mind that classification of these habitats is a complicated process with varying degrees of accuracy. There are entire manuals dedicated to wetlands delineation, and it is a subjective process determining where "riparian/woodland" and "lake" areas begin and end. It is also significant that despite the extent of wetlands protection in place, wetlands habitat still manages to rank second in most-impacted habitats within the CHU. This information is a red flag for conservationists, and it illustrates the problems within the system; *this is quantitative evidence against the "No Net Loss" policy.*

These numbers illustrated that "No Net Loss" strategy needs to be quantitatively reevaluated, as the CHU's habitat overall is at a 2.5:1 impacts to mitigation ratio. The second phase of this study revealed that there are qualitative issues as well. Evaluation of the 20 visited sites supported the claim that current mitigation measures are ineffective. The health of the resulting mitigation site is well below that of the natural habitat that was impacted. In particular, erosion is much more prevalent in mitigation sites than in the surrounding habitat. Fragmentation, due to off-site, poorly designed, or incomplete mitigation, is adversely affecting the abundance and diversity of wildlife within the CHU. The evaluated sites consistently displayed trends of increased erosion, reduced biodiversity, and incompatibility with surrounding habitat. Another barrier to effective mitigation, was the length of time between the site's impact and mitigation. The longer a site was degraded, the more divergence there was between the previous natural populations of the site and the populations that dominated the site after mitigation. Erosion and altered hydrology change the soil's composition favoring different species than before. Invasive species established footholds where native species have been removed. These findings are particularly significant because the spread of non-native/invasive species is a growing problem in Southern California. It is clear from the evidence that current impact regulations and mitigation practices are ineffective, and without change habitat within the CHU is prone to continued depletion.

Root Cause Mapping and Cybernetic Modeling of the Regulatory Mechanism

Root-cause mapping (Magliocca & Sanders, in press) is a systemic approach to exploring boundaries, articulating barriers, and formulating solutions within a complex system. Typical root cause analysis, as developed in the energy industry (ABS, 1999), identifies a linear process of distinct, causal factors that are unrelated. Root-cause mapping was created for application with systemic issues and through graduated levels of influence it exposes the symptomatic and root-cause problems of the CHU (Fig. 2). The most symptomatic problems are at the top of the root-cause map, as they are the most apparent and are directly influenced by a deeper level problem. Symptomatic problems are those that appear frequently in a system and offer the most immediate difficulty. As one travels down the map, problems grow in their influential power until the deepest level. Root-cause problems are on the lowest level of the map because they are the causal drivers of the system. The most immediate problems within the CHU are the continued degradation of environmental quality and a lack of understanding of current environmental conditions. But there are problems more causal than these. For example, agency responsiveness is weak, elected officials are misinformed about projects and problems occurring within the CHU, and mitigation is not qualitatively equivalent to natural habitat. There are problems deeper still that involve regulation and agency efficiency. These "deep root drivers" pointed to the need for a systems model to identify the issues of regulation underlying the problems. Cybernetic modeling seemed to offer the most robust approach.

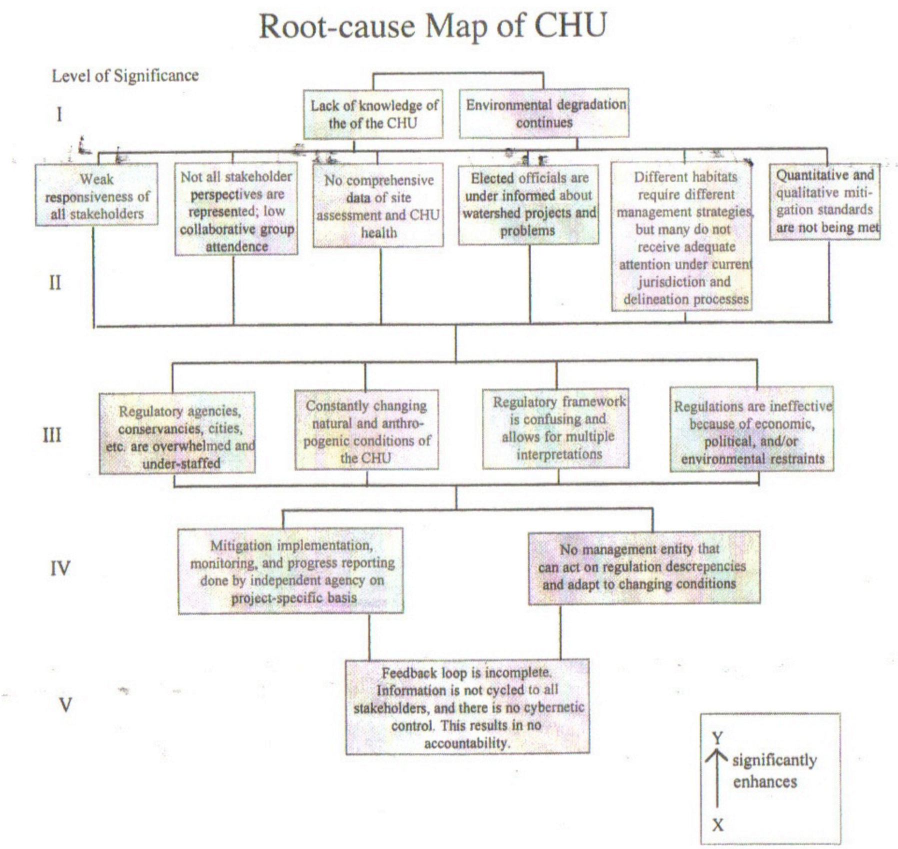

Figure 2: Root-cause map of the CHU. Deep influence increases with level number.

Cybernetic modeling was used to examine the dynamic relationships of the CHU regulatory system. The model used for this study was adapted from the model described in Lars Skyttner's work *General Systems Theory* (2001). The structure of this basic cybernetic regulatory model consists of a *sensor*, *goal setter, comparator, decision unit,* and *effector*. One path includes information entering the system through the *sensor* as input, passing through the *decision unit* where changes are determined, and exiting the system through the *effector* as output. A more adaptive path of regulation includes a parallel path of information flow and feedbacks (Fig. 3). The *sensor* receives or detects input/feedback which is sent to the *decision unit* and diverted to the *comparator.* The *comparator,* or evaluation mechanism, tests the system's state against predetermined parameters that were fed into the *comparator* by the *goal setter.* The set of goals is determined by the controller, or in the case of the CHU, by a complex, always changing, and often conflicted representation of stakeholders. Evaluation determines whether the system was successful in not only meeting the predetermined goals, but also the system's deviation from equilibrium. The inputs and state of the system are sent to the *decision unit.*

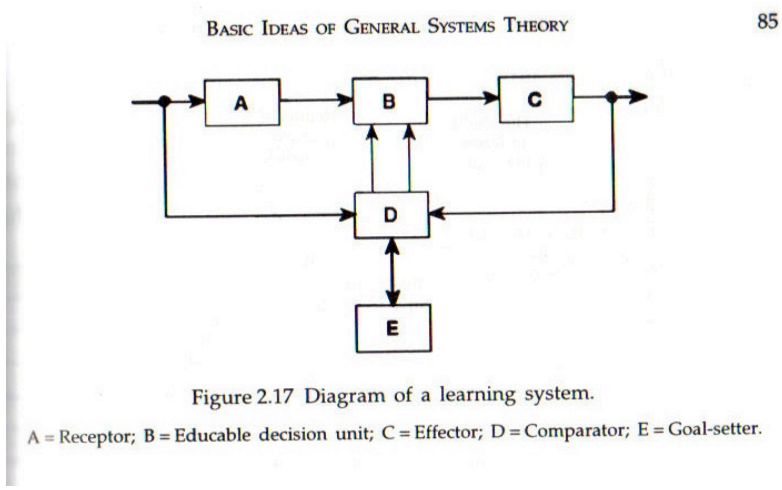

Figure 3: Basic cybernetic regulatory system

The decision unit acts to align the system's outputs with its goals, and evaluate feedback from previous cycles. In its latter function, a system can learn through an educable *decision unit.* Feedback allows a *decision unit* to adapt by acting of the rules of the system. "Rules must be adjusted in such a way that a successful behavior is reinforced , whereas an unsuccessful behavior results in modification" (Skyttner 2001). Thus, a system can evolve and maintain dynamic equilibrium through modifications made by the *decision unit* based on feedback in the form of the system's own output. Once changes are made, information is transfered from the *comparator/decision unit* to the *effector.* The *effector* applies the modifications and releases an output. Output can take the form of waste, or in cyclic processes, feedback as input for the next round of operation.

A more sophisticated model that better maps the complexity of the CHU regulatory system is seen in Figure 3 (Skyttner 2001). This model gives the observer an opportunity to examine the system's various functions throughout its life cycle (Fig. 4). In regard to the CHU, a complete "life cycle" is considered to begin with the need for a development project, and end with completed mitigation of its environmental impacts. Its next "generation" entails evaluating, designing, and implementing corrections to its previous cycle. This a revealing conceptualization because it stresses the importance of feedback loops and the cyclic nature of an evolving regulatory system. Feedback and information flow can be examined easily in phases. Note that the first phase is considered a consumer phase, the intermediate a producer phase, and the last consumer again. These are very loose terms as they can be fit to any regulatory system. They make distinctions between the roles of different system components, such as *sensor, decision unit,* and *effector.* The division of functions also illustrates how a multi-stakeholder system can be integrated by function towards a common output.

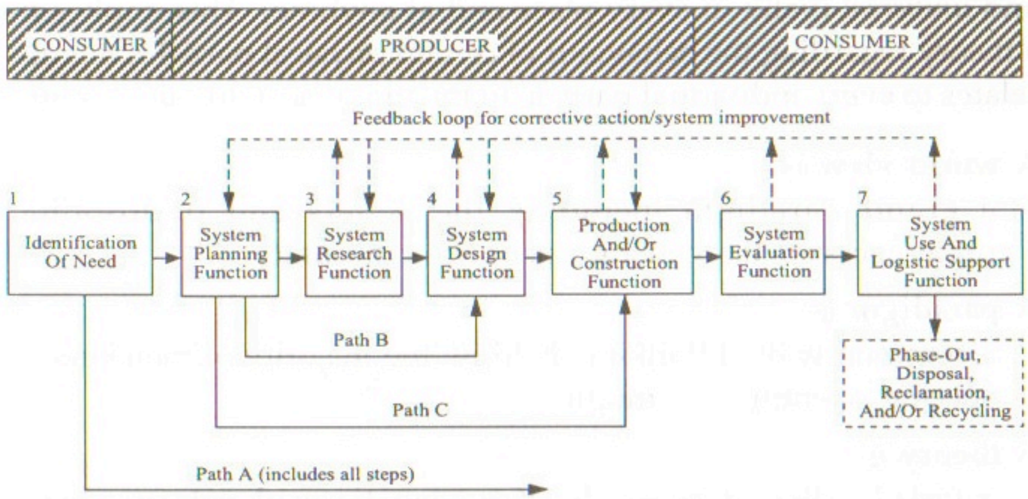

Figure 2.19 System life cycle of advanced artefacts.

Figure 4: Advanced cybernetic regulatory system that best describes the CHU

At different stages in the system's life cycles and generations, the roles of developers and conservationists are separate, and at other times, they are integrated through feedback. These distinctions are very helpful in untangling the various roles and conflicting agendas of developers and conservationists. For instance, Path A unites the process's inputs and outputs making it cyclic, which helps to distinguish between the developers' and conservationists' roles at different stages of development/mitigation. During the system's early life cycle, the developer assumes the role of the consumer. Once a project need has been identified, the producer phase is entered. Here, the system planning, research, and design functions are all integrated phases. The developer receives consultation from government regulatory agencies, biological consultants, and/or, depending on the project's stage of development, corrective feedback from conservation groups. Production is carried-out by the developer, and the last consumer stage begins. Economic success is evaluated by the developer, but the primary evaluation role goes to the conservation groups. Environmental impacts are assessed, mitigation is designed, and then implemented through the last phase of use by the developer. A new "generation" then begins with the conservationists as the first phase consumer, and mitigation becomes the focus of the next life cycle through feedback from the previous one.

Thus, the system evolves through many "generations" in a process of minimizing the environmental impacts from various economic developments. On a larger scale, the CHU acts like the basic model seen in Figure 3. However, a more sophisticated model must be used in order to describe the integrated, dynamic roles of various stakeholders. Through a cyclic process, deviations from preset goals are corrected through negative feedback. These corrections are implemented at the level of the divided functions seen in Figure 4. This becomes a "wicked" problem because of the inherent natural, regulatory, and collaborative complexity that exists in the CHU. Efficient integration of economic and conservationist interests must be achieved to maintain high levels of regulation and eliminate lags/delays on the system.

This is a very basic model of cybernetic regulation, but it illustrates the importance of feedback. Without this information transfer, regulation would be unable to adapt to changing conditions, evolve to cope with increasing complexity, and would eventually collapse. The CHU can be characterized as an open-loop system (Skyttner 2001)--one in which feedback is weak or absent. As a consequence, the state and extent of environmental impacts are not entirely known. Conservation groups are unable to adapt to changing economic development as it continues unchecked. By comparing the deviations of the CHU from the ideal cybernetic model, adjustments can be made to streamline the regulation process and close feedback loops.

Discussion

It is clear from the above analysis that something must be done to alter the path that current practices are leading us down. When one of the largest hydrologic areas, San Marcos Creek, has almost eight times as many impacted as mitigated acres, there are inconsistencies embedded in the system. This study should be viewed as an exploratory venture, as it looked at the CHU as a whole and exposed the complex systems within. This study will hopefully recapture our attention and examine the problem in a new light.

This study did not produce "hard data", like water quality or benthic macroinvertebrate samples, but instead gave insight into the quality of the mitigation being performed. Again, this was not done by "hard science", rather by system science, as the site's internal and external relationships were examined. The root-cause problem is not the impacts to mitigation ratio-- although there is an unequal ratio for the entire CHU-- but with the ineffective and isolated interactions between the system's multiple components. This is an extremely complex system that encompasses both human and natural systems, and solutions are never simple.

The deep cause of inadequate mitigation, insufficient knowledge of the CHU's state, and poor stakeholder representation stems from incomplete integration of economic and environmental objectives. There are steps in the regulatory process "life cycle" where conservationists and developers should be collaborating, but they are not. Conflicting agendas are "dysergy" in the regulation and mitigation processes (Corning, 2003). Lags, delays, and/or simple inaction result, and collaborative relationships destabilize and degrade. Information flow becomes stagnant as projects and their mitigation are designed almost entirely by the developers without input from other CHU stakeholders. Mitigation is evaluated and surveyed without feedback to the developers. Collaboration facilitates free information flow that is vital to a regulatory control system. Currently, incentive for the developers to collaborate with conservationist agencies is inadequate. A common set of goals needs to be established to facilitate information exchange, role assignment, and equity. Effective feedback will then be encouraged among all stakeholders.

Feedback-loops are essential cybernetic elements in any complex system. To draw upon a natural example, the "evolutionary arms race" between plants and herbivores is a dynamic, adaptive, and creative process. An herbivore's actions on a plant are causal to the development of that plant's defenses, which are in-turn, causal to the herbivore's evolving predatory behaviors. There is feedback involved in these organisms' interactions, and the process is iterative, driving adaptation and responsiveness. Adaptation and responsiveness are two elements lacking in the CHU regulatory system. Particularly, an effective feedback loop within the CHU will create accountability for impacts and their mitigation where relatively none currently exists. I believe this to be a *root-cause problem* of the CHU, and creating accountability through feedback is an essential first step towards a solution.

Without sufficient accountability, the system will not progress towards desired conservation, economic, and political objectives. For example, mitigation implementation, monitoring, and progress reporting is left to the party responsible for the impacts. This is an ineffective strategy because there is no method of enforcement nor incentive to consider conservation interests in the mitigation process. These conditions are most likely stem from the fact that a centralized management entity does not currently exist. Without central management, there is no mechanism to enforce stakeholder accountability and facilitate collaborative problem-solving . Collaboration breaks-down in the "Producer" phase of regulation when development and conservation roles are not integrated properly. This creates lags and delays in information transfer that reduce responsiveness and severely limit regulatory power. Thus, the central flaw in the CHU regulatory system is its open feedback loop, and this problem is exacerbated by the lack of a central management entity that can ensure accountability and collaboration.

A Proposed Solution

There are surely many solutions to this problem that are as complex as the system itself. This study, after exploration of the CHU, is prepared to propose a possible solution given the available resources of all stakeholders involved. In is our goal to create an effective feedback loop within the CHU to foster accountability, responsiveness, and adaptability. An entity is needed to feed evaluation and progress information back into the system. Mitigation monitoring and evaluation of mitigation quality and quantity will help assess overall environmental health of individual watersheds and the CHU overall.

It is this study's proposal that the "nature centers", which are associated with each watershed within the CHU, can fulfill the evaluation role. Nature centers are non-profit organizations that monitor watershed health and coordinate projects within their corresponding creek, wetland, or entire watershed. The nature centers could assess system health on a local level and compile that into a monitoring network. Where larger agencies would not be able to efficiently cover each watershed, a nature center network, with the right funding, could collect comprehensive data assessing the status of their ecological regions and compile it into a health report on the entire CHU.

The process will be ineffective, though, unless it has some "teeth". In other words, these nature centers must have solid data to educate all stakeholders on the status of their ecological regions with the purpose of taking transgressors to court for violating environmental standards. However, for this process to be set in motion, the centers would require a grant. Here is where this study and other studies like it come into play. There has been enough research done to make it clear that the CHU's natural resources continue to be depleted, and that current regulations and mitigation practices are ineffective. With these findings as backing, the centers could receive a grant to obtain a comprehensive assessment of the CHU's health. A team could be assembled in order to obtain the technically- and time-intensive "hard data" assessments and systemic indicators of qualitative health of sites in the CHU. This information would serve two purposes. First, it would inform all stakeholders of current conditions, facilitate adaptive management strategies, and encourage responsiveness from all parties involved. Second, there would be sufficient evidence to file lawsuits against parties that do not comply with environmental health standards. Both outcomes would ultimately create accountability within the system, encouraging an iterative, evolutionary process.

However, a central management component must be established for this to be efficient. The Carlsbad Watershed Network (CWN) can fulfill this role. The CWN is a collaborative group of city representatives and conservationists, but it does not represent the complete spectrum of stakeholders within the CHU. Additional parties need to include community members, developers, Amy Corp of Engineer, EPA, National Marine Fisheries, and Department of Fish And Game officials. In some form, each input in the system needs to be represented in the CWN's collaborative management. Responsive and collaborative actions and real face-to-face accountability would then be possible.

This may not may not be the best alternative, but it is a proposal that addresses the problems of the CHU at their most causal level. A cybernetic regulatory approach will address the root-cause problems and facilitate navigation through the complexity present in the CHU. The solution to the CHU's environmental health problems must be able to cope with a complex system and offer an evolutionary approach to an evolving system.

Limitations Of This Study

There are several limitations to this study. The first limitation is the collection of mitigation records. The data obtained from the 401 records and individual EIRs only represented a portion of the CHU's total mitigation. Each watershed was represented, though, which supports the assumption that the data collected was a reasonably accurate reflection of the entire CHU. As a result, there appeared to be no sampling bias. Secondly, the number of visited sites was small relative to the total number of records. In this case, sampling bias may play a major role in the results. Only sites that had viable location data could be visited. There may be a bias towards a particular watershed due to better monitoring or record-keeping practices. Overall better record-keeping practices are essential to ensuring an unbiased and comprehensive study of the CHU.

The most significant limitation in this study involves the evaluation procedure using the bioassessment worksheet. Limitations in resources such as technical expertise, man power, time allotted for study, and sampling tools dictated the nature of the qualitative evaluation process. The extent of the mitigation site was not possible to accurately measure, as some of the sites were reported to be several acres in size. As a result, the bioassessment process contained intrinsic levels of subjectivity. However, what could be viewed as this study's weakness could also be its greatest strength. The bioassessment worksheet was designed to be a qualitative evaluation specifically because of the overwhelming size of most of the sites. It can also be performed by an individual, although it was found to be most effective in a group setting. With a group of evaluators, collective experience created an insightful evaluation. The resulting dialogue revealed underlying internal and external ecological relationships of the site. Therefore, the quality of the mitigation was evaluated, which was an alternate approach to assessing the effectiveness of the "No Net Loss" policy.

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