THE POTENTIAL FOR UNCONVENTIONAL PROGRESS: COMPLEX ADAPTIVE SYSTEMS AND ENVIRONMENTAL QUALITY POLICY

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INTRODUCTION

During the 1970's and 1980's, the United States substantially improved its environmental quality. Since the early 1970's, the nation's principal model for advancing environmental quality has been the command and control system. The command and control system is the exercise of the police power of the state to compel action by establishing standards and enforcing those standards through administrative and judicial actions. This approach depends on centralized knowledge, application of authority, and limited participation in decision-making by those who must carry out such decisions. In the 1990's, national environmental management has experienced a number of pressures that call into question continued use of the conventional approach of the 1970's and 1980's. Unconventional paradigms may offer better ways to advance national environmental quality.

Complexity theory is one such unconventional approach. Drawing on lessons from experience in the physical sciences, complexity theory suggests that we consider national environmental management as a complex system that adapts over time. Such a system has complicated components that work together to produce adaptation. By understanding the general properties of these systems, we can develop more effective policies for the environmental management system.

The recognition that complex adaptive systems have the capacity to self-adjust is fundamental to complexity theory application. This permits such a system to stay in harmony with its surroundings and to advance the purpose of the system. This adaptation carries with it

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some acceptance that direct control of the emergence of new features is unlikely.[1] There are so many interactions of such a complicated nature that precise control is infeasible. Control of such systems can be achieved by influencing the sub-systems that build the overall system, rather than trying to manage the system directly. This implies paying more attention to environmental information, establishing incentives for responsible behavior, and pursuing careful implementation, not simply design, of national environmental policies. Building such an approach on flexibility, attention to goals, and innovation may offer new directions for environmental management.

I. THE DILEMMA OF COMMAND AND CONTROL REGULATION

During the 1970's and 1980's, the nation rushed its close family member, the Environment, to the emergency room. We had neglected this beloved relative while we paid attention to other more immediate interests. As a result, this close relative was suffering a decline in vital signs due to long-term abuse and neglect. In an emergency room, preservation rather than enhancement is the watchword and techniques are expedient rather than precise. That was indeed the case with our relative — command and control regulations were administered in massive doses to stabilize the patient. They worked: the patient's vital signs have stopped declining and, in fact, have improved. But patients do not recover in the emergency room. At best, the ER only prepares patients to take full advantage of the recuperative phase that follows. The intent is to return the patient to full active participation in the turbulence of life. In fact, if patients are kept in the ER too long, they become dependent on life support and do not develop their own capacities to return to a full and balanced life.

A. *The Emergency Room of Command and Control Regulation*

In order to compare command and control regulation to an emergency room, it is necessary to consider the traits of emergency room intervention.

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1. *See* STUART KAUFFMAN, AT HOME IN THE UNIVERSE (1995).

1. *Treatment is Prescribed by Experts.* The emergency room intrinsically depends heavily upon care externally applied to the patient. The patient has a passive role in developing and applying remedies. In the ER, the patient is not expected to participate actively in intervention. Protection measures are determined by specialists without much assistance from the patient, except in describing symptoms. Conventional environmental regulatory approaches have followed a similar pattern. These approaches have used either legislative or administrative prescriptions, almost always relying on technology prescribed by experts. The affected stakeholders have played only a small role in designing corrective measures. In other words, conventional environmental management has not depended entirely on the active responsibility of industry, governments, or citizens in designing actions. It has expected that these parties will "take their medicine and do what the doctor orders." The requirements for alternative fuels in the Clean Air Act represent such a prescription. They were developed by experts and imposed on stakeholders. The alternative fuels program was premised upon externally chosen and applied intervention.[2]

2. *Treatment Depends Upon Invasive Intervention.* Traditional command and control regulation and emergency rooms both often use invasive measures. Cardiac patients brought to an emergency room often face application of medicine to stabilize their heart rhythms. These medications are necessary to prevent immediate catastrophe, but do not work well as a long-term healing strategy. Similarly, command and control regulations often specify precise operating behavior and capital investment by polluting sources. Whether controlling emissions from floating roof storage tanks or from the treatment of hazardous wastes, the command and control regulatory system depends upon the government's highly precise specification of operations and investments for success.[3] Little latitude is afforded those who wish to vary from the regulations, even if the alternative makes achieving the desired results possible. This intrusion into operations was necessary when sources lacked the motivation or skill

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2. GARY C. BRYNER, BLUE SKIES, GREEN POLITICS: THE CLEAN AIR ACT OF 1990 AND ITS IMPLEMENTATION 197-204 (1995).

3. James M. Lentz and Patricia Leyden, *RECLAIM: Los Angeles' New Market-Based Smog Cleanup Program*, 46 J. AIR & WASTE MGMT. ASS'N 195, 199 (1996).

to perform.[4] Because motivation and skill have improved, adhering to such an invasive approach limits performance: it takes away the flexibility to find a better solution than the prescribed one and sets a firm ceiling on performance outcomes.

3. *Treatment is Focused.* Besides being developed by experts, applied externally, and invasive, command and control regulation shares another trait with emergency rooms: interventions are usually well-tested and very focused. Experimentation is confined to that which is essential to validate a treatment's adequacy, not optimality. The actions can be risky for, indeed, much is at risk and timidity and caution can result in catastrophe. By adhering to an established protocol, unforeseen complications can be minimized. Gains from innovation may be foregone, but survival, not enhancement, is the objective. When the nation's environmental quality was declining precipitously in the 1970's, the prescription of command and control regulation could be justified by the seriousness of the situation. Command and control regulation was necessary to achieve major improvements while avoiding confusion at a crucial time. Because environmental conditions have improved, we can broaden our focus to include long-term environmental enhancement. It may make sense to shift to pollution prevention rather than to continue to focus on increasingly restrictive end-of-the-pipe controls.

4. *Treatment Emphasizes Remediation, Not Recovery.* Both emergency rooms and command and control regulation are premised on remedial measures. Both seek to correct something that has gone very wrong. The ER often seeks to remediate trauma; command and control regulation similarly seeks to halt decline in environmental quality by abating widespread emissions into the air, land, and water. Both aim to correct rather than enhance. A patient has little hope for the long-term unless the recuperative phase emphasizes shifting the objective from remediation of the trauma to improvement. Similarly, we may staunch emissions to our air, land, and water, but unless we enlist the efforts of industries, interest groups, and consumers to take direct action to improve, not just to protect, the environment, we face

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4. *See* David B. Spence, *Paradox Lost: Logic, Morality, and the Foundations of Environmental Law in the 21st Century*, 20 COLUM. J. ENVTL. L. 145, 167 (1995) (describing the importance of self-reporting mechanisms in addition to traditional government intervention in responding to environmental problems).

a future of fighting a long-term retreat from a healthy environment. The Nature Conservancy's land purchase program may protect and improve larger ecosystems more effectively than continued application of the Clean Water Act's Section 404 dredge and fill program.

5. *Treatment Time is Limited.* Lastly, a maxim of emergency room care is to limit the reliance on extreme but necessary measures. Patients can readily lose their ability to breathe independently if they are kept on a respirator longer than necessary. The body will adjust to medicine and will need it to function if an adaptation response develops. This adds up to doing everything that is necessary in the ER to preserve life, but not doing more than is necessary. Command and control regulation provides powerful medicine for halting environmental decline. But when these regulations are administered beyond the necessary horizon, they promote dependency and limit innovation. This prevents development of longer term, self-sustaining patterns of response that offer more than the hope of damage remediation, but offer the potential for environmental enhancement.

In other words, like the ER, command and control regulation protects during traumatic times. But a life lived simply for the purposes of surviving trauma is not likely to last or to have high quality. The recuperative phase depends on a patient developing independent means of living. Similarly, as long as the objective for environmental quality remains damage mitigation or simple protection rather than enhancement, the chance for a robust, sustaining environmental policy is low. It is difficult to be successful only by avoiding catastrophe. Advancement and improvement as policy objectives offer the best chance for developing a rich environmental quality as part of our national fabric.

B. *A Recuperation that Leads to Renewal with a Future*

While emergency room activities can avert a catastrophe, it is the success of the recuperative phase that determines the viability of a patient's future. A successful recuperation and rehabilitation program leads to a return to active life. Ideally recuperation would both restore the patient's health and lead to changes that avoid a return to the emergency room.

1. *Avoiding Confinement to the Emergency Room.* If we can, we should move the patient out of the emergency room of command and

control regulation. If we continue to rely only on command and control regulation, we limit our attention to conventional approaches and may forego a wider range of means to advance environmental quality. Stasis in the nation's environmental quality is something the nation does not want.[5]

Yet today we have evidence that we are perilously close to such a stall-out in the improvement of environmental quality. The nation's political leaders seem determined to draw battle lines over environmental protection by debating the degree of regulation desirable.[6] This debate has something of a ritual nature. The debates of the mid-1990's sound distressingly similar to the debates of the early-1980's. Discourse concerning environmental quality centers around budget allocation decisions and how much regulation is necessary. The entire public discussion concerning environmental quality is taking place in a flat policy plane where the degree of regulation and the amount of public funds allocated to environmental protection are posited as the only dimensions. This debate is conventional and it can prevent the nation from considering more innovative approaches. The opportunity cost of this debate is foregone innovation and the lost chance for environmental enhancement.

Rather than discussing environmental policy in the plane of regulation versus expenditures, we need a more realistic landscape. This landscape, rather than being flat, should have multiple dimensions. Topics such as the degree and direction of scientific research, the amount and nature of technical assistance and training, and the roles of enforcement, geographic information, environmental education, and pollution prevention serve notice that an environmental policy limited to a flat policy plane is in peril of being inadequate. With an inadequate policy framework, the nation risks overlooking possible gains by oversimplifying candidate policies. Today's public discussion offers little beyond the traditional command and control approach. Most environmental policy prescriptions stop with repairing damage. If we are to learn from the clinical model of emergency room recovery, we must seek policies that prevent a return to the ER.

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5. ROPER ORG., INC., THE GREEN GAUGE REPORTS (1992) (Oral Briefing to the U.S. Environmental Protection Agency).

6. *GOP Gets Warning in Survey: Cut Environmental Funds, Lose Votes*, RALEIGH NEWS & OBSERVER, Jan. 25, 1996, at 4A.

2. *Avoiding a Return to the ER.* Without a change in the conditions that caused the need for ER care, the recovery cannot be termed a success. Perhaps the necessary change is wearing seat belts rather than sitting on them. Maybe it is changing to a low-fat diet and increasing exercise. Whatever the cause of admission to the ER, a complete recuperation includes not only regaining health but avoiding a return to the ER. One definition of insanity is doing the same thing over and over and expecting to get different results. To re-establish and secure health after an ER visit, recuperation must lead to renewal with a future of avoiding the ER.

Until now, national environmental policy has focused on "protection." The concept of protection is inherent in the idea of prevention. As Professor Jonathan Wiener points out, most of today's theory of environmental quality depends on the view that the environment must in some way be "preserved."[7] This derives from the belief that the environment has some stable, pristine condition that would exist but for the presence of humans. Wiener notes that recent insights into ecology demonstrate that such a static view is at variance with facts. The natural systems that are the subject of environmental policy are constantly changing and adapting. Any policy built on a view of the environment as not changing is likely to fall short of its stated objectives; no policy can hope to succeed if it contradicts fundamental principles, no matter how deeply it is embedded in conventional wisdom and values. If humans are part of the changing environment, a key question becomes how humans can behave responsibly when insulation of the natural environment is not possible.

Rather than establishing protection as a national environmental goal, we should consider the goal of environmental enhancement and improvement. The physical environment restlessly seeks progress and improvement. Our national policies could seek to reinforce such tendencies and make progress a central feature. A constant search for adaptation and improvement is inherent in systems whether ecological, biological, or political.[8] We have built artificial walls around both the concept of environment and the advancement of environmental goals. If we look beyond conventional approaches,

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7. Jonathan B. Wiener, *Law and the New Ecology: Evolution, Categories and Consequences*, 22 ECOLOGY L.Q. 325, 333 (1995).

8. KAUFFMAN, *supra* note 1, at 298.

perhaps we may find ways to enhance, rather than simply protect, the environment.

As an indication of potential gains from such unconventional innovations, we have only to look at the dramatic reduction of emissions prompted by the Toxics Release Inventory program of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRTKA).[9] This legislation simply requires plants to report their discharges of selected chemicals into the environment. Over five years this program saw a 43% reduction of emissions, due mostly to public pressure and information.[10] This program shows that direct edict is not the only way to achieve environmental enhancement. The use of technical assistance rather than court orders to improve the compliance of degreasers in Sonoma County, California also shows that nontraditional approaches contain promise. In this case, compliance was increased from 3% to 70% through technical assistance from the state government alone. No use was made of legal enforcement, the previously preferred approach.[11]

The foregoing examples deal with the changing world of environmental protection. As circumstances, capabilities, and limitations change, methods should shift to retain and improve the probability of success of environmental measures. We can accelerate adaptation with policies that explicitly seek to enhance the environment. But before we embark on major policy shifts, we must believe that conditions have changed to cause us to alter our basic approaches to environmental protection.

C. *The Changing World of Environmental Quality Policy*

How do we know that it is time to reconsider our approach to national environmental policy? There are ample indicators that tell us that conditions have changed and, while the old ways served us well, reliance on them alone can be perilous to long-term environmental quality.

1. *The Nature of Pollution Changes.* Pollution from large industrial sources constituted much of the nation's previous environmental challenge. Control of large point sources was appropriate

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9. 42 U.S.C. § 11023 (1995).

10. Margaret Kriz, *Does the Public Have a Right to Worry?*, 28 NAT'L J. 486 (1996).

11. Michael M. Stahl, *Enforcement in Transition*, ENVTL. F., Nov.-Dec. 1995, at 19, 24.

because those large sources were producing most of the pollution. Today, most of these sources are under control or in compliance programs, and dispersed sources, instead, cause a large portion of our pollution problems. For example, almost 60% of the volatile organic compound emissions into the nation's air come from non-industrial sources[12] and non-point sources of water pollution are the leading sources of stream pollution.[13] We find that whether it is ozone pollution in our cities or decreased water quality in our rural areas, small, dispersed sources comprise most of the current problem. This is a different problem that calls for different skills, approaches, and tools.

2. *The Nature of Remedies Changes.* With the focus shifting from large point sources to many dispersed sources, we can no longer rely on "bolt-on" control devices to abate pollution. To combat unwanted discharges, we should be seeking to employ the best management/operation practices to prevent pollution before it is generated. This implies utilizing different tools if we are to continue making progress.

3. *The More We Understand, The More We Are Concerned.* As scientific knowledge regarding the consequences of pollution improves, we find effects we were unaware of just ten years ago and at previously unknown concentrations. In 1982, we were just learning of the serious health effects of particulate matter in our lungs. Today, we regulate small particles and contemplate controlling even finer particles.[14] We are also learning the degree of interconnection of our ecosystems. Impacts on biological diversity and species survival seem to grow as we increase our knowledge.[15] Ozone layer depletion was not clear until the early 1990's.[16] As we learn more, we see that the consequences of humanity's use of technology extends farther than we have ever imagined.

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12. U.S. ENVTL. PROTECTION AGENCY OFFICE OF AIR QUALITY PLANNING AND STANDARDS, NATIONAL AIR QUALITY AND EMISSION TRENDS REPORT (1992).

13. U.S. ENVTL. PROTECTION AGENCY OFFICE OF WATER, NATIONAL WATER QUALITY INVENTORY REPORT TO CONGRESS (1992).

14. *Current Developments: Air Pollution*, 26 ENVTL. REP. (BNA) 1171 (1995).

15. Bill Dietrich, *The Nature of Our Future*, SEATTLE TIMES, Mar. 31, 1995, at A1.

16. U.S. COUNCIL ON ENVTL. QUALITY, ENVIRONMENTAL QUALITY: 23RD ANNUAL REPORT 138 (1993).

4. *Expectations Rise.* The American people continue to expect more from their environmental programs. For example, the U.S. Environmental Protection Agency (EPA) is not a static agency with a stable portfolio of responsibilities. As interest in the environment has risen in the public consciousness, we have seen expectations rise dramatically. EPA regulates more types of pollution than ever before and must see that our environment meets tougher standards. Prompting this in large measure is the public's view of the importance of the environment. A poll by the Roper Organization found that over the period from 1987 to 1990, Americans who believe the environment is a top problem "skyrocketed in only three years— from 56% calling for a major national effort in 1987 to 71% in 1990. This change was by far the largest increase in public concern about any of the issues measured."[17] The *Washington Post* reports that a leading Republican pollster warned party leaders that trying to cut spending on the environment and rolling back environmental laws could cost Republicans dearly at the polls on election day.[18]

5. *Resources Contract.* Sharp limitations on funds available at the federal level for environmental activities will continue. Given the economic condition of the nation and the size of the federal deficit, it is very unlikely that we will see resources rising to meet expanding responsibilities at the federal level in the foreseeable future. The recent shutdown of the federal government featured deficit reduction as its centerpiece; Congress considered reductions of 20-37% for the EPA's Fiscal Year 1996 budget.[19] A proverb states, "We have no money, therefore we must think." Our national environmental quality program will need to rely on creativity to replace resources.

6. *Government Relations Change.* The institutional setting for environmental protection is shifting. State and local governments have paradoxically developed greater strength than ever to meet environmental challenges while experiencing retrenchment in their basic capacities due to fiscal limitations. These governments have more legislation, more technical and managerial skills, and more resources than ever to take on environmental problems. However,

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17. The Green Gauge Reports, *supra* note 5.

18. *GOP Gets Warning in Survey: Cut Environmental Funds, Lose Votes*, *supra* note 6.

19. *Id.*

they are being squeezed by the similar promise/performance gap that the EPA faces. In many instances, they face even greater budget limitations because state and local revenue bases do not keep pace with required expenditures.[20]

7. *Business Attitudes Shift.* Corporate thinking about the environment has shifted in many firms. Many firms seek to enhance their market presence by emphasizing environmental features. In such cases the environment is not a constraint but a potent competitive advantage. "Green" goods and "green" behavior are increasingly seen as a way for responsible corporations to bolster their bottom line. Corporations are moving, as never before, to include the environment in their business calculations.[21] A major policy challenge is how to capitalize on this and enlist the talents of corporate self-interest to advance environmental quality.

8. *Acceptability of Regulation Declines.* Potent forces in Congress question the use of regulation to protect the environment. In the *Washington Post*, Linda DiVall found that "a majority of survey respondents said they believe there is too much government regulation."[22] The public appears to oppose further use of regulation so strongly that consideration of an alternative approach seems prudent. This finding is confounded by the further finding that "most said that sentiment did not apply to environmental regulation." With the burdens of regulation clearly in Congressional minds, the role of regulation in environmental quality remains uncertain.[23]

9. *Discord Increases.* Today's reliance on command and control regulation has produced a climate in which public actions induce discord. Some of this discord occurs between the federal and state levels of government. News media over the past two years have reported ongoing antagonism between EPA and state pollution agencies about use of alternative fuels for automobiles and inspec-

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20. U.S. ENVTL. PROTECTION AGENCY TASK FORCE TO ENHANCE STATE CAPACITY, STRENGTHENING ENVIRONMENTAL MANAGEMENT IN THE UNITED STATES 20 (1993).

21. Joe Breen & Paul Anastas, *Design for the Environment: The Environmental Paradigm for the 21st Century*, 15 CHEMICALS IN PROGRESS 14 (1994).

22. *GOP Gets Warning in Survey: Cut Environmental Funds, Lose Votes*, *supra* note 6.

23. Karlyn Bowman, *Skepticism Points to Washington*, 28 GOV'T EXECUTIVE 16 (1996).

tion/maintenance programs for smog controls on automobiles.[24] In *Brief for Reform*, John Quarles contends that "careful design of environmental regulation has been obstructed by intense emotional polarization."[25] Quarles goes on to argue that "when tempers flare and debates degenerate to shouting matches, a thoughtful analysis of complex questions becomes almost impossible."[26] Such discord, whether between governments or between the public and private sectors, makes it difficult, if not impossible, to seek common solutions. Preferred solutions would depend on win-win strategies rather than win-lose attitudes, but today's discord pushes stakeholders into a win-lose mindset. Instead of searching for new means to pursue national environmental goals; all sides look for means to protect narrow, short-term interests.

10. *Environmental Values Change.* A reading of the national environmental statutes shows a strong legislative statement in favor of the environment. Congress has consistently stated that its policy objective is to "protect and enhance" the nation's environment. But an equally careful examination of the means of achieving this shows "protection" to be the dominant approach. Rather than advancing environmental goals, the nation has simply sought to limit the degradation of the environment to acceptable levels. This places environmental quality as a secondary goal of the country. It is something to be used as a constraint; it has not been given equal legitimacy with other social objectives that the polity seeks to maximize. In other words, our environmental policy is to contain damage rather than improve the physical environment. As David Spence has pointed out, environmental quality is so deeply rooted in American values that it pervades the political value system.[27] No longer is it necessary to confine public policy to damage avoidance; because the public sees environmental quality as intrinsically valuable, quality should be the subject of continual improvement efforts. Yet our policy system does not presently reflect that change.

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24. *Current Developments: Air Pollution: Centralized Vehicle Emissions Testing Defended by Agency at Oversight Hearing*, 26 ENVTL. REP. (BNA) 515, 525 (1995).

25. JOHN QUARLES, AMERICAN ENVIRONMENTAL REGULATION: BRIEF FOR REFORM 3 (1995).

26. *Id.* at 4.

27. Spence, *supra* note 4, at 182.

11. *Understanding of Success Improves.* Professor Tom Morris asserts that the hallmark of success is the constancy of goals and the flexibility of methods to attain those goals.[28] Failure, according to Morris, often contains unwavering commitment to methods while goals are changed to ones that are attainable through those familiar methods. If a healthy environment remains the national goal, it may be time to reconsider the methods. Reliance on protection, as contrasted with improvement, and reliance on command and control may be outdated as single-purpose approaches.

II. THE OPPORTUNITY OF COMPLEX ADAPTIVE SYSTEMS

The forces at work on national environmental policy signal a need to look beyond command and control regulatory approaches alone. We need new theories to fit this new phase. We cannot apply the emergency room measures of command and control regulation if we are in the recovery phase. If we cannot use the ER model except in remediation, what paradigm can we use to guide our actions to promote a sustainable, healthy environment? Complexity theory may help us design these new environmental policies. We can expect our environmental management system to do what the environment itself does: constantly seek the best conditions for survival and growth. Recent work in meteorology, ecology, and evolutionary biology offers insight into how large systems sustain health and adapt to new conditions. Although most work in complexity theory involves the behavior of natural systems, we can apply complexity theory to considering policy and management systems. This can promote a vigorous search for fresh approaches that encourage widespread innovation. Such innovation can advance recovery and sustained enhancement of the environment and lead to continuous improvement of environmental quality, not simply avoidance of further damage. Sustained environmental improvement could avoid a return to the emergency room of command and control regulation.

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28. TOM MORRIS, TRUE SUCCESS: A NEW PHILOSOPHY OF EXCELLENCE 154 (1994).

A. *Key Features of Complex Adaptive Systems*

What are the key features of complex adaptive systems theory and how might that theory apply to environmental management systems?

1. *Systems: Components with a Common Purpose.* Complexity theory holds that complex activities are the result of a system seeking to adapt to its environment.[29] Basic to complexity theory is the concept of a system. C. West Churchman defines a system as "a set of parts coordinated to accomplish a set of goals."[30] The concept of many elements acting to achieve a common outcome yields two features of a system: (1) there are a number of components; and (2) these components seek to accomplish a shared objective, the achievement of which would be difficult, if not impossible, without the combined efforts of all components. The components work together to move the entire set to a different general condition, one that would not be possible without the combined efforts of all.

2. *These Systems are Indeterminately Complicated.* The relationship between and among the components of such systems is difficult, if not impossible, to comprehensively characterize. Each component, due to the number of potential interconnections and reactions, has a very large range of impacts. When all the components come into play, a descriptive model that predicts with accuracy and precision the internal functioning of the system becomes almost impossible. This trait of unpredictability was first discovered in meteorology. While it is possible to write a predictive model for weather, such a model does not produce consistently precise and replicable results. The large number of interactions between the variables that determine the weather makes determinative modeling almost impossible. One must either simplify the system by ignoring potentially important components and risk producing a model that is inaccurate, or rely on careful observation of behavior to determine patterns of adaptation rather than precisely determined outcomes.[31]

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29. *See* ROGER LEWIN, COMPLEXITY (1992).
30. C. WEST CHURCHMAN, THE SYSTEMS APPROACH 29 (1968).
31. *See* LEWIN, *supra* note 29.

3. *These Systems are Non-linear and Dynamic.* Complexity theory has found that complex adaptive systems provide outputs that subsequently are used by the system as inputs for another round of activities. The outcome of the operating system becomes an input into the next cycle of the system. What happens next is a direct result of what has happened before. The basketball court presents a non-linear dynamic system: actions during the present depend on what happened before — the score, who is playing well, and who is in what position. There are rules and boundaries, but within that roughly bounded condition, much variability occurs. As a result, even small perturbations, such as a player's sprained ankle, can be magnified so that unforeseen outcomes characterize the long-term system behavior. Such non-linearity implies that the component parts interact so that the results of the interactions change the very conditions of later interactions. The systems change through time as a result of these interactions. Change and adaptation are traits of such systems; playing the game changes the rules of the game.[32] Both Zen and Taoist philosophies reflect this in the parable: "No one steps in the same river twice." Change in non-linear dynamic systems occurs over time and yields an ever-new stream of conditions. This recursive and self-referential quality is a characteristic of complex adaptive systems.

4. *As These Systems Change, New Conditions Emerge.* Emergence is a basic trait of complex adaptive systems.[33] As a system functions, or operates, its components interact and the system feeds back into another iteration. New properties emerge that can be quite different from previous ones. The complicated interactions of the components of the system make it practically impossible to predict how such properties will emerge. This emergence may be quite sudden and unpredictable. Such "hinge point" changes can produce dramatic improvements or catastrophes in the system's properties. Because it is quite difficult to predict when and how such hinge points will occur, careful observation is the best strategy when trying to "tune" the system to a particular quality.[34]

5. *The Conditions Emerge Toward Patterns.* When complex adaptive systems self-alter and new properties emerge, these

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32. *See* JAMES GLEICK, CHAOS (1987).
33. KAUFFMAN, *supra* note 1, at 24.
34. *See* MARGARET J. WHEATLEY, LEADERSHIP AND THE NEW SCIENCE (1992).

properties display a unique type of order. Rather than displaying regular repetitive properties over time, these patterns display a rough approximation to a general form. These patterns are called attractors; the outputs of the system seem to be attracted to these general forms of outputs, producing repetitive patterns that are regularly aperiodic. There is variation in these attractors over time such that precise prediction is impossible, but general pattern prediction may be possible.[35]

6. *The Patterns that Emerge Often are Self-Similar.* Complex adaptive systems can display unique structures. The largest structure of a complex adaptive system is built of sub-structures that resemble the superordinate structure. In other words, the global structure is derived from lesser-level activity rules. Such a system with self-similarity across scales is referred to as fractal. The existence of such repetitive patterns on different scales implies that the behavior of the superordinate structure often can be understood by examining the traits of the subordinate structures.

B. *Viewing the Environmental Management System as a Complex Adaptive System.*

Is the U.S. environmental management system a complex adaptive system? If it is, perhaps we can use the general properties of complex adaptive systems to assist in designing new approaches beyond the command and control regulation system.

1. *Is it a System in Which The Components Interact in a Complicated Manner?* Does the environmental management system have a set of components, or is it predominately driven by simple forces and players? The interactions of scientific knowledge, political interests, managerial competence, legal constraints, multiple levels of government, public interest groups, and private corporations combine to affect environmental quality. There are a large number of such components which constantly influence each other. Financial incentives, court orders, legal rights, and public opinion interact not only to produce today's environmental quality, but also to yield the unique approach that characterizes institutional responsibilities for environmental management in the United States today. Facing such

35. GLEICK, *supra* note 32, at 135.

a system, we must consider all components in order to move toward the common goal of environmental quality. Simply building the best sewage treatment plant may not be the answer to a water quality problem. Improved nonpoint source controls, a better operation and maintenance program for an existing plant, or stronger enforcement might yield a better environment.

Another component of complexity in our environmental management system is federal enforcement of environmental law, which has acquired great importance over the past twenty-five years. In 1971, EPA Administrator William Ruckelshaus sought civil fines many times greater than any previously sought against industries and cities violating air and water laws. He used enforcement against industries and cities to define EPA both politically and organizationally.[36] To some degree, Administrator Anne Burford resigned due to a reduction in vigorous enforcement during her tenure.[37] The relationship between state environmental agencies and EPA has been the most strained when disagreements have arisen concerning proper legal action against violators of environmental laws.[38] Much of the recent debate in Congress over EPA resources has concerned funds for enforcement and how much enforcement is appropriate.[39] In sum, legal enforcement represents a major enterprise in environmental protection. A close look at the enforcement program reveals a complex and large system. Systems thinking can help analyze this vital part of the national environmental protection effort. Do plant managers, attorneys, government engineers, and specialized consultants to all parties work to achieve compliance? Or is legal action an end in itself and compliance of only limited importance when compared to the deterrence and retribution aspects of enforcement? In other words, is the whole really greater than the sum of its parts? As part of a successful inquiry, we must seek to identify as many of the relevant parts of the environmental management system as possible and examine the overall goal of the system.

Can the relationships between the components of the environmental management system be simply characterized? Can interactions be predicted with precision? Because this system functions at the

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36. MARC K. LANDY ET AL., THE ENVIRONMENTAL PROTECTION AGENCY: ASKING THE WRONG QUESTIONS 35-36 (1990).

37. Bud Ward, *The Train Moves On*, ENVTL. F., Nov.-Dec. 1994, at 41, 42-44.

38. U.S. EPA TASK FORCE TO ENHANCE STATE CAPACITY, *supra* note 20, at 6.

39. *Current Developments: Air Pollution*, 26 ENVTL. REP. (BNA) 1203, 1209 (1995).

intersection of science, politics, law, and values, precise description of the interactions does not seem possible. It is possible to make informed estimates of how the components will interact, but these estimates are necessarily broad and contain a wide degree of variation. This implies that we cannot predict with precision the way the system will behave. Success may derive from closely watching the system's functioning and adjustment.

2. *Is the System Non-linear and Dynamic?* The interplay between politics and science that Marc Landy has described[40] demonstrates how parts of the environmental management system can change each other over time. In setting the national ambient air quality standard for ozone, political concerns affected the type of scientific analysis conducted. This analysis explored the impacts of possible standard levels. These impacts then served to change the political interests of many players. Such outcomes affecting inputs that in turn affect outcomes is characteristic of the environmental management system in areas such as state/federal relations, research programs, and standards setting. This implies that flexibility and an organization committed to learning will be more likely to succeed.[41]

If we have a system with complementary parts working to a larger purpose, is it non-linear and dynamic? Do the results of the system, both ecological and institutional/political, serve as initializing conditions for another cycle of the system to operate? For example, did the steel industry's adverse response to William Ruckelshaus's enforcement actions in 1971 impact future enforcement actions? According to Robert Yuhnke, it did.[42]

3. *Is Emergence a Property of the System?* Does the environmental management system display the property of emergence? In other words, does the system develop distinctive traits over time that were not dominant earlier? For the past twenty-five years, the regulatory/administrative state, or command and control system, has been the preferred approach for advancing environmental quality. In the early 1970's, possible inclinations toward the use of urban planning and scientific research and development as the dominant paradigms were entertained, but gradually environmental quality has

40. LANDY ET AL., *supra* note 36, at 50-82.

41. *See* PETER M. SENGE, THE FIFTH DISCIPLINE (1990).

42. Robert Yuhnke, *Launch of a Movement*, ENVTL. F., Nov.-Dec. 1994, at 32, 35.

come to depend upon the function of the command and control system.[43] This trait of emergence characterizes a system that has developed a distinctive pattern that did not exist in its present form at the beginning of the environmental era. With changes to new system states possible, perhaps even likely, it is important to be prepared to adjust methods and practices to harmonize with the newly emerging order.

If we determine that emergence seems to be a property that we are observing, what states do we see the system emerging towards? Does the emergent system have the properties we value, such as success in advancing environmental quality and acceptable limitations on freedom, both personal and institutional? Perhaps even more critical is to understand how to promote these properties. Today's debates on environmental quality management suggest that agreement eludes the environmental community about the direction in which the environmental management system is emerging.

The trait of emergence carries with it acceptance that direct control of the emergence is unlikely. There are so many interactions of such a complicated nature that precise control is infeasible. This is contrary to conventional political attitudes. In order to use the paradigm of complex adaptive systems, environmental leaders will have to admit that they cannot determine with infallible predictability the outcomes of the programs they have created. While this may seem self-evident, one only needs to review the debate over the enactment of the Clean Air Act Amendments of 1990 to see the importance of certainty for outcomes and the associated control measures.[44] Is the country ready to publicly accept what has always been the case: namely, that the connections between actions and outcomes are ambiguous at best and that sometimes the greatest progress in environmental matters comes from unforeseen events? Lead was banned from gasoline to protect the catalytic converters needed to abate air pollution. It also reduced lead air pollution by 98% in urban areas, an unintended, but positive consequence.[45]

4. *Is the System Self-Similar?* The final property is the degree to which one level of the system appears similar to the next level: is it

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43. *See* LANDY ET AL., *supra* note 36, at 36 (describing early EPA command and control enforcement techniques).

44. *See* RICHARD E. COHEN, WASHINGTON AT WORK 30-33 (1992).

45. U.S. EPA OFFICE OF AIR QUALITY PLANNING AND STANDARDS, *supra* note 12.

fractal in character? In environmental management, Congressional interest regarding over-regulation follows similar reactions at the state level that have been occurring for a number of years. The 104th Congress considered regulatory reform measures as part of the majority party's environmental program. Measures such as cost-benefit analysis and risk assessment have been implemented at state levels. Self-similarity seems to be a property of this part of the environmental management system. If we want to change the large system, our best hope, says complexity theory, is to change the component systems.[46] The implication is to focus more on the level where direct environmental service is provided in order to change the larger environmental management system. Different levels have similar problems, so by focusing attention on the component systems, we stand a better chance of successfully altering the larger system. Also, when variation or innovation occurs at these subordinate levels, there is a wider range of experiments with lesser stakes. Many small improvement efforts can show more success at today's stage than a single large uniform approach that may have been adequate earlier.

To manage non-linear dynamic systems, we need to move across scales in order to see the methods and results of one level validly scaled up to the next level of the system. In specific terms, we need to be able to translate results and learning at the local and state government levels into those at the federal level. In asking ourselves whether we have fractal policy consequences, we need to be able to see the nesting of systems that are characteristic of such complex adaptive systems.

Lastly, we need to determine if patterns of results are emerging. Are attractors appearing? By asking ourselves to identify these patterns toward which the national environmental policy system is emerging, we may position ourselves to more readily identify possible futures before they become reality. With some understanding of the attractors toward which environmental policy is emerging, we can test to see if those attractors meet our requirements. If so, we can look at the system for ways to strengthen them; if not, we can look for ways to alter the system's emergence. While we are unable to control the emergence, we may be able to influence its nature to a more effective degree than we could otherwise.

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46. J.B. Ruhl, *Complexity Theory as a Paradigm for the Dynamical Law-and-Society System: Wake-up Call for Legal Reductionism and the Modern Administrative State*, 45 DUKE L.J. 849, 887 (1996).

III. TAKING STEPS TO APPLY COMPLEXITY THEORY TO ENVIRONMENTAL QUALITY POLICY

If environmental management is a complex adaptive system, we can use our knowledge of complexity's general properties to inform our policies. How might we design policies to improve national environmental quality?

A. *Get Accurate, Detailed Environmental Data*

First, information on the actual state of the environment should be given highest priority. If we are in a state of continuous change and emergence, having some picture of that state is essential for us to respond and adapt. At present, no valid water quality and solid waste data exist that comprehensively and reliably characterize the totality of our water or land quality.[47] Air pollution data is widely collected, but, with only a few monitors in each urban area, much is left to interpolation. Also, data lags almost two years from collection to reliable use.[48] With solid information on environmental trends, we would be able to enlist the efforts of more of the players in the environmental management system: their interests in environmental quality would be more clearly established. Very little serves as well to galvanize a community's action than specific understanding of the health consequences of an industry's emissions. When environmental data is explained to people in terms of the impact upon their lives, data is translated into information. With a clear picture of the proximate effects of their actions, these players are more likely to consider these effects when doing business. Information, therefore, is key not only to get an accurate fix on the state of environmental affairs, but also to enlist all the players needed to improve the system.

B. *Challenge Sources to Achieve Measurable Goals for Sustained Progress*

The better the goals of a system, the better the chance of achieving them. Careful attention to clear goals for all stakeholders in environmental activities is essential. Specific and measurable goals

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47. U.S. COUNCIL ON ENVTL. QUALITY, *supra* note 16, at 248.

48. U.S. EPA OFFICE OF AIR QUALITY PLANNING AND STANDARDS, *supra* note 12.

for all stakeholders can improve the chances for success by providing concrete purposes for pollution control efforts. When goals are either vague or responsibility is not clearly assigned, the goals' chances of success are diminished. Today's EPA-state relations rely on specifying activities rather than goals to achieve.[49] In the absence of an established goal of a specific groundwater quality, specification of program design has taken a front seat in the EPA's groundwater strategy. We have emerged to a process-oriented rather than goal-oriented approach.

Because complex adaptive systems constantly adjust, why not take advantage of this property when setting goals? If we wish not only to protect but also to improve the environment, we can establish clear goals that require sources, whether industries or consumers, to consistently perform slightly better than they do currently. As the system achieves these goals, the goals can be adjusted to provide for an ever-improving environment, based on our knowledge of where improvement is most beneficial. The Clean Air Act ozone control program has such a requirement. Certain cities are required to achieve a specific percentage reduction in volatile organic compounds annually. This avoids the attempt to accomplish huge gains in single leaps. The inability of the 1970 and 1977 Clean Air Acts to achieve nationwide ozone attainment hints at the difficulty of applying single-leap control programs successfully.

C. *Use All Parts of the Environmental Management System*

Environmental quality management is more than writing regulations and enforcing them. Technical assistance, pollution prevention, and public information are all legitimate means to affect actions that can improve the environment. Use of all the components of the system can increase the chance of success. The challenge is to select and deploy those components in any particular situation so that the most effective means of enhancing the environment are used. This test of comparative advantage can substantially expand the tools used to improve environmental quality.

Using comparative advantage poses two challenges. First, governments must be far more broad-minded in considering how to advance environmental quality. Tax policy, capital and operational spending, and information dissemination should accompany traditional

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49. U.S. EPA TASK FORCE TO ENHANCE STATE CAPACITY, *supra* note 20, at 6.

regulation as candidates for action. Secondly, incentives for pollution sources must be structured so that the sources can exercise maximum innovation in finding the necessary environmental improvements.

D. *Use Incentives to Promote Responsible Behavior*

The use of positive incentives can be a major strength of using complex adaptive systems to advance environmental quality. Under the command and control system, the principal incentive is avoidance of adverse consequences associated with not complying with established standards. These consequences may take the form of administrative or judicial fines or the criticism of the surrounding community. But these incentives are all essentially ones of avoidance: the prime motivator is avoiding an adverse consequence.

Why not include positive incentives as part of the tools for improving environmental quality? The trading of acid rain pollution credits has enlisted the creative energy of many of the utility companies in the United States to reduce sulfur dioxide emissions. An environmental management system that establishes positive rewards, such as increased profits, for responsible environmental stewardship can expand the creative energies brought to bear on the nation's environmental problems.

E. *Pay Close Attention to Implementation*

Next, we must focus our environmental efforts at the lowest possible level and consider how environmental policies are implemented. Mary Riveland notes that "policy is what happens, not what you intended."[50] We cannot satisfy ourselves with equating policy with pronouncement, but must work at the level of specific action to ensure that policy has the effects we seek. This means being concerned, at the federal level, with local and state government environmental actions as the initial sub-system that builds into the national environmental management system. We may get a far stronger source inspection program by improving inspection targeting than by redesigning grant sanctions for states that have weak inspection programs. Complex adaptive systems theory tells us that the best control of large systems comes from controlling the component

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50. Mary Riveland, Lecture at Terry Sanford Institute of Public Policy, Duke University (Feb. 16, 1996).

systems.[51] Therefore, we can strengthen the effectiveness of environmental policy by focusing on state and local governments.

This concern for component systems should extend to the actions taken by businesses and consumers whose choices and actions need to change to benefit the environment. As discussed above, solid information permits knowing how these vital players are actually impacting the environment and can lead to a more realistic, and hence, more effective environmental policy.

Politicians, practitioners, and academics need to pay substantial attention not simply to policy design but to policy implementation as well. Most national environmental initiatives spend the majority of their energy in policy design. We have previously assumed that a well designed policy will lead inevitably to a well implemented policy. Complex adaptive systems theory tells us that no design, no matter how well conceived, can possibly anticipate all the opportunities and problems likely to be encountered in implementing the policy. Our institutions need to recognize that implementation is at least as critical to success as policy design, and resources and attention need to be allocated accordingly.

F. *Make Innovation a Priority*

We need to promote experimentation and continuous improvement in carrying out national environmental policy. Fundamentally, we need to move away from national approaches that take a one-size-fits-all approach. We need to recognize that unmoderated control can be the enemy of innovation, and we desperately need innovation if we are to adapt to the emerging challenges of the future in environmental management. If we shift the emphasis from control and stability to innovation and improvement, this does not mean we discard a national view. It simply means that the pursuit of the national interest needs to admit that there may be many innovative ways to achieve the goal. Experimentation, innovation, and creativity, focused on achieving environmental improvement, will become even more important in the future.

This experimentation should be purposeful. This means choosing to innovate as a conscious approach instead of maintaining established ways of doing business. It means, for example, that EPA not undertake a permit-by-permit review of a state's water quality

51. LEWIN, *supra* note 29, at 12-13.

discharge permits, but instead devote time to work with the state to develop innovative, probabilistic permit limits. Simply dabbling in innovation will not establish the innovations necessary to meet continually changing conditions. A measure of organizational competence in environmental management should become purposeful innovation. As Peter Drucker notes:

> The foundation of innovative strategy is planned and systematic sloughing off of the old, the dying, the obsolete. Innovating organizations spend neither time nor resources on defending yesterday. Systematic abandonment of yesterday alone can free the resources, and especially the scarcest resource of them all, capable people, for work on the new.[52]

Environmental management policies that meet Drucker's requirement will gauge success, in part, by the degree to which old methods, attitudes, and behaviors are relinquished.

At the implementation level, continuous improvement, both in the conduct of operations and the ever-improvement of environmental conditions, will become vital. Total quality management sees the pursuit of excellence as a never-ending path.[53] The ecological health of our world is at least as important as the production of consumer products. We need policies that recognize the unlikelihood that we will ever reach a time when the quality of the environment is satisfactory. We are learning too much about the impacts of man on nature to expect we will ever reach the level of satisfactory impacts. Complete satisfaction with environmental quality may be an unattainable goal; far more realistic is the goal of continuous improvement of the quality of our environment.

G. *Emphasize Flexibility*

We need to adopt flexibility as a specific policy objective. Complex adaptive systems theory indicates that we are unlikely to ever anticipate completely the consequences of the national environmental quality system. We will have unforeseen problems and unforeseen opportunities. Our policies should be built with adaptabil-

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52. PETER F. DRUCKER, PEOPLE AND PERFORMANCE 153 (1977).

53. *See* MARY WALTON, THE DEMING MANAGEMENT METHOD 123 (1986).

ity and agility as two of their undergirding principles. We do not know what the future will look like, but we can be reasonably certain that it will not look like today, and it will not look like what we have envisioned it to be. We do know that we will be surprised, so it makes sense to be prepared to be surprised and to turn that surprise to our advantage. This means avoiding rigid policies governing how we will move forward, and it means having a clear picture of where we want to go so that, when the shortcuts present themselves, we can take advantage of them.

CONCLUSION

This article has sought to explain why it is necessary to change the direction of environmental management and to consider a possible new direction, complex adaptive systems theory. The emergency room approach of command and control regulation has worked well. It has halted the decline in national environmental quality and realigned the nation's institutional interests to emphasize environmental quality. But the traits that contributed to the success of command and control regulation threaten to impede further environmental progress. The limitations on innovation, the focus on remediation, the rigidity of methods, and the confining of interests to special technical groups all limit the future effectiveness of command and control regulation. The nation risks stalling environmental protection if it adheres solely to command and control regulation as the paradigm for future actions. The command and control approach can only protect the environment from certain types of threats. It does not easily abate pollution from small, dispersed sources. It is inherently a defensive approach, and it does not provide pathways for widespread innovation to improve the environment. Adhering to the conventional approach of the past twenty-five years can deny us the chance to truly improve tomorrow's environment.

Complex adaptive systems theory offers a way to broaden the approaches, the stakeholders, and the innovation brought to environmental quality management. By considering all parts of the environmental quality system, complex adaptive systems theory offers a paradigm that, while not discarding the appropriate use of command and control regulation, expands the means for environmental protection so that innovation and improvement, rather than control and protection, become the major functions of environmental quality management.